Ur Next GF: Urine as Next Generation Fertilizer with Meat and Bone Meal Applied on *Vigna radiata* (Monggo plant)

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Abstract: Fertilizers play an important role in providing crops with essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K), which supplements plant growth. Compared to synthetically composed commercial fertilizers, next generation fertilizers are manufactured from low-energy mechanisms and are composed of nutrients from repurposed wastes which make them cost-efficient and sustainable. With the objective of determining which would deem to be an effective next generation fertilizer, we focus on human urine and meat and bone meal, to which its processing included solar drying, freezing, grinding, and utilizing additives to prevent fungal growth as well as improve efficacy. Three iterations, each with four set ups: plain urine, urine and meat and bone meal, control, and meat and bone meal only; were used to examine which content would prove more beneficial to the growth and quality of the chosen plant, Vigna radiata. The study adapted a quantitative analysis that aimed to measure the plant height, leaf area index, and dark green color index through the conduction of statistical tests and the use of ImageJ. As a result, the paper was able to conclude that the combination of urine and meat and bone meal poses a great potential for future fertilizer use.

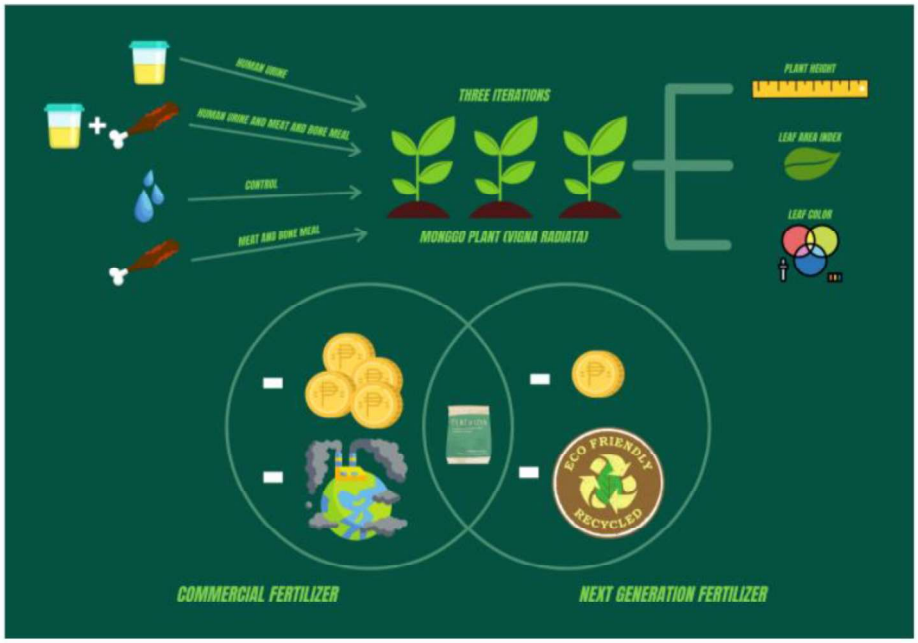


Figure 1. *Graphical Abstract*

Key Words: Next generation fertilizer; human urine; meat and bone meal; vigna radiata

1. INTRODUCTION

Compared to synthetically composed commercial fertilizers, next generation fertilizers are manufactured from low-energy mechanisms and are composed of nutrients from repurposed wastes. They are better in terms of nutrient use efficiency (NUE) which have a potential boost in crop productivity and quality in the future as sources of plant nutrients. Its capability to bridge the imbalanced use and nutrient gap generated by their synthetic counterpart in soil is one of the reasons why it is better than commercial fertilizers (Singh, Praharaj, & Jat, 2019).

The study was conducted by developing crop-specific formulae from human urine and meat and bone meal, both organic materials for cost-efficiency and accessibility. Urine, an exemplar of human excreta, defined as a liquid output produced by the kidneys, contains significant amounts of nitrogen (N), phosphorus (P), potassium (K), and other micronutrients (Nagi & Zseni, 2017). Processed from slaughterhouse waste, the meat and bone meal comprises concentrations of N, P, and calcium (Ca). Thus, both possess the essential nutrients necessary for plant growth (Möller, 2015). With next generation fertilizers, one can cut costs since its vital component is human urine which is free and always readily available. As farmers do not have a considerable budget for planting crops, the fertilizer would be able to assist them in their finances. Moreover, as COVID-19, a massive health threat in the country, continues to warrant quarantine protocols leading to a multitude of people remaining in their homes, we thus investigate how households can use their excrement and readily available household ingredients to grow their own foods.

Considering the mechanisms of nutrient delivery, this study aims to determine which and what constituent would be deemed the most effective and beneficial to the chosen plant subject, Vigna radiata, also known as the monggo plant. Additives such as sodium bicarbonate (NaHCO3) were utilized to generate a slow-release fertilizer that prevents fungal growth in plants and enhances efficacy (Jamilah et al., 2020).

2. METHODOLOGY

The urine's pH level was accounted for by using a pH meter and was subjected to a freeze-thaw process for further stabilization. If the pH level did not meet the preferred value of around 6.8, the addition of Ca(OH)2 was employed. Urine was stored in a sealed container, placed inside a cooler with ice and salt that was replenished every two hours. It was kept inside for seventy-two hours before it was thawed at room temperature. For the meat and bone meal, it was first subjected to boiling for an hour to soften its structure.

Afterwards, ample amounts of boiled meat and bone meal were blended which resulted in a paste-meal component. When under high temperatures, organic matter retains its minerals, such as phosphorus (Möller, 2015). The meat and bone meal supplements the plant with phosphorus that the urine lacks. Both the processed urine and meat and bone meal were mixed and once diversified, was transferred to a drying pan, covered with a plastic lid, and solar dried for forty-eight hours. Subsequently, the product produced was a paste fertilizer. It was then stored in a sealed container and placed in a cool and dry place. All equipment used were identical and purchased from the same shops.

A randomized block design consisting of four set-ups of monggo plants per block was used to gauge the fertilizer's effectiveness. The dependent variables in this study were the plant height, leaf area index, and leaf color of the plant while the independent variable was the fertilizer, which was separated into four groups: Set-up A, Set-up B, Set-up C, and Set-up D. Set-up A was a monggo plant fertilized with a controlled amount of urine fertilizer; Set-up B was fertilized with the product from the mixture of urine and meat and bone meal while Set-up C was not fertilized at all. This distinction also acted as the baseline or controlled set-up for the comparison of data. Meanwhile, Set-up D was fertilized with meat and bone meal only. All set-ups were situated indoors with direct access to sunlight. Each set-up has 100 grams of soil and were situated in identical pots. A total of three iterations, which is defined as a process modification, with each iteration having two trials were done during the study. Three iterations were conducted since this a novel project; and so the procedures incorporated in the methodology such as the mix formulation and application will solely be dependent on the successes and failures of the preceding iterations.

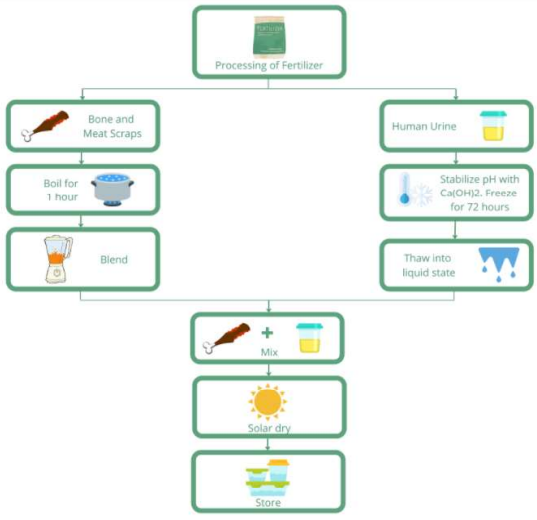


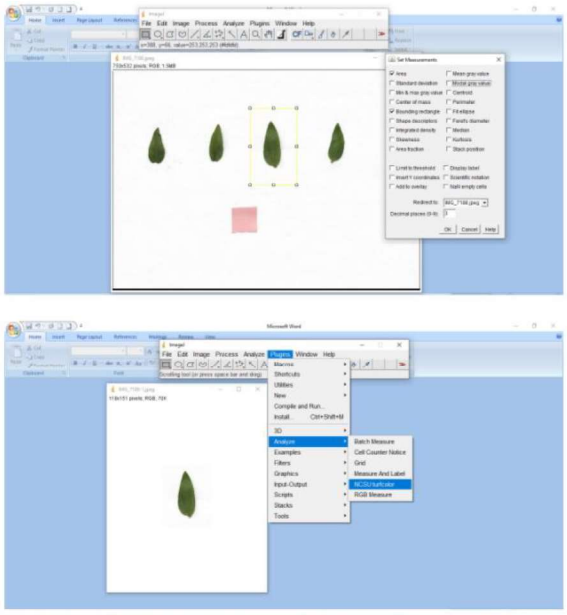
Figure 2.1 *General Procedure*

Table 2.1 *Summary of All Iterations*

	First Iteration	*Second Iteration*	*Third Iteration*
Set-up A (Urine Only)	50 grams	10 grams	70 grams
Set-up B (Urine and Meat)	50 grams	10 grams	70 grams
Set-up C (Control)	-	-	-
Set-up D (Bone and Meat only)	50 grams	10 grams	70 grams
Water	50 mL	10 mL	25 mL
Baking Soda	13.6 grams	10 grams	-
Frequency	Everyday for one week	Once every 3 days for four weeks	Once in five weeks
Soil	100 grams	100 grams	200 grams
Data to be collected	Potential revisions	Plant height	Leaf area index, color, and plant height

One-way ANOVA was utilized in analyzing the data for plant height collected from the experiment because the researchers aimed to differentiate the results and test whether the differences within the means of the data were significant. For the leaf area index and color, the software ImageJ was used. ImageJ is an open-source imaging software that offers an estimate of real-life dimensions of given pictures of objects by measuring the number of pixels it has in comparison to an object with a known measurement. In terms of the color, a plugin made by NC State University for ImageJ was utilized in order to measure the leaves' dark green color index which includes saturation, brightness values, and hue angle (Zhang, Pinnix, Zhang, Miller, & Rufty, 2017). Leaf samples were collected from the set-ups at the end of the experiment period and were photographed, edited, and ran through the program.

Figure 2.2 *ImageJ Interface*



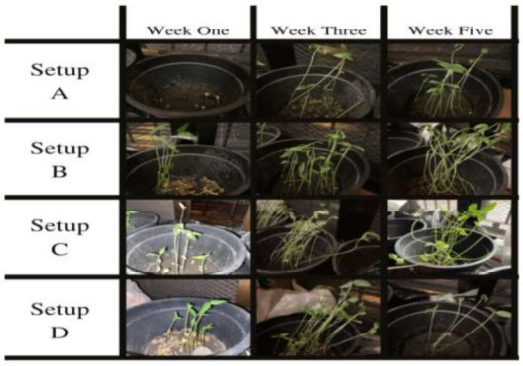
For the leaf area index and color, mean values were utilized since the sample size was too small to conduct a one-way ANOVA test (Tabachnik & Fidell, 2012).

3. RESULTS AND DISCUSSION

Table 3.1 *Summary of Recorded Mean Values of Parameters*

	Set-up A	**Set-up B**	**Set-up C**	**Set-up D**
Final Plant Height (Second Iteration)	20.1 cm	19.2 cm	19.15 cm	18.65 cm
Final Plant Height (Third Iteration)	18.6 cm	26.9 cm	20.9 cm	22.5 cm
Final Leaf Area (Third Iteration)	$5.73cm^2$	$6.87cm^2$	$4.57cm^2$	$4.8\ cm^2$
DGCI Mean (Third Iteration)	0.373	0.396	0.361	0.333

Figure 3.1 *Documentation of all Fertilizer Set-ups in the Third Iteration*



The first iteration was conducted as preliminary grounds only to test out the feasibility of using urine and meat and bone meal as a component for a next generation fertilizer. At the end of the experimental period, the urine and meat and bone meal fertilizer has shown to have the highest final plant height, and is thus the most effective out of all fertilizers.

For the second iteration, a change in the increments of fertilizer, baking soda, and water was made based on ocular observations from the first iteration. The one-way ANOVA testing conducted showed that the P-value for the means of plant height between the groups has a value of 0.50. Since it has exceeded the 5% significance level, we can infer that the difference between the means was not statistically significant. Despite this conclusion on the test, we can infer that Set-up A, with the urine-only fertilizer, is the plant with the most effective fertilizer during the second iteration given that it has the highest final plant height. A possible reason why the urine-only fertilizer became the most effective in terms of plant growth can be attributed to the addition of sodium bicarbonate into every fertilizer application. According to Gafter, Edelstein, and Levi (1985), sodium bicarbonate can inhibit the absorption of the nutrient phosphorus. Since the meat and bone meal component of the fertilizers was supposed to mostly supplement the phosphorus demand of the plants, the large amount of sodium bicarbonate may have nullified the effectiveness of all fertilizers containing meat and bone meal. Another potential factor to its boosted effectivity is that human urine is better suited for multiple applications, since fertilizing before the plant's seedling stage is not effective for plant growth and production due to mainly high ions intensity in low saline soil and high leaching of nutrients from soil (Sene, 2013).

For the third iteration, the one-way ANOVA testing conducted showed that the P-value for the means of plant height between the groups has a value of 0.08. Since it has exceeded the 5% significance level, we can infer that the differences between the means were not statistically significant. Despite this conclusion on the test, we can infer that Set-up B, with the urine and meat and bone meal fertilizer, is the plant with the most effective fertilizer during the third iteration given that it has the highest final plant height. The data collected were also in line with the tentative hypothesis formulated by the researchers which states that the addition of sodium bicarbonate may have disrupted the effectiveness of the meat and bone meal component of the fertilizers which contain it during the second iteration. Furthermore, it was found out that the most effective and low-maintenance method for mixed component fertilizers would be to have a one-time application; in a similar study that was conducted with maize, it was concluded that higher meat and bone meal doses contributed to a higher grain yield and that the yield-forming effect of meat and bone meal was not dependent on the frequency of application (Nogalska et al., 2013).

Leaf color is an indicator of the nitrogen level present in a plant. In line with the values presented in the table, we can infer that fertilizer Set-up B had the biggest leaf area index and highest dark green color index (DGCI) mean. In a study by Siddons (2013), the DGCI of a plant was utilized as a method to measure the nitrogen content of several plants. In the wheat and turf that was examined in the study, it was detected that its DGCI values and leaf N concentration have a strong relationship. A higher DGCI value indicated a higher amount of N present. Therefore, based on this, as fertilizer set-up B had the highest DGCI mean of 0.396, we can infer that it contains the most amount of N. Since the population for both DGCI and leaf area was too small, it was not possible to have it undergo ANOVA testing.

4. CONCLUSIONS

In this study, amidst the four fertilizer set-ups, the researchers learned that the fertilizer for set-up B, which contained combined urine and meat and bone meal, poses the greatest potential as a next generation fertilizer. Baking soda may accompany urine itself, but an alternative may be needed when it is needed to be mixed alongside phosphorus-rich components such as meat and bone meal. Furthermore, after conducting three different ways of applying the fertilizers, the researchers were able to determine that the most effective and low-maintenance method is to utilize a one-time application when using a mixed component fertilizer. On the other hand, when using urine-only fertilizer, it is preferable to utilize a slow-release mechanism with the use of an additive.

The differences between the means of plant heights in the second and third iterations were found to be not statistically significant. However, comparing the raw data to one another will infer an evident difference that can corroborate the high possibility of developing a next generation fertilizer from urine and meat and bone meal once further research, enhanced methodologies and instruments are incorporated.

The experimental part of this study was unfortunately conducted during the implementation of quarantine measures in the country because of COVID-19; therefore the researchers had limited resources. For further research similar to a novel project such as this, the researchers recommend that consistency of the location, materials, and equipment must be maintained in producing a next generation fertilizer to provide more cohesive and solid results. It is also recommended to cover a wider array of

parameters that the researchers were not able to measure such as number of leaves, number of roots and the exact NPK demand of the plant and the soil to be used. Another type of plant, preferably one with a longer growth cycle is apt for this kind of study so that there are more results to be obtained and analyzed. When using a slow-release mechanism, baking soda is not advisable to be used upon phosphorus-rich components as it may potentially disrupt the phosphorus delivery of the fertilizer. Lastly, to corroborate a fertilizer's effectiveness as a next generation fertilizer, conduct a study comparing it with a commercial fertilizer.

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6. REFERENCES

Achakzai, A. et al. (2012). Effect of nitrogen fertilizer on the growth of mung bean [Vigna radiata (L.) Wilczek] grown in Quetta. Pak. J. Bot., 44(3), 981-987. Retrieved December 23, 2020, from https://www.pakbs.org/pjbot/PDFs/44(3)/21.pdf

Andreev, N. et al. (2017). Lactic acid fermentation of human urine to improve its fertilizing value and reduce odour emissions. Journal of Environmental Management, 198(1), 63-69. https://doi.org/10.1016/j.jenvman.2017.04.059

Axe, J. (2017). What are nitrates? Reasons to avoid nitrates (and better alternatives). https://draxe.com/nutrition/nitrates/

Bachik N.A. et al. (2017). The determination of nitrogen value at various reading points on rice leaf using RGB imaging. Acta Horticulturae, (1152), 381–386. https://doi.org/10.17660/actahortic.2017.1152.51

Beganovic, J., Kos, B., Lebos Pavunk, A., Jokic, M., & Suskovic, J. (2014). Traditionally produced sauerkraut as source of autochthonous functional starter cultures. Microbiol. Res, 169, 623-632. https://doi.org/10.1016/j.micres.2013.09.015

Bouatra S. et al. (2013). The Human Urine Metabolome. Encyclopadea Brittanica. Retrieved June 17, 2020, from https://www.britannica.com/topic/meat

Chen, J., Lu, S., Zhang, Z., Zhao, X., Li, X., Ning, P., & Liu, M. (2018). Environmentally friendly fertilizers: a review of materials used and their effects on the environment. Science of the Total Environment, 613-614, 829-839. https://doi.org/10.1016/j.scitotenv.2017.09.186

Chipako, T. & Randall, D. (2019). Urine treatment technologies and the importance of pH. Journal of Environmental Chemical Engineering, 8(1). https://doi.org/10.1016/j.jece.2019.103622

Department of Agriculture, Forestry, & Fisheries of Republic of South Africa (2010). Mung bean production guideline [PDF File]. https://www.daff.gov.za/docs/Brochures/MbeanpGUDELINS.pdf

Fresenius Kidney Care (2020). 6 common chronic kidney disease medications. https://www.freseniuskidneycare.com/kidney-disease/managing-ckd/medications

Gafter, U., Edelstein, S., & Levi, J. (1985). Effect of Bicarbonate Feeding on Intestinal Absorption of Calcium and Vitamin D Metabolism in Rats. Clinical Science, 68(1), 97–100. https://doi.org/10.1042/cs0680097

Ganrot, Z., Dave, G., & Nilsson, E. (2007). Recovery of N and P from human urine by freezing, struvite precipitation and adsorption to zeolite and active carbon. Bioresource Technology, 98(16), 3112–3121. https://doi.org/10.1016/j.biortech.2006.10.038

Gensch, R., Itchon, G., & Miso, A. (2011). Urine as liquid fertilizer in agricultural production in the Philippines: A practical field guide. Cagayan de Oro City: Xavier University Press.

Gesselschaft, F. (2015). Meat and bone meal as a source of phosphorus. https://phys.org/news/2015-12-meat-bone-meal-source-phosphorus.html

Hashemi, S. & Han, M. (2017). Methods for controlling stored urine odor in resource-oriented sanitation. Journal of Water, Sanitation, and Hygiene for Development, 507-514. https://doi.org/10.2166/washdev.2017.098

Hashemi, S. & Han, M. (2019). Field evaluation of the fertilizing potential of biologically treated sanitation products. Science of the Total Environment, 650, 1591-1598. https://doi.org/10.1016/j.scitotenv.2018.09.009

Hou, D., Yousaf, L., Xue, Y., Hu, J., Wu, J., Hu, X., Feng, N., & Shen, Q. (2019). Mung Bean (Vigna Radiata L.): Bioactive polyphenols, polysaccharides, peptides, and health Benefits. Nutrients, 11.6, 1238–. https://doi.org/10.3390/nu11061238

Ison, L. (2020, June 28). Data shows high price of fertilizer prior to centralized bidding.
Retrieved January 19, 2021, from https://www.pna.gov.ph/articles/1107299#:~:text=Based%20on%20data%20released%20by,PHP1%2C029.98%20(June).

Jagtap, N. & Boyer, T. (2018). Integrated, multi-process approach to total nutrient recovery from stored urine. Environmental Science: Water Research and Technology, 4, 1639-1650. https://doi.org/10.1039/c8ew00004b

Jamilah et al. (2020). Effects of biochar and chromolaena odorata liquid fertilizer enriched with sodium bicarbonate on soil and muskmelon (Cucumis melo L.). Planta Tropika: Jurnal Agrosains (Journal of Agro Science), 8 (1). https://doi.org/10.18196/pt.2020.108.7-14

Jara-Samaniego, J., et al. (2017). Development of organic fertilizers from food market waste and urban gardening by composting in Ecuador. Plos One, 12(7). https://doi.org/10.1371/journal.pone.0181621

Jayathilakan, K. et al. (2012). Utilization of byproducts and waste materials from meat, poultry and fish processing industries: a review. Journal of Food Science and Technology, 49(3), 278–293. https://doi.org/10.1007/s13197-011-0290-7

Jeng, A. et al. (2006). Meat and bone meal as nitrogen and phosphorus fertilizer to cereals and rye grass. Nutrient Cycling in Agroecosystems, 76, 183-191. https://doi.org/10.1007/s10705-005-5170-y

Kirchmann, H., Pettersson, S. (1995). Human urine-chemical composition and fertilizer use efficiency. Nutr. Cycl. Agroecosyst, 40, 149-154. https://doi.org/10.1007/bf00750100

Lind, B., Ban, Z., & Bydén, S. (2001). Volume reduction and concentration of nutrients in human urine. Ecological Engineering, 16(4), 561-566. https://doi.org/10.1016/s0925-8574(00)00107-5

Mawis, S. (2019, May 18). Solid waste mismanagement in the Philippines. Business Inquirer. https://business.inquirer.net/270819/solid-waste-mismanagement-in-the-philippines

Mayuga, J. (2020, February 5). PHL only has 10 percent of needed sanitary landfills, says DENR exec. Business Mirror. https://businessmirror.com.ph/2020/02/05/phl-only-has-10-percent-of-needed-sanitary-landfills-says-denr-exec/

Moncel, B. (2020, November 4). What is baking soda? https://www.thespruceeats.com/what-is-baking-soda-p2-1328637

Möller, K. (2015). Assessment of alternative phosphorus fertilizers for organic farming : meat and bone meal [PDF File]. https://orgprints.org/29505/1/moeller2015-factsheet-Meat-and-bone-meal.pdf.

Nagy, J. & Zseni, A. (2017). Human urine as an efficient fertilizer product in agriculture. Agronomy Research, 15, 490-500.

Nogalska, A. et al. (2013). The effect of increasing doses of meat and bone meal (MBM) applied every second year on maize grown for grain. Chilean Journal of Agricultural Research, 73(4). http://dx.doi.org/10.4067/S0718-58392013000400015

O.K, N., Niyokuri, A.N., Rono, J.J., Fashaho, A., & Ogweno, J.O.. Effect of different rates of nitrogen fertilizer on the growth and yield of zucchini (Cucurbita pepo cv. Diamant L.) Hybrid F1 in Rwandan high altitude zone. International Journal of Agricultural and Crop Sciences, 5, 54-62. https://www.researchgate.net/publication/303150166_Effect_of_different_rates_of_nitrogen_fertilizer_on_the_growth_and_yield_of_Zucchini_Cucurbitapepocv_Diamant_L_hybrid_F1_in_Rwandan_high_altitude_zone

Okareh, O. T., Oyewole, S. A., & Taiwo, L. B. (2014). Conversion of Food Residuals to Organic Fertilizer: A Strategy for Promoting Food Security and Institutional Waste Management in Nigeria. Journal of Research in Environmental Science and Toxicology, 3(4), 66-72. https://www.researchgate.net/publication/266905536_Conversion_of_Food_Residuals_to_Organic_Fertilizer_A_Strategy_for_Promoting_Food_Security_and_Institutional_Waste_Management_in_Nigeria

Plant Care Today (2021). 30 ways to use natural baking soda in the garden. https://plantcaretoday.com/baking-soda-garden-uses.html

Pradhan, S., Holopainen, J., & Heionen-Tanski, H. (2009). Stored Human Urine Supplemented with Wood Ash as Fertilizer in Tomato (Solanum lycopersicum) Cultivation and Its Impacts on Fruit Yield and Quality. Journal of Agricultural and Food Chemistry, 57, 7612-7617. https://doi.org/10.1021/jf9018917

Pronk, W. & Kone, D. (2008). Options for urine treatment in developing countries. Desalination 248, 360-368. https://doi.org/10.1016/j.desal.2008.05.076

Raper, E., Fisher, R., Anderson, D. R., Stephenson, T., & Soares, A. (2018). Alkalinity and external carbon requirements for denitrification-nitrification of coke wastewater. Environmental Technology, 39(17), 2266–2277. https://doi.org/10.1080/09593330.2018.1437779

Samanthi (2018, December 13). Difference between lycopene and beta carotene. https://www.differencebetween.com/difference-between-lycopene-and-beta-carotene/#Beta%20Carotene

Schnug, E. (2005, August 29). The use of meat and bone meal as organic farming fertiliser. https://www.thepigsite.com/articles/the-use-of-meat-and-bone-meal-as-organic-farming-fertiliser

Sene, M. (2013). Application of human urine as liquid fertilizer in agriculture. [PDF File]. Hokkaido University Collection of Scholarly and Academic Papers, 56. https://eprints.lib.hokudai.ac.jp/dspace/bitstream/2115/53892/1/Sene_Moustapha.pdf

Shiel Jr., W. (2018, December 27). Medical definition of urine. https://www.medicinenet.com/urine_pee_health_color_odor_urinalysis/article.htm

Siddons, U. (2013). Dark Green Color Index as a Method of Real-Time in-Season Corn Nitrogen Measurement and Fertilization [PDF file]. 78-79. https://core.ac.uk/download/pdf/72842769.pdf

Speake, C. (2013). 20 clever uses for baking soda in the garden – make life easy! https://thegardeningcook.com/baking-soda-in-the-garden/

Tabachnick, B. G. & Fidell, L. S. (2012). Using multivariate statistics (6th ed.). Boston, MA: Pearson.

Udernt, K.M, Larsen, T.A., & Gujer, W. (2006). Fate of major compounds in source-separated urine. Water Sci. Technol. 54, 413-420. https://doi.org/10.2166/wst.2006.921

U.S. National Library of Medicine (2021). Urine 24-hour volume. https://medlineplus.gov/ency/article/003425.htm#:~:text=The%20normal%20range%20for%2024,about%202%20liters%20per%20day)

Wang, Y., Wang, D., Shi, P., & Omasa, K. (2014). Estimating rice chlorophyll content and leaf nitrogen concentration with a digital still color camera under natural light. Plant Methods, 10, 36. https://doi.org/10.1186/1746-4811-10-36

Walden, A. (2021). The differences between quick-release and slow-release fertilizers. https://ashtonwalden.com/the-differences-between-quick-release-and-slow-release-fertilizers/#:~:text=Quick%2DRelease%20Fertilizers,rapid%20growth%20on%20new%20lawns.

World Health Organization. (2020). Coronavirus. https://www.who.int/health-topics/coronavirus#tab=tab_1

Yin, Z., Guo, W., Xiao, H., Liang, J., Hao, X., Dong, N., … Yin, F. (2018). Nitrogen, phosphorus, and potassium fertilization to achieve expected yield and improve yield components of mung bean. PLOS ONE, 13(10). https://doi.org/10.1371/journal.pone.0206285

Zhang, C., Pinnix, G. D., Zhang, Z., Miller, G. L., & Rufty, T. W. (2017). Evaluation of Key Methodology for Digital Image Analysis of Turfgrass Color Using Open-Source Software. Crop Science, 57(2), 550. https://doi.org/10.2135/cropsci2016.04.0285

Development of a Cost-effective Microbial Fuel Cell (CEMFC) to Generate Electricity from Carbohydrate Food Waste

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Abstract: Due to the ever-increasing demand for electricity and the growing solid waste management problem prevalent in the Philippines, there exists a need for an innovation that can solve both problems simultaneously while being accessible to impoverished households. This study investigated the effectiveness of utilizing accessible materials such as earthenware ceramic, baking soda, charcoal, and food waste in developing a Cost-effective Microbial Fuel Cell (CEMFC). Eight prototypes were created using such materials, with 7 having the anode wrapped around the PEM and one having the anode placed around the inside of the container. The voltage output and duration were measured after which the performance of the uniform prototypes was compared with the varying prototypes, as well as that of a commercial battery. The effects of the placement of the anode on the efficiency of the fuel cells were also investigated by creating two prototype models. The results were analyzed with the application of an Independent t-Test and MANOVA. The mean voltage produced by the uniform CEMFCs was 0.21 Volts and the average duration of all the prototypes was 14 days. The prototypes also had a lower efficiency compared to a commercial battery (p-value < 0.05), however no significant difference was observed on the two prototype variations made based on the position of the bioanode (p-value $= 0.5740$). It was concluded that while the CEMFC was able to produce electricity, the voltage generated wasn't enough to fully power devices, thus further studies regarding scaling up methods for higher electricity production is recommended.

Key Words: cost-effective microbial fuel cell; anode; voltage; duration; bioanode

1. INTRODUCTION

Electricity, despite being a fundamental human right, is not readily available to millions of people in Southeast Asia. According to Rosario (2019), in the Philippines alone, 13 to 16 million people have no access to electricity. Moreover, these people can usually be found in rural or underdeveloped areas, making it more difficult for them to receive the help they need due to the lack of facilities and resources in their location. The efforts of the nation's main energy provider, Meralco Corporation, on increasing the number of coal power plants to meet the population's electricity needs prove to be both insufficient and detrimental to the environment (Domingo, 2019). Similar to many third world countries, the Philippines also faces the issue of solid waste management, either due to the lack of proper disposal facilities or inefficient waste processing techniques ("Philippines Solid Waste at a Glance", 2017).

Microbial fuel cells (MFC) are a type of emerging technology which utilizes the ability of bacteria to release protons and electrons from organic molecules through an oxidation process (Wen et al., 2010). Multiple studies have already investigated various factors that may affect the performance of an MFC including the presence of a magnetic field, difference in pH levels, and the use of a polyaniline sponge as an anode (Sun et al., 2017; Xu et al., 2018; Yin et al., 2016). Despite this, none of the studies mentioned sought to create a cost-effective MFC. There is also a knowledge gap with regards to the effects of the placement of the anode as similar research studies were only concerned with investigating electrode treatments that can help increase the efficiency of the MFC as opposed to studying specific parameters that may affect its performance. Consequently, this study aimed to develop a Cost-effective Microbial Fuel Cell (CEMFC) with the utilization of the following independent variables: (i) ceramic as a cation separator, (ii) charcoal as a bioanode, (iii) baking soda as pH regulator, and (iv) ground carbohydrate food waste mixed with water as a substrate. The efficiency of the created prototypes served as the dependent variable which was measured with the use of two parameters, namely voltage and duration. The researchers also

investigated the effects of the placement of the anode on the performance of the CEMFC.

2. Literature Review

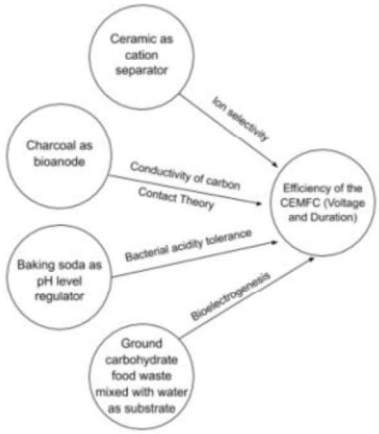

Figure 1. *Conceptual Framework*

The utilization of ceramic as a cation separator, charcoal as a bioanode, baking soda as a pH regulator, and ground food waste mixed with water as a substrate directly influenced the efficiency of a microbial fuel cell. To elaborate, first, the ion selectivity of a cation separator has proven to be a determining factor concerning its effectiveness. Ion selectivity controls how easily protons will pass through the PEM (Harnish, 2009). Consequently, if the ion selectivity of a cation separator proved to be diverging from the protons present in the anode, a cation build-up may occur; increasing the acidity of the solution, and killing the microorganisms present, rendering the microbial fuel cell inefficient. On the other hand, a porous separator would allow protons to pass more quickly, preventing cation accumulation in the anode (Winfield et al., 2016). Previous studies have proven that ceramic has high porosity and no ion selectivity, making it a preferable material for the PEM (Winfield et al., 2016; Winfield et al., 2013; Pasternak et al., 2016). Second, the conductivity of the anode, as well as the presence of more significant contact among the particles, influence the overall voltage generation efficiency and current measure of a microbial fuel cell, in the sense that more points of contact allow for the formation of a channel for electrons to flow through (Gonzales et al., 2004). Previous studies proved that carbon-based materials including biochar and charcoal have high conductivity when increasing the number of points of contact between each molecule by compacting the charcoal, making it a suitable bioanode material (Cheng & Logan, 2006; Chaijak et al., 2018; Li et al., 2017; Qiao et al., 2007). Third, bacterial acidity tolerance determines what pH level the anode should have for optimum power generation as some microorganisms may thrive in neutral environments rather than basic or acidic ones (Sun et al., 2019; Biffinger et al., 2008). The voltage output, and duration of a microbial fuel cell have been proven to vary with the microbial communities' activity present, subsequently being affected by the pH levels (Helin et al., 2018). Baking soda has been examined to have basic properties, thus raising pH levels slightly above the neutral mark and below the critical pH level where the bacterial activity starts to decline (Finch, 2017; Mentzer, 2019; Sun et al., 2019). Finally, the electrogenic ability of the microbial colonies present in wastes is the driving force that converts the organic molecules present in substrates to electrical energy via anaerobic digestion (Sivasankar et al., 2018; Raghavulu et al., 2013; Logrono et al., 2015; Kondaveeti et al., 2019). Related studies have discovered that food waste have high COD concentrations as well as carbohydrates, sugars, and phenolics, making it a viable substrate to foster the growth and digestion of nutrients of microbial communities in a microbial fuel cell (Socaci et al., 2017; Lin et al., 2013; Paritosh et al., 2017; Farcas et al., 2017).

2. METHODOLOGY

2.1 Research Design

The researchers utilized the factorial design under the experimental structure in the study. This allowed them to collectively investigate the effects of the following independent treatments on the dependent variable: (i) ceramic as cation separator, (ii) charcoal as a bioanode, (iii) baking soda as pH regulator, and (iv) ground food waste mixed with water as a substrate.

2.2 Data Gathering Procedure

The researchers conducted the data gathering procedure by creating 8 MFC prototypes, of which 7 had the bioanode wrapped around the PEM while 1 had the anode wrapped around the inside of the container.

2.2.1 Preparation and Acquisition of Materials

The researchers accomplished the Research Ethics Checklist given to them and had the letter of approval to perform the experiment signed by the research head prior to the conduction of the experiment. The materials were sourced from online stores and local markets as the researchers could no longer gather the samples and items needed from the partner community due to the restriction imposed by the pandemic.

2.2.2 Construction of CEMFC Prototypes

The researchers ground the carbohydrate food waste collected prior to the assembly of the prototype. The earthenware ceramic pot was placed in the middle of the plastic container. After which the charcoal was mixed with flour paste and molded around the inside of the container for one of the prototypes and around the outside of the pot for the rest of the CEMFCs until a thickness of 1 cm was achieved. A steel mesh placed inside the earthenware pot served as the cathode. The voltage output of each of the 8 CEMFC units was measured at a time interim of 30 minutes via a multimeter. The researchers then determined the duration by computing the interval where the MFC is producing electricity. The voltage values gathered concerning the level of time were averaged once complete. The same procedure was done with a commercial battery, after which the researchers compared the data collected from the two set-ups.

3.2.3 Application of Statistical Treatment

After the conduction of the experiment, the researchers properly disposed of the materials used so as to prevent contamination. The data gathered were recorded, sorted, and tabulated prior to the conduction of data analysis.

3.3 Data Analysis

The data gathered by the researchers was analyzed with the application of an independent samples t-Test and Multivariate Analysis of Variance (MANOVA). This allowed the researchers to investigate the existence of a significant difference in the efficiency or performance of the CEMFC and that of a commercial battery, as well as determine if there was a variation in the duration of the control and experimental group prototypes.

3.4 Research Locale

The researchers conducted the entire research experiment, including the grinding of the food waste sample, the compaction of charcoal powder, the construction of the CEMFC, pH regulation, and operation of the CEMFC prototypes, in their respective venues due to the restrictions imposed by the COVID-19 pandemic. The materials were sourced from online retailers.

3. RESULTS AND DISCUSSION

The following data were gathered in line with the experiment performed:

Amount of voltage produced with the utilization of independent variables such as ceramic as cation separator, charcoal as bioanode, ground carbohydrate food waste mixed with water as a substrate, and baking soda as pH regulator much as possible occupy only one column page. Table headings should be re-indicated for catenated tables.

Table 1. *Summary of the Day-to-day Mean Voltage Output of Each Prototype*

	1	2	3	4	5	6	7	Vary
Day 1	0.191 8	0.004 9	0.1	0.003	0.003	0.164	0.0 12	0.4837
Day 2	0.392 3	0.021 2	0.14	0.011	N/A	0.637	0.0 2	0.3382
Day 3	0.532 1	0.053 2	0.197	0.03	N/A	0.7	0.0 20	0.2615
Day 4	0.344 5	0.066	0.275	0.044	N/A	0.595	0.0 27	0.2867
Day 5	0.348 1	0.079 7	0.35	0.023	N/A	0.547	DP	0.09
Day 6	0.387 9	0.101 2	0.405	0.012	N/A	0.57	DP	0.0633
Day 7	0.393	0.123 6	0.508	0.055	N/A	0.517	DP	0.1214
Day 8	0.398 9	0.148 5	0.4	0.015	N/A	0.485	DP	0.0723
Day 9	0.258 1	0.169 6	0.3	0.023	N/A	DP	DP	0.0336
Day 10	0.147 8	0.181 7	0.27	0.025	N/A	DP	DP	0.0242
Day 11	0.099 1	0.225 4	0.08	0.038	N/A	DP	DP	DP
Day 12	DP	0.249 3	DP	0.038	N/A	DP	DP	DP
Day 13	DP	0.259 7	DP	0.009	N/A	DP	DP	DP
Day 14	DP	0.289 9	DP	0.023	N/A	DP	DP	DP
Day 15	DP	0.283 8	DP	0.038	N/A	DP	DP	DP
Day 16	DP	0.283 1	DP	0.049	N/A	DP	DP	DP
Day 17	DP	0.282 7	DP	0.08	N/A	DP	DP	DP
Day 18	DP	0.282 7	DP	0.06	N/A	DP	DP	DP
Day 19	DP	0.255 1	DP	0.057	N/A	DP	DP	DP
Day 20	DP	0.214 4	DP	0.075	N/A	DP	DP	DP
Day 21	DP	0.167 2	DP	0.163	N/A	DP	DP	DP
Day 22	DP	DP	DP	0.027	N/A	DP	DP	DP
Day 23	DP	DP	DP	0.862	N/A	DP	DP	DP
Mean of voltage output				0.21 V				0.18 V

Table 1 shows that the average voltage produced by the uniform MFC prototypes is 0.21 V, while the varying prototype produced a mean of 0.18 V. Additionally, most of the prototypes had an inconsistent voltage production in which the electricity being produced would either slightly increase before gradually decreasing or significantly increase before plunging. Such results are in line with similar research studies cited in the paper. For instance, it was proven by Winfield et al. (2016) that ceramic's porosity makes it a preferred material for proton exchange membranes as it allows protons to pass through it easily while also providing a positive environment for the metabolism of electro-active microorganisms. An earthenware type of ceramic was also discovered to help yield the highest amount of overall MFC productivity compared to mullite, pyrophyllite, and alumina (Pasternak et al., 2016).

Table 2. *Approximate Maximum Mean Voltage Produced by Each CEMFC Prototype*

Prototype #	Maximum Voltage output / Peak of Voltage Output	Minimum Voltage Output
1	0.532	0.099
2	0.290	0.005
3	0.508	0.08
4	0.862	0.003
5	0.003	0.003
6	0.637	0.164
7	0.028	0.012
Vary	0.484	0.024

Table 2 shows that the uniform MFCs also varied in their average maximum and minimum voltage production, with the highest data recorded being 0.862 V and the lowest, 0.003 V. Subsequently, the varying prototype had an average maximum voltage of 0.484 V and a minimum of 0.024 V. The overall voltage production capability of the fuel cell could be inferred as a result of the feasibility of the said low-cost materials to be used in MFCs. For instance, it was studied that the application of a carbon material as a bioanode, can increase the electricity production capacity of an MFC (Winfield et al., 2016; Pasternak et al., 2016; Sun et al., 2018).

Average duration of the uniform prototypes with respect to the utilization of ceramic as cation separator, charcoal as bioanode, ground carbohydrate food waste mixed with water as a substrate, and baking soda as pH regulator.

Table 3. *Summary of the Duration or Lifespan of the Individual CEMFC Prototypes*

MFC #	# of Days Active
1	11
2	21
3	11
4	23
5	ins. Data
6	8
7	3
Average	13

Table 3 shows that the researchers determined that control group 2 lasted the longest for a total of 21 days, followed by control group 1 for a total of 11 days, while the experimental group lasted a total of 10 days. All 3 groups averaged a total of 14 days of voltage production. This is similar to the findings of previous studies which stated that an average MFC lasts for about a few days to a few months considering the stability of the biocatalysts present (Wang & Jia, 2007).

Table 4. *Multivariate Test: Wilks Lambda*

Effect	Value	F	Significance
Duration	.000	180262.757 b	.000
Duration*Group	.000	4828.622b	.000

Table 4 shows that a significant difference in the duration of the three groups was also discovered (p-value < 0.05). Such a variation may be due to the slight fluctuation in temperature of the research environments or a change in pH level (Mano et al., 2002; Sun et al., 2018). The behavior exhibited by the prototypes is also in line with the findings of similar research that longer-lasting MFCs produce less voltage and vice versa (Li, 2013).

Significant difference between the efficiency (voltage) of a CEMFC and the performance of a commercial battery

Table 5. *Independent t-Test Analysis Between the CEMFC Prototypes and the Commercial Battery*

	Mean of Uniform Prototypes	Voltage from Commercial Battery
Mean	0.211412742	1.735
Variance	0.025229298	0
Observations	23	4
Hypothesized Mean Difference	0	
df	22	
t Stat	-46.00220699	
P(T<=t) one-tail	1.15594E-23	
t Critical one-tail	1.717144374	
P(T<=t) two-tail	2.31187E-23	
t Critical two-tail	2.073873068	

Table 5 shows that based on the independent t-Test analysis, it was determined that the CEMFCs (Mean = 0.2114 V; SD = 0.1588) produced a significantly lower average voltage compared to the commercial battery (Mean = 1.735 V; SD = 0). (t = -46.00; p-value < 0.05). These results could be attributed to an accidental increase in the pH level of the substrate on a select number of prototypes due to the inability of the cation separator to transfer some H+ away from the substrate as a result of a great variation in the PEM and substrate volume ratio (Harnisch & Schröder, 2009; Chae et al., 2008; Sun et al., 2018).

Difference in the efficiency of the CEMFC prototypes (voltage and duration) based on the placement of the bioanode

Table 6. *Independent t-Test Analysis Between the Two Prototype Variants Based on the Location of the Bioanode*

	Mean of Uniform Prototypes	Mean of Varying Prototype
Mean	0.21143478	0.17749
Variance	0.02521698	0.02418709
Observations	23	10
Hypothesized Mean Difference	0	
df	18	
t Stat	0.57253786	
P(T<=t) one-tail	0.28702008	
t Critical one-tail	1.73406361	
P(T<=t) two-tail	0.57404016	
t Critical two-tail	2.10092204	

Table 6 shows that there was no observed significant difference between the voltage production of the MFC prototype variant which had its bioanode wrapped around the PEM (Mean = 0.2114 V; SD = 0.1588), and the voltage output of the MFC prototype which had the bioanode wrapped around the inside of the container (Mean = 0.1775; SD = 0.1555). (t = -0.57; p-value = 0.5740). Consequently, the absence of such difference may be justified by the notion that a minimum distance of 2 cm must be attained for the MFC to reach peak electricity production and both prototype models must have attained the optimal

distance needed (Cheng & Logan, 2006). While it is true that some studies stated that the surface structure and area of the electrode may influence the mass transfer, metabolites, and electron transfer in the MFC, the variations were observed to be trivial in a large scale (Rahimnejad et al., 2015; Yu et al., 2020).

4. CONCLUSIONS

It was evident that while the CEMFC prototypes were able to produce electricity, several factors, among which the placement of the bioanode is not included, still tend to influence the overall performance of the fuel cell. However, given additional development to increase the efficiency of the MFC, there is a high possibility that these fuel cells will eventually be able to become a conventional power source in the future due to its sustainability and cost-effectiveness.

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6. REFERENCES

(2017, November). Philippines Solid Waste at a Glance. Senate Economic Planning Office. https://legacy.senate.gov.ph/publications/lrs_publications.asp

Cheng & Logan (2006). Ammonia treatment of carbon cloth anodes to enhance power generation of microbial fuel cells. Electrochemistry Communications, 9(3), 492-496. https://www.sciencedirect.com/science/article/pii/S138824810600467X.

Domingo, R. (2019, May 1). Serious power shortage seen in the next few years. Philippine Daily Inquirer.http://search.ebscohost.com/login.aspx?direct=true&db=n5h&AN=96XFPDI20190501.00114.2&site=ehost-live

Li, J. (2013). An experimental study of microbial fuel cells for electricity generating: performance characterization and capacity improvement. Journal of Sustainable Bioenergy Systems, 3(3), 171-178. https://www.researchgate.net/publication/276043847_An_Experimental_Study_of_Microbial_Fuel_Cells_for_Electricity_Generating_Performance_Characterization_and_Capacity_Improvement

Mano, N., Mao, F., & Heller, A. (2002). A miniature biofuel cell operating in a physiological buffer. Journal of the American Chemical Society, 124(44), 12962-12963. https://pubs.acs.org/doi/10.1021/ja028514g

Pasternak, G., Greenman, J., & Ieropoulos, I. (2016). Comprehensive study on ceramic membranes for low-cost microbial fuel cells. Chemsuschem, 9(1), 88–96. https://pubmed.ncbi.nlm.nih.gov/26692569/

Rosario. (2019). 13 M Filipinos still without electricity; party-list solons seek P28.5 to address it. Manila Bulletin. https://news.mb.com.ph/2019/08/06/13-m-filipinos-still-without-electricity-partylist-solons-seek-p28-5-to-address-it/.

Sun, H., Jianchang Li, Meihong Yang, & Qiongli Shao. (2018). Influence of Initial pH on Anodic Biofilm Formation in Single-Chambered Microbial Electrolysis Cells. Polish Journal of Environmental Studies, 28(3), 1377. http://www.pjoes.com/Influence-of-Initial-pH-on-Anodic-Biofilm-nFormation-in-Single-Chambered-Microbial,89503,0,2.html

Wen, Q., Wu, Y., Zhao, L., & Sun, Q. (2010). Production of electricity from the treatment of continuous brewery wastewater using a microbial fuel cell. Fuel, 89(7), 1381-1385. https://www.researchgate.net/publication/244068308_Production_of_Electricity_From_the_Treatment_of_Continuous_Brewery_Wastewater_Using_a_Microbial_Fuel_Cell

Winfield, J., Gajda, I., Greenman, J., & Ieropoulos, I. (2016). A review into the use of ceramics in microbial fuel cells. Bioresource technology, 215, 296-303. https://www.sciencedirect.com/science/article/pii/S0960852416304382

Xu, H., Qi, L., Chen, Y., Wen, Q., Wu, J., Duan, T., & Wang, Y. (2018). Preparation and microbial fuel cell application of sponge-structured hierarchical polyaniline-texture bioanode with an integration

of electricity generation and energy storage. Journal of Applied Electrochemistry, 48(11), 1285. https://link.springer.com/article/10.1007/s10800-018-1252-9

Yin, Y., Huang, G., Di, M., Xue, C., Li, W., Zhang, L., & Liu, Y. (2017). Increased electroactive species concentration in anodic biofilm of Geobacter-inoculated microbial fuel cells under static magnetic field. Research on Chemical Intermediates, 43(2), 873. https://www.researchgate.net/publication/305694977_Increased_electroactive_species_concentration_in_anodic_biofilm_of_Geobacter-inoculated_microbial_fuel_cells_under_static_magnetic_field

A Review on the Potential and Efficacy of Plant-Based Mosquito Repellents Against DEET-Based Mosquito Repellents

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Abstract: The number of insect-borne diseases has brought many health-related issues, prompting the search, discovery, and formulation of insect repellents to prevent the acquisition of diseases. However, the preferred and conventional chemical-based repellent has downsides contrary to the benefits, such as the concern towards human and environmental safety. Meanwhile, scientific understanding of plants is mainly underexplored, resulting in people's preferences for chemical-based insect repellents. The main objective of this review was to evaluate the efficacy of N, N-diethyl-3-methyl-benzamide (DEET), found in chemical-based repellents, and terpenes, found in plant essential oil-based repellents, to show the potential of both, along with the possibility of using plant-based repellents as an alternative to the conventional ones. The review was done by comparing and analyzing the fundamental data obtained from previous studies, focusing on the DEET or essential oil concentration, repellency rate, protection time for the efficacy, and the mosquito species that the tested repellents have shown to repel. After reviewing and comparing the results from primary sources, the researchers concluded that DEET-based and plant-based repellents both have potential depending on the concentration and the process of repellent formulation, as some plant-based repellents demonstrate longer protection times and thus greater potential than some of the DEET-based ones.

Key Words: DEET; terpenes; mosquito repellent; repellent-active compounds; efficacy

1. INTRODUCTION

1.1. Background of the Study

Blood-sucking and disease-carrying insects are a major cause of illness to children and adults worldwide, especially in tropical and subtropical climates (Family Doctor, 2017). This prompted the search and formulation of repellents that contain the ingredient N, N-diethyl-3-methyl-benzamide (DEET) to prevent such insect-borne diseases. While DEET repellents are proven to be the most preferred and widely used (Moore et al., 2018), there are human safety and environmental concerns along with its use. High concentrations (10% or more) being needed for the application to be effective can produce adverse effects such as dermal reactions, neurotoxic and cardiotoxic effects, seizures, or convulsions (Legeay et al., 2018). DEET has also been detected in wastewater, surface water, and groundwater (Gao et al., 2020). Moreover, studies have shown that these conventional repellents can already be resisted by Aedes aegypti (Almadiy, 2020). Thus, it is significant to search for repellent alternatives that do not include hazardous chemicals and instead take on safer and natural ingredients that pose fewer risks, such as those derived from plant extracts. Although plants as repellents have potential and are already moderately used, the scientific understanding of these plants is underexplored. This review looks more into plant-based repellents, evaluates their efficacy, and compares them to those of chemical-based repellents.

1.2. Research Objectives

To be able to evaluate and compare the efficacy of chemical-based and plant-based mosquito repellents with the active compounds present, the researchers did the following:
research published articles dating from 2016 to 2021;
determine the properties of active compounds of both chemical-based and plant-based repellents;
compare and evaluate significant similarities and

differences in the efficacy of DEET and essential oils with terpenes as mosquito repellents; and
conclude the potential of plant-based repellents as an alternative to chemical-based repellents.

1.3. Scope and Limitations

The scope of this review is the evaluation of the potential of chemical repellents based on DEET and natural repellents based on plant essential oils (EOs) containing terpenes. This review covered various studies that measured the repellent activity of the said compounds against mosquito species of the order Diptera. With the reported data from previous studies, the present study is only in the form of a written review. A conclusion regarding the potential of plant-based repellents and chemical-based repellents was formulated only through the obtained information from the gathered studies.

1.4. Significance of the Study

The study serves as an exploration and evaluation of plant-based and chemical-based repellents through their efficacy. Through this, the study imparts knowledge to the general public by providing information and conclusions about the potential of the conventional chemical-based repellents and the natural repellents that are accessible and environmentally friendly. It contributes to the awareness of communities in tropical and subtropical areas regarding the advantage and usefulness of phytochemicals from plants to control insects. On a larger scale, this could contribute to the production of chemical-based and plant-based repellents, as a broader understanding of the two is essential for future innovations.

2. METHODOLOGY

2.1 Subsection

Give the support for your main claim by showing evidence for it. What are the foundations of your claim (theoretical framework)? What conclusion/s follow from it. How are you deriving the conclusion from the basis/bases of your claim (methodology)? It is not always necessary to actually state the specific logical rules for your inferences. It depends on the style that you are taking on in writing your paper. (In papers that are not highly analytical, if you find it necessary to label the actual process/es of derivation of your conclusion, do it in the footnotes.) But the correct inference must be made apparent here and you have to convince your audience of your argument.

Figures and tables should be referred to in the text. They should be centered as shown below and must be of good resolution.

2. Review of Related Literature

2.1. Active Compounds

2.1.1. Chemical-Based N, N-diethyl-3-methyl-benzamide

Chemical compounds are often used in the formulation of commercially available repellent products. Figure 1 shows the chemical structure of one of the most widely used synthetic chemicals, N, N-diethyl-3-methyl-benzamide, commonly known as DEET.

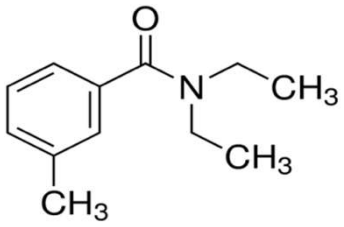

Figure 1. Chemical Structure of N, N-diethyl-3-methyl-benzamide

DEET is known to be the 'gold standard' for repellents for its long-lasting repellency towards different species of arthropods such as mosquitoes, ticks, fleas, and flies. DEET-based repellents are available worldwide today in various formulations, including aerosols, creams, lotions, sprays, gels, sticks, and wipes (towelettes) at concentrations ranging from 5% to 100% (Riffell, 2019).

2.1.2. Plant-Based Terpenes

Among the classes of plant secondary metabolites, terpenes is the largest and most diverse group. As shown in Figure 2, terpenes are composed of branched 5-carbon isoprene units assembled in different ways and are thus classified according to the number of isoprene units they contain (Ali, 2020; Ramirez-Gomez et al., 2019). These lipid-soluble compounds are synthesized by all organisms through the mevalonate and deoxy-D-xylulose pathways (Sahebi et al., 2017).

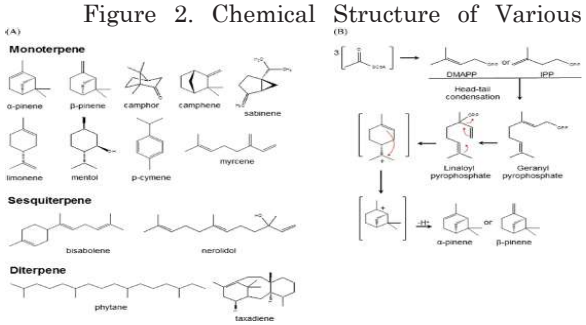

Figure 2. Chemical Structure of Various Terpenes

Monoterpenes, which consist of two isoprene units, are important components of plant EOs. Limonene, linalool, linalyl acetate, citronellal, and carvone are some of the monoterpenes (Hussein & El-Anssary, 2018). Terpenes and terpenoids being constituents of most EOs, allow them to act as insect repellents (Ali, 2020; Valduga et al., 2019).

2.2. Study Designs and Methods

2.2.1. Gas Chromatography-Mass Spectrometry

Gas chromatography-mass spectrometry (GC-MS) is the method used to identify and quantify the active constituents in the extracted EOs from plants. The identification of the chemical components and the calculation of their corresponding percentage compositions are done as the peaks of the chromatographs are compared with the library (Arpiwi et al., 2020; Manh & Tuyet, 2020).

2.2.2. Nanoemulsion and Microencapsulation Processes for Repellent Formulations

Mohammadi et al. (2019) used the process of nanoemulsion for the formulation of some plant-based repellents. Nanoemulsion is the two-phase dispersion of two immiscible liquids, either water in oil or oil in water droplets which are stabilized by an amphiphilic surfactant (Singh et al., 2017). Moreover, Misni et al. (2016) utilized microencapsulation to formulate some repellent lotions tested against Ae. aegypti. Microencapsulation is a method used particularly in commercial repellent formulations, wherein the EO is encapsulated by a natural or synthetic polymeric membrane for it to control the release rate and prevent the volatile compounds from evaporating (Beestman 2003, Tuetun et al., 2008, as cited in Misni et al., 2016).

2.2.3. Repellency Test

The arm-in-cage method is a measurement test of efficacy for topical mosquito repellents under laboratory conditions. In this method, starved female mosquitoes are contained in the test cage where the skin impregnated with the repellent is exposed. The repellent is applied to the forearm area while a glove contours the unexposed part to prohibit the mosquitoes from biting there (Colucci & Müller, 2018). Mohammadi et al. (2019), Manh and Tuyet (2020), Misni et al. (2016), and Arpiwi et al. (2020) used this method based on the WHO guidelines (2009) with a few modifications to determine the efficacy of mosquito repellents.

3.1. Search Strategies and Inclusion Criteria

This review used research articles and studies written and published in various journals over the last five years, from 2016 to 2021. Most articles were researched using Google Scholar, ScienceDirect, and PubMed and were accessed using the researchers' accounts and the De La Salle University Library's online databases. To look for published works done by other researchers relevant to the scope, the search terms used were 'mosquito repellent,' 'DEET,' 'secondary metabolites,' 'terpenes,' 'chemical constituents,' and 'repellent activity.'

3.2. Screening Process

With various available publications about the repellent activities of DEET and plant EOs with terpenes, the researchers screened the date of publication and article types, not considering those published earlier than 2016 or were in the form of a review article. The titles and abstracts were then screened; articles that focused on larvicidal activity or did not test against mosquitoes were eliminated. Lastly, the full-text articles of those deemed relevant to the review were checked for eligibility; those that did not provide sufficient information about the active compounds DEET or terpenes and their protection ability against mosquitoes were excluded.

3.3. Data Analysis Strategy

With the researched related works, the researchers presented the properties of the active compounds of chemical-based and plant-based repellents. Essential data and results from the publications, such as the plant species, plant parts used, and the EO's active constituents, DEET or EO concentration in the formulated repellent, repellency rate, protection time, and mosquito species repelled by each of the formulations, were organized and summarized into a table, ordered by the chemical-based DEET, then the plant-based EOs. Analysis and evaluations on the efficacy of different repellent formulations based on protection time were then made to compare the potential of chemical-based and plant-based mosquito repellents.

3. RESULTS AND DISCUSSION

3.1. Active Compounds

Table 1. *N, N-diethyl-3-methyl-benzamide Tested on Aedes aegypti and Anopheles stephensi*

DEET Concentration in Formulated Repellent	Repellency Rate	Repellency Time	Insect Repelled	Reference
25%	100%	6.10 hours	*Anopheles stepehnsi*	Mohammadi et al. (2019)
20%	100%	6 hours	*Aedes aegypti*	Manh & Tuyet (2020)
20%	100%	4 hours	*Aedes aegypti*	Misni et al. (2016)
15%	100%	4 hours		
10%	100%	2 hours		
5%	100%	2 hours		

Table 2. *Plant Essential Oils Tested on Aedes aegypti and Anopheles stephensi*

Plant – part EO was obtained	Active Constituents in EO (GC-MS)	EO Concentration in Formulated Repellent	Repellency Rate	Repellency Time	Insect Repelled	Reference
Peppermint (*Mentha piperita*) – aerial parts	d-limonene (19.72%), thymol (19.02%), carvacrol (12.37%)	50% 50% (Nanoemulsified)	100% 100%	2.89 hours 4.17 hours	*Anopheles stephensi*	Mohammadi et al. (2019)
Eucalyptus (*Eucalyptus globulus*) – leaves	1,8-cineole (59.45%), terpinene (10.91%)	50% 50% (Nanoemulsified)	100% 100%	0.96 hours 5.51 hours	*Anopheles stephensi*	Mohammadi et al. (2019)
Wild mint (*Mentha arvensis*) – fresh plant leaves	menthol (66.04%), menthyl acetate (22.19%), menthone (2.51%), limonene (2.04%)	25% 50% 100%	100% 100% 100%	0.75 hours 1.5 hours 2.75 hours	*Aedes aegypti*	Manh & Tuyet (2020)
Chaste tree (*Vitex agnolia*) – fresh leaf samples	cis-ocimene (44.57%), α -thujene (22.63%), cyclopentene,3-isopropenyl-5,5-dimethyl (18.19%), α-pinene (6.38%)	4% 5% 6%	99.74% 100% 100%	3 hours 3 hours 3 hours	*Aedes aegypti*	Arpino et al. (2020)
Lime (*Citrus aurantifolia*) – leaves	limonene, β-pinene - Al-Jaouni et al. (2018)[a]	20% 20% (Microencapsulated) 15% (Microencapsulated)	92.76% 100% 100%	1 hour 2 hours 2 hours	*Aedes aegypti*	Misni et al. (2016)
Pomelo (*Citrus grandis*) – fruit peel	limonene, β-pinene, 3-carene - Sajid et al. (2016)[b]	20% 20% (Microencapsulated) 15% (Microencapsulated)	94.67% 100% 100%	1 hour 2 hours 2 hours	*Aedes aegypti*	Misni et al. (2016)
Galangal (*Alpinia galanga*) – rhizome	carotol, eucalyptol - Singh et al. (2020)[c]	20% 20% (Microencapsulated) 15% (Microencapsulated)	96.89% 100% 100%	1 hour 2 hours 2 hours	*Aedes aegypti*	Misni et al. (2016)

ABC other studies that identified the active constituents present in the same EOs were used because the researchers who tested on these EO-based repellents did not perform GC-MS.

The researchers of the present study were able to compile the data from previous studies, as summarized in Tables 1 and 2, because these studies used the same bioassay method or study design wherein the formulated repellents were directly applied to the skin of the forearm of human subjects. The studies provided information about the repellency rate, repellency time, and species repelled by the formulated repellents. Moreover, the DEET or EO concentrations listed in the tables refer to the percentage by volume composition of either DEET or a plant EO in each of the repellents formulated by the researchers.

Table 1 shows the interrelation of the repellency rate and repellency time of a formulated repellent with a particular DEET concentration tested on either Ae. aegypti or An. stephensi. Meanwhile, Table 2 shows the EOs obtained from certain parts of plants whose repellent formulations were tested on either Ae. aegypti or An. stephensi.

As can be seen in Table 1, DEET-based repellents provide long protection times, depending on the DEET concentration, against Ae. aegypti and An. stephensi, thus being widely used in conventional repellents. In contrast, Table 2 shows that all the active constituents in plant EOs identified by the researchers contained an abundance of terpenes as the major compounds, which previous studies explain to provide the potential of plant-based repellents against different mosquito species.

Several studies present the comparable potential of DEET-based and plant-based repellents in terms of protection time. The nanoemulsified eucalyptus-based repellent at 50% concentration having a complete protection time (CPT) of 5.51 hours against An. stephensi (Table 2) is shown to be close to the formulated 25% DEET repellent with a CPT of 6.10 hours against the same species (Table 1).

Meanwhile, the 5% and 10% concentrated DEET-based repellents, which present complete protection against Ae. aegypti after 2 hours (Table 1), exhibit the same repellent potential to a 15% or 20% concentration of a microencapsulated repellent based on the EO of either lime, pomelo, or galangal in terms of the time for complete protection (Table 2). There are even some plants that have demonstrated a longer CPT than the previously mentioned DEET-based repellents. As presented in Table 2, these were the 100% wild mint EO-concentrated repellent, which had a CPT of 2.75 hours, and chaste tree EO-based repellents at a concentration of either 5% or 6%, as they both demonstrated complete protection against Ae. aegypti up to 3 hours post-application. Given that these 5% and 6% chaste tree EO-based repellents already exhibit a high repellency rate at a longer time of protection, although formulated at a low concentration, chaste tree-based formulations with higher concentrations of EO may provide a longer CPT and exhibit a greater potential.

Furthermore, Tables 1 and 2 show that as the EO concentration in the formulated repellent is increased, the corresponding time that provided complete protection also increased. Although DEET-based repellents formulated at higher concentrations of the active compound demonstrate a longer protection time, the risks or concerns in human and

environmental safety associated with their concentrations and their use reduce their advantageous potential. In addition, as shown in Table 2, the nanoemulsion and microencapsulation processes for the formulation of plant-based repellents have significantly increased their protection time and potential, similar to DEET, compared to those that were formulated the standard way, with no additives present. The effects of these additives and methods and the concerns that may come with higher concentrations of plant EOs require further study to potentially widen the use of plant-based repellents.

Such comparisons from different articles over similar variables, including DEET or EO concentration, repellency rate, or protection time, show that plant-based repellents that contain an abundance of terpenes as active constituents indeed have potential repellent properties against various mosquitoes that is comparable to that of DEET.

4. CONCLUSIONS

Comparing the various studies that presented the concentration, repellency rate, and protection time of DEET-based and plant-based repellents, it has been found that both have their potential repellent properties. Some of the repellents formulated with plant essential oils that contain terpenes, depending on the concentration, even exhibit longer protection times than DEET. This clearly shows that essential oil from plants can be utilized as an alternative to DEET-based repellents, which are known to have drawbacks, harms, and disadvantages.

Awareness regarding the potential of repellents based on various plant species that contain terpenes must thus be increased, as they can also be preferred and used as an alternative to chemical-based repellents. Moreover, further research is recommended on the repellents toward other mosquito species and insects, the plants containing other secondary metabolites as major compounds, and the repellent formulations that would improve their longevity and potentially widen their application and utilization.

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6. REFERENCES

Ali, B. (2020). Salicylic acid: An efficient elicitor of secondary metabolite production in plants. Biocatalysis and Agricultural Biotechnology. https://doi.org/10.1016/j.bcab.2020.101884

Al-Aamri, M. S., Al-Abousi, N. M., Al-Jabri, S. S., Alam, T., & Khan, S. A. (2018). Chemical composition and in-vitro antioxidant and antimicrobial activity of the essential oil of Citrus aurantifolia L. leaves grown in Eastern Oman. Journal of Taibah University Medical Sciences, 13(2), 108-112. https://doi.org/10.1016/j.jtumed.2017.12.002

Almadiy, A. A. (2020). Chemical composition, insecticidal and biochemical effects of two plant oils and their major fractions against Aedes aegypti, the common vector of dengue fever. Heliyon, 6(9), e04915. https://doi.org/10.1016/j.heliyon.2020.e04915

Arpiwi, N. L., Muksin, I. K., & Kriswiyanti, E. (2020). Essential oils from Vitex trifolia as an effective repellent for Aedes aegypti. Biodiversitas, 21(10), 4536–4544. doi: 10.13057/biodiv/d211060

Colucci, B., & Müller, P. (2018). Evaluation of standard field and laboratory methods to compare protection times of the topical repellents PMD and DEET. Scientific Reports, 8(1), 1. https://doi.org/10.1038/s41598-018-30998-2

Family Doctor. (2017). Insect-borne diseases. Retrieved from https://familydoctor.org/condition/insect-borne-diseases/

Gao, X., Wang, X., Li, J., Ai, S., Fu, X., Fan, B., Li, W., & Liu, Z. (2020). Aquatic life criteria derivation and ecological risk assessment of DEET in China. Ecotoxicology and Environmental Safety, 188, 109881. https://doi.org/10.1016/j.ecoenv.2019.109881

Hussein, R. A. & El-Anssary, A. A. (2018). Plants secondary metabolites: The key drivers of the pharmacological actions of medicinal plants. Herbal Medicine. Philip F. Builders, IntechOpen. http://dx.doi.org/10.5772/intechopen.76139

Legeay, S., Clere, N., Apaire-Marchais, V., Faure, S., & Lapied, B. (2018). Unusual modes of action of the repellent DEET in insects highlight some human side effects. European Journal of Pharmacology, 825, 92–98. doi:10.1016/j.ejphar.2018.02.033

Manh, H. D. & Tuyet, O. T. (2020). Larvicidal and repellent activity of Mentha arvensis L. essential oil against Aedes aegypti. Insects, 2020(11), 198.

Misni, N., Nor, Z. M., & Ahmad, R. (2016). New candidates for plant-based repellents against Aedes aegypti. Journal of the American Mosquito Control Association, 32(2), 117-123. doi: 10.2987/moco-32-02-117-123.1

Mohammadi, R., Khoobdel, M., Negahban, M., & Khani, S. (2019). Nanoemulsified Mentha piperita and Eucalyptus globulus oils exhibit enhanced repellent activities against Anopheles stephensi. Asian Pacific Journal of Tropical Medicine, 12(11), 520–527. doi: 10.4103/1995-7645.271292

Moore, E. L., Scott, M. A., Rodriguez, S. D., Mitra, S., Vulcan, J., Cordova, J. J., … Hansen, I. A. (2018). An online survey of personal mosquito-repellent strategies. PeerJ, 6. https://doi.org/10.7717/peerj.5151

Ramirez-Gomez, X. S., Jimenez-Garcia, S. N., Campos, V. B., & Campos, M. L. G. (2019). Plant metabolites in plant defense against pathogens. Plant Diseases – Current Threats and Management Trends. http://dx.doi.org/10.5772/intechopen.87958

Riffell, J. (2019). Olfaction: Repellents that congest the mosquito nose. Current Biology, 29(21), R1124-R1126. https://doi.org/10.1016/j.cub.2019.09.053

Sahebi, M., Hanafi, M. M., van Wijnen, A. J., Akmar, A. S. N., Azizi, P., Idris, A. S., Taheri, S., & Foroughi, M. (2017). Profiling secondary metabolites of plant defence mechanisms and oil palm in response to Ganoderma boninense attack. International Biodeterioration & Biodegradation, 2017(122), 151-164. http://dx.doi.org/10.1016/j.ibiod.2017.04.016

Sajid, A., Sarfraz, R. A., Hanif, M. A., & Shahid, M. (2016). Evaluation of chemical composition and biological activities of Citrus pseudolimon and Citrus grandis peel essential oils. Journal of the Chemical Society of Pakistan, 38(2), 266. http://web.a.ebscohost.com/ehost/pdfviewer/pdfviewer?vid=2&sid=f1070230-6aa1-4453-a2dd-90230e35a4c3%40sessionmgr4008

Singh, Y., Meher, J. G., Raval, K., Khan, F. A., Chaurasia, M., Jain, N. K., & Chourasia, M. K. (2017). Nanoemulsion: Concepts, development and applications in drug delivery. Journal of Controlled Release, 252, 28–49. https://doi.org/10.1016/j.jconrel.2017.03.008

Singh, S., Sahoo, B. C., Kar, S. K., Sahoo, A., Nayak, S., Kar, B., & Sahoo, S. (2020). Chemical constituents analysis of Alpinia galanga and Alpinia calcarata. Research Journal of Pharmacology and Technology, 13(10), 4735-4739. doi: 10.5958/0974-360X.2020.00834.3

Valduga, A. T., Goncalves, I. L., Magri, E., & Finzer, J. R. D. (2019). Chemistry, pharmacology and new trends in traditional functional and medicinal beverages. Food Research International, 2019(120), 478-503. https://doi.org/10.1016/j.foodres.2018.10.091

Solar Power Integration in Water (H2O) Distillation (SPIN-HD)

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Abstract: As the world faces a looming crisis of water scarcity and contamination, water use and safe consumption have been compromised worldwide. People depend on tap water whose contamination causes a wide range of diseases, which are often life-threatening. Given that water purifying methods are not commonly accessible in households, and solar stills are only efficient with sunlight, this study employed a creation of a solar-powered water distiller prototype that can be used in small settings. The study consisted of designing and building a battery-powered safety testing setup, safety testing, designing and building of the solar-powered water distiller prototype, prototype testing, and data collection. An integration of hardware materials, i.e., 2 stainless steel cylindrical containers, AWG 14, car glow plug heater, customized condensation sloping lid, and 12V4.5Ah battery, was done in building the safety testing setup. The safety testing was followed by the removal of the 12V4.5aH battery, and the consequent integration of the 50-watt solar panel, solar charge controller, and 12V30Ah battery. After five (5) experimental testings, the solar-powered water distiller prototype produced an average volume of 58.6mL in an average heating time of 112.2 minutes, making an average distillation rate of 31.3mL/hr. Such a distillation rate was obtained under an average ambient temperature of 31.2oC, average starting battery voltage of 12.3, and average end battery voltage of 4.1.

Key Words: water distillation; solar distillation; distillation

1. INTRODUCTION

Water is crucial to human survival. It eliminates body toxins, flushes waste, and regulates body temperature. It is the key to survival that humans can only last 3-4 days without it. Unfortunately, within the past hundred years, water use has been growing at a rate more than twice the human population's growth, making water insufficient to meet global demands. As water supplies continue to shrink, some parts of the world face a looming crisis (Casella, 2019). About 4 billion people, representing nearly two-thirds of the world's population, experience severe water scarcity once a month in a year (Mekonnen and Hoekstra, 2016).

Safe and readily available water is vital for public health, primarily when used for drinking and food production. However, in 2017, 2.2 billion people do not have safely managed drinking water services located on-premises, available when needed, and free from fecal and priority chemical contamination (WHO, 2019). Consequently, people have depended on tap and underground water reservoirs for their freshwater needs but these sources do not always prove to be beneficial to one's health due to the presence of excessive salinity and deficient sanitation, which widely exposes people to water-borne illnesses, such as diarrhea, cholera, and typhoid fever.

The process of water distillation requires heat to evaporate water. The vapor, then, undergoes condensation, producing distilled water. This process removes water impurities, which can be any suspended substance, such as heavy materials, salts, and microbiological organisms (Kucera, 2005). Moreover, in distillation, solar energy can be utilized wherein the heat of the sun will heat the water, which is placed underneath a transparent cover, to evaporation. In the study conducted by Arunkumar, Vinothkumar, Ahsan, Jayaprakash, and Kumar in 2012, the most productive solar still model was the tubular solar still coupled with pyramid solar still, which has tubes and a 4-phased glass sloping top where the water vapor condensed, and accumulated. However, the downside of solar distillers like this is that although they can yield an ample amount of distilled water, they cannot function unless solar energy can be harnessed. They also depend their productivity on their size, meaning that the smaller they are, the less the volume they can subject to distillation.

As the mentioned global problem of water purifying methods not being commonly accessible in households and solar stills being inefficient in the absence of sunlight, this study aimed to integrate hardware materials to create a solar-powered water distiller, which can be used in small settings.

2. METHODOLOGY

The activities done in attaining the research objectives were composed of the designing and building of the battery-powered safety testing setup, safety testing, designing and building of the solar-powered water distiller prototype, and prototype testing and data collection. The completion of activities ranged for nine months (July 2020 to March 2021).

2.1. Materials

The materials used in building the battery-powered safety testing setup were two Phelps Dodge AWG 14 (1 meter each), stainless steel car glow plug heater, two stainless steel cylindrical containers (9in height x 8.9in diameter each), CSBattery 12V4.5Ah/20HR battery, and a customized stainless steel condensation sloping lid (See Figures 1-2).

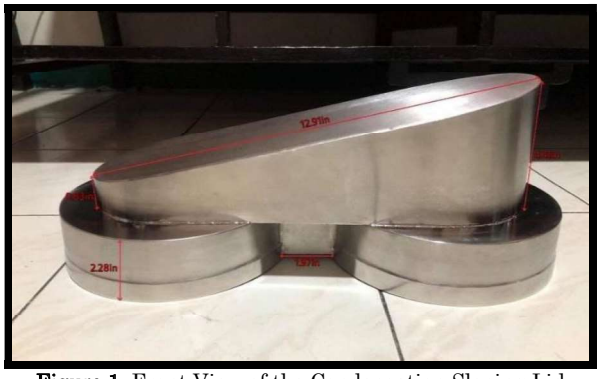

Figure 1. Front View of the Condensation Sloping Lid

Figure 2. Bottom View of the Condensation Sloping Lid

The same wirings, heater, containers, and sloping lid were used in building the solar-powered water distiller prototype, only that a 50-watt foldable monocrystalline solar panel from Best Choice Philippines, DJ Scorpio Lead Acid 12V30Ah/20HR battery, and a PWM solar charge controller were added in the setup.

A measuring pitcher, measuring cup, Google-searched weather indicator, multimeter, and timer were used for the data collection.

2.2. Designing and Building of the Battery-powered Safety Testing Setup

In accordance with the diagram shown in Figure 3, the procedures in building the battery-powered safety testing setup involved the attachment of the car glow plug heater into the two 1-metered AWG 14, insertion of heater on the inside bottom of container 1, adjoining of reservoir container to the first container via condensation lid, and connection of AWG 14 to the 12V4.5Ah battery.

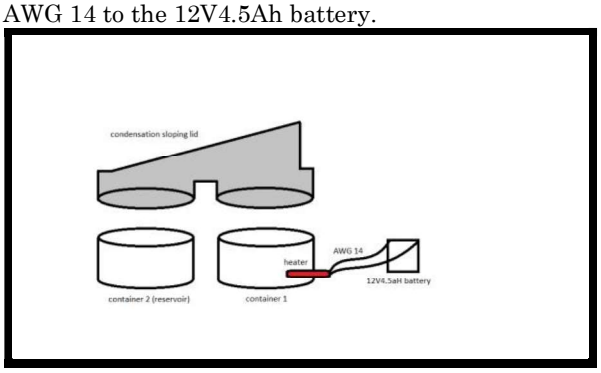

Figure 3. Battery-Powered Safety Testing Setup Diagram

2.3. Safety Testing

For this phase, 1L of water was subjected to distillation using the battery-powered safety testing setup. The safety testing determined whether the heater worked given a power source.

2.4. Designing and Building of the Solar-powered Water Distiller Prototype

The 12V4.5Ah battery was removed from the safety testing setup. It was followed by the integration of the 12V30Ah battery, 50-watt solar panel and solar charge controller, as shown in the diagram in Figure 4.

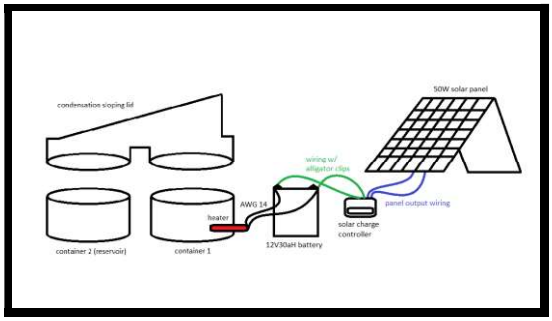

Figure 4. Final Prototype Diagram

2.5. Prototype Testing and Data Collection

The prototype was tested for five consecutive days. It was given three hours from 11AM to 2PM to perform its mechanism (Figure 5). The ambient temperature was recorded for each experiment. The solar charge controller's float charge, lead reconnect, load disconnect, programmable timer, and battery type were set as 14.5v, 11.0v, 10.7v, 24, and B1, respectively. The voltage in the battery, 5-10 seconds after the heating process started, was measured and was regarded as the starting battery voltage. The heating of the car glow plug was timed until it came to a stop. The battery's voltage was measured again and was regarded as the end battery voltage. After the system shut down, the prototype was given 40 minutes to cool down to give time for the remaining impure hot water to evaporate and condense. Finally, the volume of produced distilled water was recorded.

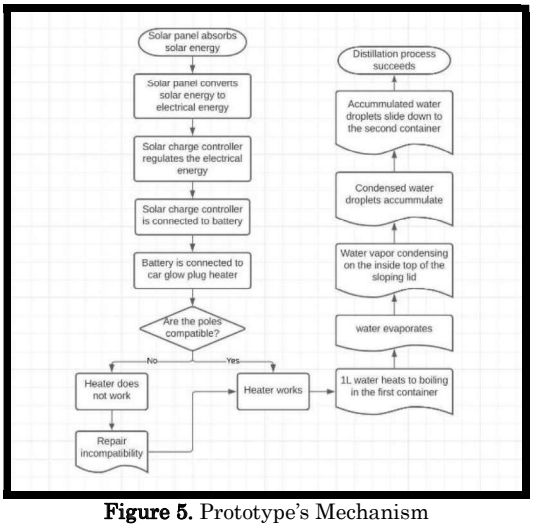

Figure 5. Prototype's Mechanism

2.6. Data Analysis

To assess whether there were significant differences in the prototype's performance, all data values from each experiment were put in a table for comparison. The mean of all data values per category was computed including the 5 distillation rates (mL/hr) that served as the prototype's average rate of distillation. The rate of distillation per experiment was determined through the formula rate of distillation= volume (mL)hour (hr).

3. RESULTS AND DISCUSSION

3.1. Safety Testing

The safety testing setup shown in Figure 6 was built according to its design (Figure 3). The incandescence of the car glow plug heater shown in Figure 7 proved that the positive and negative polar attachment between it and the AWG 14 (Figure 8) was compatible after being powered by the 12V4.5Ah battery.

Figure 6. Safety Testing Setup

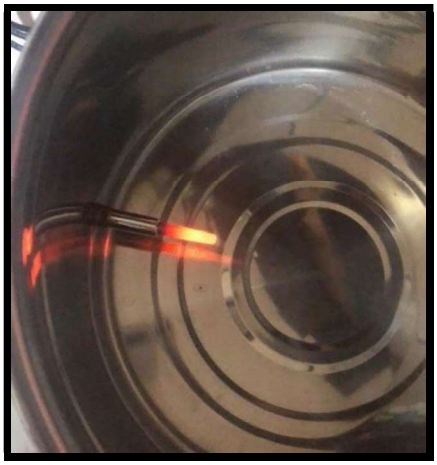

Figure 7. Incandescence of Heater

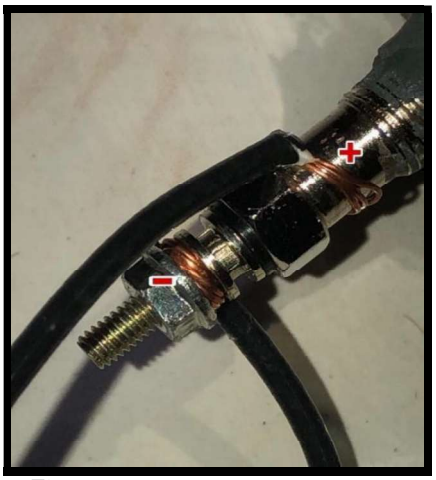

Figure 8. Heater Attached to AWG 14

As the 1L of water was heated in the first container during the safety testing, condensed water droplets formed on the cylindrical wall of the container whose surface area was not submerged (see Figure9).

Figure 9. Condensed Water Droplets on the Unsubmerged Wall of the Container

After 14 minutes, the battery was drained and the heater stopped. No distilled water was collected in the second container.

3.2. Final Prototype Testing

Figure 10. Final Prototype

After the safety testing, the building of the final prototype (Figure 10) was done according to its design shown in Figure 4.

Simultaneous prototype testing and data collection started when the heating process of the final prototype began. The heating process started when the wirings attached to the heater were pressed against their corresponding electrical poles in the 12V30Ah battery. The wirings' attachment and detachment to the battery poles served as the on and off of the prototype's heating process.

After the 12V30Ah battery's voltage dropped to an average of 4.1 (see Table 1), the heating process stopped. As the prototype cooled, a considerable amount of water droplets formed on the vertical bounds of the lid when it was detached from the containers (see Figure 11).

Figure 11. Condensed Water Droplets on the Lid's Vertical Bounds

The testing results after the 5-day trials can be seen in Table 1 below.

Table 1. *Final Prototype Testing Experimental Results*

Experimental trial	Ambient temperature (°C)	Starting voltage (v)	End voltage (v)	Heating time (mins)	Volume of distilled water (mL)	Rate of distillation (mL/hr)
1	32	12.4	4.1	113	59.2	31.4
2	30	12.3	4.1	109	57.6	31.7
3	31	12.5	4.1	115	59.5	31.0
4	32	12.1	4.3	108	57.4	31.9
5	31	12.1	4.1	116	59.2	30.6
Average	31.2	12.3	4.1	112.2	58.6	31.3

4. CONCLUSIONS

There was no irregularity in terms of the prototype's distillation rate obtained from each trial. The prototype was able to produce a relatively low volume of distilled water, an average of 58.6mL to be exact, in an average time of 112.2 minutes, making an average distillation rate of 31.3mL/hr. Such a rate can be obtained with specific conditions, i.e., average ambient temperature of 31.2oC, average starting battery voltage of 12.3, and average end battery voltage of 4.1.

Based on the conducted testings, it can be concluded that such a low distillation rate resulted

from four main reasons. First, the containers were too big for a 1L distillation trial. A liter of water that was poured into the first container left an ample amount of area unfilled, which concomitantly resulted to the exposure of an ample amount of unsubmerged surface area in the container. The unsubmerged surface area, then, became a vertical bound where the vapor adhered, condensed, and dropped for redistillation. Second, there was also an ample amount of vertical surface area in the condensation sloping lid where the vapor condensed. From there, the condensed droplets also cycled to drop to the first container for redistillation as the heating process continued. Third, the car glow plug heater that was inserted was too short to reach the middle of the first container. It was only able to concentrate its heat on the container's side, which made most of the vapor condense on the inside vertical bounds of the prototype. Lastly, the solar panel's wattage is too low to recharge the 12V30aH battery while the battery continued to use up its power to supply the heating process.

Although a maximum of 3.7 liters can be poured into the first container, based on the final prototype testing, the prototype's power could only make the heating process work for less than 2 hours. A load bigger than 1 liter would lengthen the time for the water to heat and evaporate, thereby draining the battery with the prototype only producing less than an average of 31.3 mL per hour or none at all.

To yield more distilled water with the same average heating time the 50-watt solar panel and 12V30Ah battery could support, there are two ways that can be considered. First, it is recommended to replace the car glow plug heater with a circular DC heater that can evenly distribute the heat among the load. However, it is crucial to take note that the heater's wattage should not exceed 50; otherwise, the battery will drain in less than the average heating time of 112.2 minutes due to the replacement's higher consumption. Second, to avoid distilled water losses, as much as possible, minimize the surface area of the sloping lid's vertical bounds by coming up with a modified lid model. Also, the use of smaller containers is recommended if only a load of 1 liter or less is preferred for the prototype. On the other hand, to distill bigger loads using the prototype with the same containers and heater, it is recommended to raise the wattage of the solar panel, as well as the battery's voltage and amp-hour rating (Ah).

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6. REFERENCES

Ahsan, A., Arunkumar, T., Jayaprakash, R., Kumar, S., and Vinothkumar, K. (2012). Experimental Study on Various Solar Still Designs. ISRN Renewable Energy, 2012(18), 1-10. 10.5402/2012/569381

Alumeco. (n.d.). Corrosion: Reasons and Solutions. https://www.alumeco.com/knowledge-technique/general/corrosion-of-aluminium-surfaces

Casella, C. (2019, August 7). Nearly 25% of The World's Population Faces a Water Crisis, And We Can't Ignore It. Science Alert. https://www.sciencealert.com/17-countries-are-facing-extreme-water-stress-and-they-hold-a-quarter-of-the-world-s-population

Castelo, J. (2020, May 20). How to Make a Solar Still: The Ultimate Purification

Device. World Water Reserve. https://worldwaterreserve.com/potable-water/purification/how-to-make-a-solar-still/

Copper Development Association Inc. (2007, April). Gauging the Difference.
https://www.copper.org/consumers/copperhome/HomePlan/safety/gauging_difference.html

H2o Labs. (n.d.) Stainless Steel Water Distiller Model 300SSE with Glass Carafe.

http://www.h2olabs.co.uk/p-8-stainless-steel-model-300sse-water-distiller-with-glass-carafe.aspx

Inganäs, O., & Sundström, V. (2015). Solar energy for electricity and fuels. Ambio, 45(2016). 15-23. https://doi.org/10.1007/s13280-015-0729-6

Kamrin, M., Hayden, N., Christian, B., Bennack, D., & D'Itri, F. (1991, March). Distillation for Home Water Treatment. https://www.extension.purdue.edu/extmedia/WQ/WQ-12.html#:~:text=Distillation%20relies%20on%20evaporation%20to,condenses%20to%20form%20purified%20water.

KaTom Restaurant Supplies (2020, April 15). Food-grade Metals. https://www.katom.com/learning-center/food-grade-metals.html?__cf_chl_captcha_tk__=65b2cad600aafa0a852bac9e58a00b0584dd1e90-1616681637-0-Ad4bdHWgXq27iTPKhoUP0RXwIK23vP63Aq8Shjb_Dg_ibR-mYRE2kq5azTNjUoZ6Ul72tTl2v9b-JSvILf6bA0BrAfmQmvTtT6N1ofIkrGvaNZqwi8JW-a_aaGAoAwTm_oU08q9_GTBk5RUxW3v7moTvQgkKvmo5Fj3IQuoCF7uiEj1VvF6k7SS3s1_RxpStVcNzDp68iLDw4R4ZHKie_hyqi5rkGw0XN6C8s-nWK4L4-Q5sVOb9jUZXuv9hB8xsbcDERQfvEzLCdAKkb4etxHlpDXWuuNzm81vPP2qumqPL05r1_EacpjI3hFq_wUO7mnfEhiLSO-q_icllqEFaaHb28jJAxwNAARSH8sbFaq6v480eUN_v0UNpkpntgN0olpiGJcCj07RzboudD-5deqTn8VlgQlFJ_w81P01ajnCyuFU1C5uIZ45fungKMshz5Wu8-hSHH2hAXJu5geETC6cxfga0fBMjbOPgz5VKvvVtEJD1lFX72p_-KIqT7alLJLc07N2L2ZOygf8p7ZXGSHA8pPo8LZuvIBT-UGadBuHRoFRVt-8xJsTJsS1A3VXdSvK8hS12UEWcFbSghF-OcSZFyi1UYWJ-FnRbQGv5j7_5_6FzfBJmNB4aYyedO_r_Yxh1D068WcAnw7rutUsjwGM

Kucera, B. (2005, September 26). Water Distillation. Water Quality Products. https://www.wqpmag.com/water-distillation

Mekonnen, M. M., & Hoeskstra, A. Y. (2016). Four billion people facing severe water scarcity. Science Advances, 2(2). 10.1126/sciadv.1500323

Morningstar Corporation (n.d.) Why PWM? https://www.morningstarcorp.com/wp-content/uploads/2014/02/8.-Why-PWM1.pdf

Nicholson, J. (2018, March 13). How Does a Solenoid Work? https://sciencing.com/a-solenoid-work-4567178.html

Solar Power Secrets (2020, September 8). The Definitive Guide to Solar Charge Controllers: MPPT and PWM Charge Controllers in Off-Grid Solar Power Systems. https://solarpanelsvenue.com/mppt-and-pwm-charge-controllers-in-off-grid-solar-power-systems/

United States Environmental Protection Agency. (2016, September 29). Types of Drinking Water Contaminants. https://www.epa.gov/ccl/types-drinking-water-contaminants

US Food and Drug Administration. (2013). Food Code. https://www.fda.gov/media/87140/download

World Health Organization (2019, June 14). Drinking-water. https://www.who.int/news-room/fact-sheets/detail/drinking-water

World Health Organization (2019, June 14). Sanitation. https://www.who.int/news-room/fact-sheets/detail/sanitation#:~:text=Some%20827%20000%20people%20in,killer%20but%20is%20largely%20preventable.

Zonesun Technology Limited. (2020). ZONESUN 4L Portable Stainless steel Water Distiller Pure Water Filter, Purifier Water Distiller Filter. https://www.zonesuntech.com/products/4l-portable-stainless-steel-water-distiller-pure-water-filter-purifier-water-purifier-water-distiller-filter-treatment-container?fbclid=IwAR2tAorRWCv_yxjS6Q6rVSpKsFGY92zl1IoBwbTeVs2Jzdnja9DLPQv_Vlg

A Systematic Approach for the Paper Review on the Utilization of Citrus Fruit Waste in the Philippines

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Abstract: One of the main contributors to the waste problem in the Philippines is citrus fruits because of their high yield. Various studies have investigated the utilization of citrus fruit waste for different applications. However, there is a lack of a systematic mapping study that can bring these studies together. Thus, this study employed a systematic approach to determine the utilization of citrus fruit wastes which will be beneficial to reduce waste in the landfill. This study sought to: 1) investigate the trends in current research on citrus fruit waste utilization, 2) identify the processes undergone by citrus fruit waste to achieve their respective applications, and 3) observe the techniques that have been utilized to evaluate the efficiency and performance of citrus fruit waste products. The study performed a general search for papers related to citrus fruit waste utilization in Scopus search engine. The documents were organized into specific categories, and data extraction was performed. After the data was analyzed and the following results were obtained: there is a continuous increase in the amount of research on citrus fruit waste utilization, citrus fruit peels are the most commonly used type of waste, citrus fruit wastes undergo rigorous processes that mostly involve heat to reach their applications, and most studies utilize pore size and BET surface area to evaluate fruit waste products. In conclusion, citrus fruit waste utilization is a topic with great potential, and will contribute to solving the waste management problem in the country.

Key Words: citrus fruit waste; waste treatment; environment; systematic mapping study; sustainable management

1. INTRODUCTION

The Philippines is a tropical country with a high production of fruit-related products yielding high amounts of fruit waste (Zafar, 2020; PSA, 2019a, 2019b, 2019c, 2019d). In 2015, it imported over 86,967 metric tons of citrus fruits, contributing to the amount of citrus fruit waste in the country (PSA, 2015). Solid waste management is an issue in the country due to the high rates of waste generation (Atienza, 2020). Thus, the majority is placed into dumpsites or waterways, contributing to flooding and pollution (Flores et. al., 2018). Data shows that 95% of household solid waste can be reused. 43% of which can be recycled and 52% can be composted (Castillo & Otoma, 2013). This implies that there is a lack of awareness for their usefulness and has led to the belief that most solid waste is purposeless.

One topic of interest is the use of citrus fruit waste, which is rich in carbon and has been observed in wastewater treatment as an absorbent for wastewater contaminants (Pathak et.al. 2017). Common and sustainable citrus fruit waste utilization methods such as biochar, nanocatalyst, and activated carbon were discussed in research regarding citrus fruits. Biochar is a crushed carbon material modified through physical and chemical activation processes utilizing raw waste materials such as sewage sludge. It is utilized as an adsorbent of pollutants, catalysts, and soil amendment (Cha et al., 2016). Contrarily, activated carbon (AC) has high levels of porosity, adsorptive capacity, and surface area. It is also activated using either physical or chemical processes through agricultural bio-waste materials such as palm shells. Lastly, nanocatalysts are yielded from nanomaterials and are applied in carbon nanotubes, water purification, and biodiesel production (Chaturvedi et al., 2012).

In this study, a systematic mapping approach will be utilized to gather and synthesize data (Petersen, 2015). This is employed to create an overview of a research area without progressing it. It serves only as a congregation of published knowledge

within a given limit and to identify knowledge gaps for future research. (James, 2016). As it stands, there have been numerous studies related to citrus fruit utilizations, but a lack of a systematic mapping study that can collect and bring all of these studies together.

In this paper, we will employ a systematic mapping approach for the utilization of citrus fruit wastes that can be applied in the Philippines. The objective of the study is to create a framework for the systematic mapping of the different applications of citrus fruit waste through literature search, in terms of; their utilization, processes, and performance. Recent trends and advances in the studies will also be examined. The scope of this study will be limited to citrus fruits local to the Philippines, such as calamansi, pomelo, and orange. Aside from this, the study will also be limited to sustainable biomass utilization methods, like activated carbon, biochar, and nanocatalysts. This research will be considered as a desktop study; it will focus on the data analysis of literature for results. Only research published from 2009 to 2020 in the English language found in Scopus will be included.

2. METHODOLOGY

The systematic mapping approach was used in this study to provide an overview of the different utilizations of citrus fruit waste. This study will follow a systematic approach shown in Figure 2.1 which were adapted from a study by Petersen et. al in 2008.

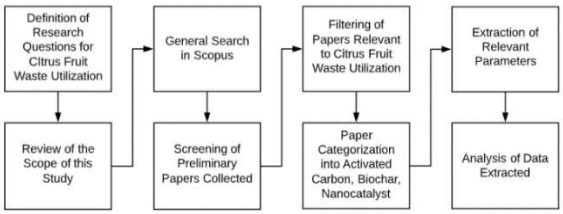

Figure 2.1 *Systematic Mapping Process for Citrus Fruit Waste Utilization*

2.1 Definition of Research Questions and Review of Scope

For this study, the following research questions were identified:

1. What are the trends in the current research on citrus fruit waste utilization?
2. What are the processes undergone by citrus fruit waste to achieve their respective applications?
3. What techniques have been utilized to evaluate the efficiency and performance of citrus fruit waste products?

As a review of scope, this study will focus on citrus fruits that are abundant and originate from the Philippines and will only consider studies published in Scopus between 2009 and 2020.

2.2 General Search

In compliance with the scope mentioned for this study, a search protocol was formulated. Firstly, the search engine chosen for this study was Scopus and the primary method of search was through article title, abstract, and keywords. The search utilized Boolean operators to limit the results appropriately and only considered papers that were published between 2009-2020 and in the English language. The search string utilized for the search was: (TITLE-ABS-KEY (citrus AND (sinensis OR grandis OR microcarpa OR poonensis OR maxima OR citrofortunella)) AND TITLE-ABS-KEY (waste AND material)).

2.3 Filtering of Relevant Papers and Categorization

The papers returned by the search string were filtered by the reading of their abstract, title, and keywords. Only papers deemed relevant to the study were collected for data extraction. The papers would be categorized into activated carbon, biochar, and nanocatalyst.

2.4 Extraction of Relevant Data and Analysis

Extraction of relevant information was then performed. Specific parameters from each paper were observed and recorded for further analysis and comparison. For activated carbon, the parameters that would be observed are particle size, BET surface area, and maximum adsorption capacity. For biochar, the parameters that would be recorded are BET-N2 specific surface area, total pore volume, and ash content. Lastly, for nanocatalysts, the parameters that would be observed are utilization and yield. Then, the recorded data would be analyzed and presented using graphs and figures.

3. RESULTS AND DISCUSSION

RQ1: What are the trends in the current research on citrus fruit waste utilization?

The search string that was previously defined returned 145 papers, 91.7% of which were published as journal articles, while the rest were presented as a conference paper or included in a book chapter. Through a search analysis within Scopus, it can be seen in Figure 3.1 that there has been a progressive increase in the amount of studies related to citrus fruit waste utilization. Of the 145 results, only 55 were found to be relevant to this study, 38% of which were related to activated carbon, 29% of which were under

biochar, and 33% were under nanocatalyst as seen in Figure 3.2.

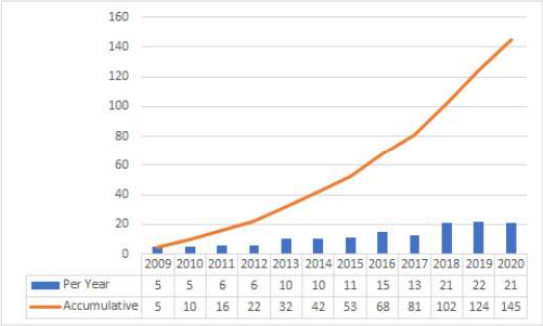

Figure 3.1 *Number of papers throughout 2009-2020.*

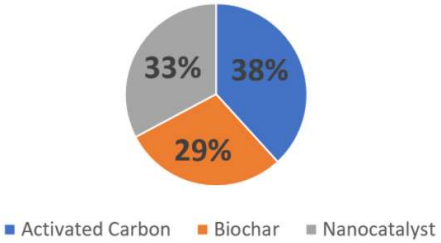

Figure 3.2 *Classification of selected papers based on type of citrus fruit waste utilization.*

RQ2: What are the processes undergone by citrus fruit waste to achieve their respective applications?

Biochar

The production of biochar requires the heating of a biomass with little to no oxygen. This was observed to be commonly through pyrolysis, as 13 of the 16 collected studies utilized this method. The figure below shows the process of biochar production.

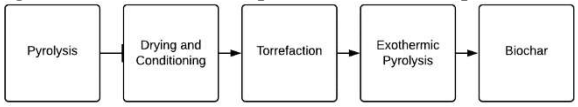

Figure 3.3 *Process of Biochar Production*

In pyrolysis, Drying and Conditioning occurs when biomass is dried in the temperatures between 100°C and 150°C for a moisture content of 15%. Next, Torrefaction enables the biomass to be grinded as it is heated to higher temperatures between 200°C and 280°C. Exothermic Pyrolysis then occurs when the temperature reaches 250°C to 300°C up until 400°C where the molecular bonds are broken further (Biochar for Sustainable Soils, n.d.).

Activated Carbon

Activated carbon production requires activation of a biomass. In the context of citrus fruit waste, peels are the most commonly used biomass. This is subjected through activation to produce porous material and can occur physically or chemically. Seven (7) of the 21 researched papers utilized physical activation, while 14 utilized chemical activation. The figure below shows the process of activated carbon production.

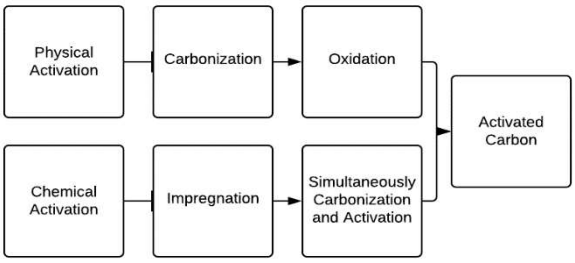

Figure 3.4 Process of Activated Carbon Production

In physical activation, the material undergoes carbonization before activation. During carbonization, the material is placed into a furnace where it is cooked at extreme temperatures ranging from 600-900°C for several hours. Certain studies have noted that higher carbonization temperatures have led to higher adsorptive capacity (Zeng et. al., 2013). Next, oxidation occurs through a process involving steam, where the carbonized material is exposed to oxidizing atmospheres in the form of steam at temperatures above 250°C.

In chemical activation, the carbon material is impregnated with certain chemicals, typically acids or strong bases. This is done by crushing and milling the material into small particles which are then mixed with the desired chemicals. Once the impregnation process is finished, the material is subjected to temperatures between 250-600°C where it is simultaneously carbonized and chemically activated. Then, the resulting carbon is washed with water to remove remaining acid and is subsequently dried.

Nanocatalysts

Nanoparticle production is mostly done through green synthesis as it is environmentally friendly and efficient. All 18 studies collected for nanocatalysts utilized green synthesis as their method of production. The figure below shows the process of nanocatalyst production.

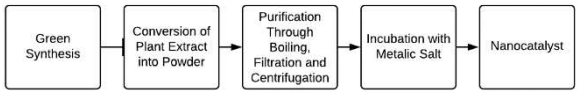

Figure 3.5 *Process of Nanocatalyst Production*

Green synthesis utilizes microorganisms to produce nanoparticles and is achieved through the selection of an environmentally acceptable solvent and appropriate reducing agents (Jegadeeswaran et. al., 2012). In the context of citrus fruit waste, fruit peels are regularly utilized as the reducing agents.

The process of green synthesis begins with the chosen parts of the plant, which are washed then cut into small pieces. Afterwards, the small pieces are finely grinded and boiled in water for several hours. The extract can be further purified through filtration and centrifugation. Once the extract is complete, the appropriate metallic salt is incubated with the extract in water to produce the nanoparticles of the desired metal ion.

RQ3: What techniques have been utilized to evaluate the efficiency and performance of citrus fruit waste products?

Biochar

BET-N2 Specific Surface Area

Figure 5.3.1.1 illustrates the surface areas of the biochar wherein the largest surface area is found to be 2457.367 m2/g in Cheng et al. (2020). For the least of the biochar, it would be 0.21 m2/g in Abdelhafez (2016). It can also be observed that the majority of the results ranged from 6.7 - 53 m2/g.

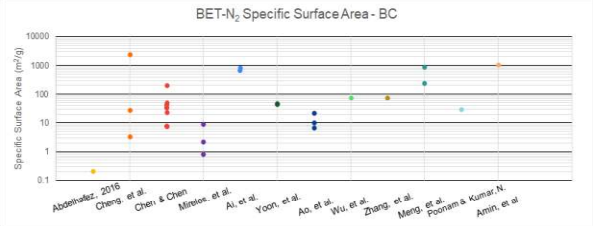

Figure 3.6 *BET-N2 Specific Surface Area*

Total Pore Volume

For Figure 5.3.1.2, it illustrates the total pore volume of gathered works. The largest pore volume of 1.14 cm3/g found in Cheng et al. (2020) and the least in Abdelhafez (2016) with 0.00016 cm3/g. The majority of the results appear to lie within 0.008 - 0.035 cm3/g.

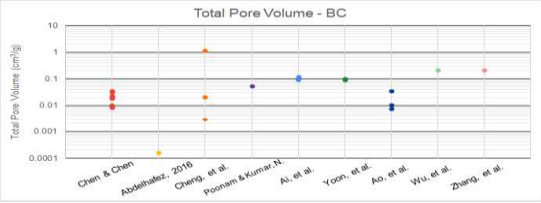

Figure 3.7 *Total Pore Volume - BC*

Ash Content

In Figure 3.8, the study with the highest ash content observed was 34.22% in Ai, et al. (2020). Meanwhile, the least observed was 0.30% found in Chen and Chen (2009), utilizing similar materials to Ai et al. (2020), but differing in their preparation and processes.

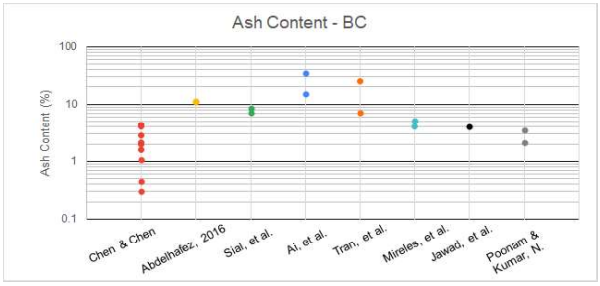

Figure 3.8 *Ash Content - BC*

Activated Carbon

Particle Size

In Figure 3.9, the activated carbon with the smallest particle size is ≤0.063 mm from Nemr et al. (2009) and the largest is 0.5 mm from both Fernandez, et al. (2015), and Oruc, et al. (2019).

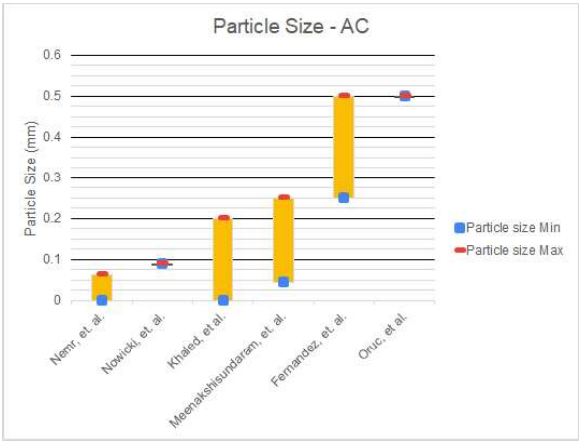

Figure 3.9 *Particle Size - AC*

BET Surface Area

The largest BET surface area observed was 2209.17 m2/g in Wei et al. (2019) as they chemically activated orange peels with phosphoric acid. For the smallest BET surface area, it was 2.6 in Li et al.(2016).

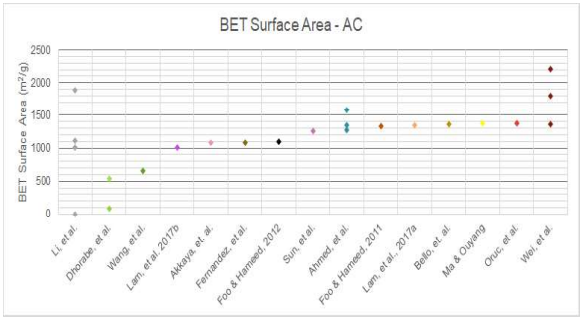

Figure 3.11 *BET Surface Area - AC*

Maximum Adsorption Capacity

The highest maximum adsorption capacity observed was 680 mg g-1 from Li et al. (2016) wherein they tested for their chemically activated pomelo peels with potassium hydroxide, with a ratio of KOH to the pre-carbonized product for 3:1. And the lowest capacity observed was 1.210 mg g-1 in Meenakshisundaram et. al. (2009) for their physically activated lemon peel.

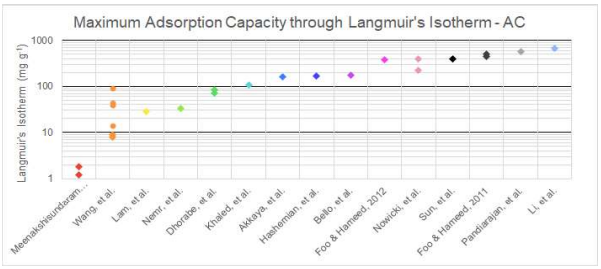

Figure 3.12 *Maximum Adsorption Capacity through Langmuir's Isotherm - AC*

Nanocatalysts

The smallest particle size observed is 5 nm in Dalul et al. (2020) while the largest size observed was from Ain Samat and Md Nor (2013) with 200 nm.

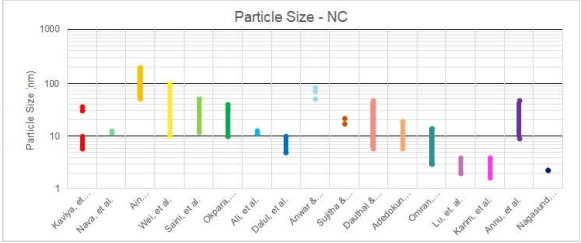

Figure 3.13 *Particle Size – NC*

4. CONCLUSIONS

This study has reviewed the state of the field of citrus fruit waste utilization through a systematic mapping approach. It was concluded that citrus fruit waste has a wide range of possible utilizations. This paper only focused on the applications related to waste management, thus, there is still a potential to expand the scope of this research field. Furthermore, there is an increasing trend in research related to citrus fruit waste utilization since there is a growing interest in its use due to its abundance and accessibility. Additionally, the published papers on citrus fruit waste utilization were sorted into three categories -- biochar, activated carbon, and nanocatalyst. Of the 55 papers collected, 38% were related to activated carbon, 29% were under biochar, and 33% were under nanocatalyst. Citrus fruit waste undergoes rigorous processes in order to achieve their respective applications, most of which involve subjection to high temperatures, such as pyrolysis and carbonization. Most studies evaluate citrus fruit waste products through pore size, adsorption capacity, and BET surface area.

6. REFERENCES

Abdelhafez, A.A., & Li, J. (2016). Removal of Pb(II) from aqueous solution by using biochars derived from sugar cane bagasse and orange peel. Journal of the Taiwan Institute of Chemical Engineers, 61, 367-375. doi: 10.1016/j.jtice.2016.01.005

Adedokun, O., Roy, A., Awodugba, A.O., & Devi, P.S. (2017). Fluorescent carbon nanoparticles from Citrus sinensis as efficient sorbents for pollutant dyes. Luminescence, 32(1), 62-70. doi: 10.1002/bio.3149

Ahmed, S., Rafat, M., & Ahmed, A. (2018). Nitrogen doped activated carbon derived from orange peel for supercapacitor application. Advances in Natural Sciences: Nanoscience and Nanotechnology, 9(3), 035008. doi: 10.1088/2043-6254/aad5d4

Ai, T., Jiang, X., Zhong, Z., Li, D., & Dai, S. (2020). Methanol-modified ultra-fine magnetic orange peel powder biochar as an effective adsorbent for removal of ibuprofen and sulfamethoxazole from water. Adsorption Science and Technology, 38(7-8), 304-321. doi: 10.1177%2F0263617420944659

Ain Samat, N., & Md Nor, R. (2013). Sol-gel synthesis of zinc oxide nanoparticles using Citrus aurantifolia extracts. Ceramics International, 39, S545-S548.

Akkaya Sayğılı, G., Sayğılı, H., Yılmaz, C., & Güzel, F. (2020). Lead recovery from aqueous environment by using porous carbon of citrus fruits waste: equilibrium, kinetics and thermodynamic studies. Separation Science and Technology (Philadelphia), 55(15), 2699-2712. doi: 10.1080/01496395.2019.1653917

Amin, M.T., Alazba, A.A., & Shafiq, M. (2019). Comparative study for adsorption of methylene blue dye on biochar derived from orange peel and banana biomass in aqueous solutions. Environmental Monitoring and Assessment, 191(12), 735. doi: 10.1007%2Fs10661-019-7915-0

Annu, Ahmed, S., Kaur, G., Sharma, P., Singh, S., & Ikram, S. (2018). Fruit waste (peel) as bio-reductant to synthesize silver nanoparticles with antimicrobial, antioxidant and cytotoxic activities. Journal of Applied Biomedicine, 16(3), 221-231. doi: 10.1016/j.jab.2018.02.002

Anwar, Y., & Alghamdi, K.M. (2020). Imparting antibacterial, antifungal and catalytic properties to cotton cloth surface via green route. Polymer Testing, 81, 106258. doi: 10.1016/j.polymertesting.2019.106258

Atienza, V. (2020). Waste Management in the Philippines. In Pariatamby, A., Shahul Hamid, F., & Bhatti, M. S. (Eds.), Sustainable Waste Management Challenges in Developing Countries, 270-286. IGI Global. doi: 10.4018/978-1-7998-0198-6.ch011

Ao, H., Cao, W., Hong, Y., Wu, J., & Wei, L. (2020). Adsorption of sulfate ion from water by zirconium oxide-modified biochar derived from pomelo peel. Science of the Total Environment, 708, 135092. doi: 10.1016/j.scitotenv.2019.135092

Bello, O.S., Ahmad, M.A., & Semire, B. (2015). Scavenging malachite green dye from aqueous solutions using pomelo (Citrus grandis) peels: kinetic, equilibrium and thermodynamic studies. Desalination and Water Treatment, 56(2), 521-535. doi: 10.1080/19443994.2014.940387

Biochar for Sustainable Soils. (n.d.). Biochar production and by-products. Biochar for Sustainable Soils. Retrieved January 4, 2021, from

https://biochar.international/the-biochar-opportunity/biochar-production-and-by-products/

Castillo, A. L., & Otoma, S. (2013). Status of Solid Waste Management in the Philippines. Retrieved January 24, from: https://www.jstage.jst.go.jp/article/jsmcwm/24/0/24_677/_pdf

Cha, J. S., Park, S. H., Jung, S. C., Ryu, C., Jeon, J. K., Shin, M. C., & Park, Y. K. (2016). Production and utilization of biochar: A review. In Journal of Industrial and Engineering Chemistry, 40, 1–15. Korean Society of Industrial Engineering Chemistry. doi: 10.1016/j.jiec.2016.06.002

Chaturvedi, S., Dave, P. N., & Shah, N. K. (2012). Applications of nano-catalyst in new era. Journal of Saudi Chemical Society, 16(3), 307–325. doi:10.1016/j.jscs.2011.01.015

Chen, B., & Chen, Z. (2009). Sorption of naphthalene and 1-naphthol by biochars of orange peels with different pyrolytic temperatures. Chemosphere, 76(1), 127-133. doi: 10.1016/j.chemosphere.2009.02.004

Cheng, D., Ngo, H.H., Guo, W., Chang, S.W., Nguyen, D.D., Zhang, X., Varjani, S., & Liu, Y. (2020). Feasibility study on a new pomelo peel derived biochar for tetracycline antibiotics removal in swine wastewater. Science of the Total Environment, 720, 137662. doi: 10.1016/j.scitotenv.2020.137662

CSI Designs (2020). WHAT IS PRESSURE DROP AND HOW DOES IT AFFECT YOUR PROCESSING SYSTEM? Retrieved March 24, from: https://www.csidesigns.com/blog/articles/what-is-pressure-drop-and-how-does-it-affect-your-processing-system

Dalal, U., Gupta, V.K., Reddy, S.N., & Navani, N.K. (2020). Eradication of water borne pathogens using novel green nano Ag-biocomposite of Citrus Limetta peels. Journal of Environmental Chemical Engineering, 8(2), 103534. doi: 10.1016/j.jece.2019.103534

Dauthal, P., & Mukhopadhyay, M. (2015). Agro-industrial waste-mediated synthesis and characterization of gold and silver nanoparticles and their catalytic activity for 4-nitroaniline hydrogenation. Korean Journal of Chemical Engineering, 32(5), 837-844. doi: 10.1007/s11814-014-0277-y

DeSilva, F. (2000). Activated Carbon Filtration. Retrieved March 24, from: https://www.watertreatmentguide.com/activated_carbon_filtration.htm

Dhorabe, P.T., Lataye, D.H., & Ingole, R.S. (2017). Adsorptive removal of 4-nitrophenol from aqueous solution by activated carbon prepared from waste orange peels. Journal of Hazardous, Toxic, and Radioactive Waste, 21(2), 04016015. doi: 10.1061/(ASCE)HZ.2153-5515.0000332

Domingues, R. R., Trugilho, P. F., Silva, C. A., Melo, I. C. N. A. de, Melo, L. C. A., Magriotis, Z. M., & Sánchez-Monedero, M. A. (2017). Properties of biochar derived from wood and high-nutrient biomasses with the aim of agronomic and environmental benefits. PLoS ONE, 12(5), e0176884. doi: 10.1371/journal.pone.0176884

Fernandez, M.E., Nunell, G.V., Bonelli, P.R., & Cukierman, A.L. (2014). Activated carbon developed from orange peels: Batch and dynamic competitive adsorption of basic dyes. Industrial Crops and Products, 62, 437-445. doi: 10.1016/j.indcrop.2014.09.015

Flores, R. M., Feratero, V. J., Soneja, S. K. C., Gonzales, R. P. A. R. (2018). A Case Study about the Improper Waste Disposal in Barangay Mojon Tampoy, Philippines. Retrieved January 24 from:
https://www.researchgate.net/project/A-Case-Study-about-the-Improper-Waste-Disposal-in-Barangay-Mojon-Tampoy-Philippines

Foo, K.Y., & Hameed, B.H. (2011). Microwave assisted preparation of activated carbon from pomelo skin for the removal of anionic and cationic dyes. Chemical Engineering Journal, 173(2), 385-390. doi: 10.1016/j.cej.2011.07.073

Foo, K. Y., & Hameed, B. H. (2012). Preparation, characterization and evaluation of adsorptive properties of orange peel based activated carbon via microwave induced K 2CO 3 activation. Bioresource Technology, 104, 679–686. doi: 10.1016/j.biortech.2011.10.005

Gunamantha, I. M., & Widana, G. A. B. (2018). Characterization the potential of biochar from cow and pig manure for geoecology application. IOP Conference Series: Earth and Environmental Science, 131(1), 12055. doi: 10.1088/1755-1315/131/1/012055

Hashemian, S., Salari, K., & Yazdi, Z.A. (2014). Preparation of activated carbon from agricultural wastes (almond shell and orange peel) for adsorption of 2-pic from aqueous solution. Journal of Industrial and Engineering Chemistry, 20(4), 1892-1900. doi: 10.1016/j.jiec.2013.09.009

James, K. L., Randall N. P., & Haddaway, N. R. (2016). A methodology for systematic mapping in environmental sciences. Environmental Evidence, 5, 7. doi:10.1186/s13750-016-0059-6

Jawad, A. H., Al-Heetimi, D. T. A., & Mastuli, M. S. (2019). Biochar from orange (Citrus sinensis) peels by acid activation for methylene blue adsorption. Iranian Journal of Chemistry and Chemical Engineering, 38(2), 91–105.

Jegadeeswaran, P., Shivaraj, R., & Rajendran V. (2012). Green synthesis of silver nanoparticles from extract of Padina tetrastromatica leaf. Digest Journal of Nanomaterials and Biostructures, 7(3), 991-998.

Karim, N.A., Rubinsin, N.J., Burukan, M.A.A., & Kamarudin, S.K. (2019). Sustainable route of synthesis platinum nanoparticles using orange peel extract. International Journal of Green Energy, 16(15), 1518-1526. doi: 10.1080/15435075.2019.1671422

Kaviya, S., Santhanalakshmi, J., Viswanathan, B., Muthumary, J., & Srinivasan, K. (2011). Biosynthesis of silver nanoparticles using citrus sinensis peel extract and its antibacterial activity. Spectrochimica Acta - Part A: Molecular and Biomolecular Spectroscopy, 79(3), 594-598. doi: 10.1016/j.saa.2011.03.040

Khaled, A., Nemr, A.E., El-Sikaily, A., & Abdelwahab, O. (2009). Removal of Direct N Blue-106 from artificial textile dye effluent using activated carbon from orange peel: Adsorption isotherm and kinetic studies. Journal of Hazardous Materials, 165 (1-3), 100-110. doi:10.1016/j.jhazmat.2008.09.122

Lam, S.S., Liew, R.K., Wong, Y.M., Azwar, E., Jusoh, A., & Wahi, R. (2017). Activated Carbon for Catalyst Support from Microwave Pyrolysis of Orange Peel. Waste and Biomass Valorization, 8(6), 2109-2119. doi: 10.1007%2Fs12649-016-9804-x

Lam, S.S., Liew, R.K., Wong, Y.M., Yek, P.N.Y., Ma, N.L., Lee, C.L., & Chase, H.A. (2017). Microwave-assisted pyrolysis with chemical activation, an innovative method to convert orange peel into activated carbon with improved properties as dye adsorbent. Journal of Cleaner Production, 162, 1376-1387. doi: 10.1016/j.jclepro.2017.06.131

Li, H., Sun, Z., Zhang, L., Tian, Y., Cui, G., & Yan, S. (2016). A cost-effective porous carbon derived from pomelo peel for the removal of methyl orange from aqueous solution. Colloids and Surfaces A: Physicochemical and Engineering Aspects, 489, 191-199. doi: 10.1016/j.colsurfa.2015.10.041

Ma, X., & Ouyang, F. (2013). Adsorption properties of biomass-based activated carbon prepared with spent coffee grounds and pomelo skin by phosphoric acid activation. Applied Surface Science, 268, 566-570. doi: 10.1016/j.apsusc.2013.01.009

Makarov, V. V., Love, A. J., Sinitsyna, O. V., Makarova, S. S., Yaminsky, I. V., Taliansky, M. E., & Kalinina, N. O., (2014). "Green" nanotechnologies: synthesis of metal nanoparticles using plants. Acta Naturae, 6(1), 35-44.

Meenakshisundaram, M., Kannan, N., & Rejinis, J. (2009). Removal of azure a from aqueous solution by CAC and new activated carbon form orange peel and lemon peel. Electronic Journal of Environmental, Agricultural and Food Chemistry, 8(8), 574-583.

Meng, H., Nie, C., Li, W., Duan, X., Lai, B., Ao, Z., Wang, S., & An, T. (2020). Insight into the effect of lignocellulosic biomass source on the performance of biochar as persulfate activator for aqueous organic pollutants remediation: Epicarp and mesocarp of citrus peels as examples. Journal of Hazardous Materials, 399. doi: 10.1016/j.jhazmat.2020.123043

Mireles, S., Parsons, J., Trad, T., Cheng, C. L., & Kang, J. (2019). Lead removal from aqueous solutions using biochars derived from corn stover, orange peel, and pistachio shell. International Journal of Environmental Science and Technology, 16(10), 5817–5826. doi: 10.1007/s13762-018-02191-5

Nagasundaram, N., Kokila, M., Sivaguru, P., Santhosh, R., & Lalitha, A. (2020). SO3H@carbon powder derived from waste orange peel: An efficient, nano-sized greener catalyst for the synthesis of dihydropyrano[2,3-c]pyrazole derivatives. Advanced Powder Technology, 31(4), 1516-1528. doi: 10.1016/j.apt.2020.01.012

Nava, O.J., Soto-Robles, C.A., Gómez-Gutiérrez, C.M., Vilchis-Nestor, A.R., Castro-Beltrán, A., Olivas, A., & Luque, P.A. (2017). Fruit peel extract mediated green synthesis of zinc oxide nanoparticles. Journal of Molecular Structure, 1147, 1-6. doi: 10.1016/j.molstruc.2017.06.078

Nemr, A.E., Abdelwahab, O., El-Sikaily, A., & Khaled, A. (2009). Removal of direct blue-86 from aqueous solution by new activated carbon developed from orange peel. Journal of Hazardous Materials, 165 (1), 102-110. doi: 10.1016/j.jhazmat.2008.03.060

Nowicki, P., Kazmierczak-Razna, J., & Pietrzak, R. (2016). Physicochemical and adsorption properties of carbonaceous sorbents prepared by activation of tropical fruit skins with potassium carbonate. Materials and Design, 90, 579-585. doi: 10.1016/j.matdes.2015.11.004

Okpara, E.C., Fayemi, O.E., Sherif, E.M., Junaedi, H., & Ebenso, E.E. (2020). Green wastes mediated zinc oxide nanoparticles: Synthesis, characterization and electrochemical studies. Materials, 13(19), 4241.

Omran, B.A., Nassar, H.N., Fatthallah, N.A., Hamdy, A., El-Shatoury, E.H., & El-Gendy, N.S. (2018). Waste upcycling of Citrus sinensis peels as a green route for the synthesis of silver nanoparticles. Energy Sources, Part A: Recovery, Utilization and Environmental Effects, 40(2), 227-236. doi: 10.1080/15567036.2017.1410597

Oruç, Z., Ergüt, M., Uzunoğlu, D., & Özer, A. (2019). Green synthesis of biomass-derived activated carbon/Fe-Zn bimetallic nanoparticles from lemon (Citrus limon (L.) Burm. f.) wastes for heterogeneous Fenton-like decolorization of Reactive Red 2. Journal of Environmental Chemical Engineering, 7(4), 103231. doi: 10.1016/j.jece.2019.103231

Pandiarajan, A., Kamaraj, R., Vasudevan, S., & Vasudevan, S. (2018). OPAC (orange peel activated carbon) derived from waste orange peel for the adsorption of chlorophenoxyacetic acid herbicides from water: Adsorption isotherm, kinetic modelling and thermodynamic studies. Bioresource Technology, 261, 329-341. doi: 10.1016/j.biortech.2018.04.005

Pathak, P. D., Mandavgane, S. A., & Kulkarni, B. D. (2017). Fruit peel waste: Characterization and its potential uses. Current Science, 113(3), 444–454. doi: 10.18520/cs/v113/i03/444-454

Petersen, K., Feldt, R., Mujtaba, S., Mattsson, M. (2008). Systematic Mapping Studies in Software Engineering. In: Proceedings of the 12th international conference on evaluation and assessment in software engineering. BCS Learning & Development Ltd., Swindon, pp 68 - 77

Petersen, K., Vakkalanka, S., & Kuzniarz, L. (2015). Guidelines for conducting systematic mapping studies in software engineering: An update. Information and Software Technology, 64, 1-18. doi: 10.1016/j.infsof.2015.03.007
https://www.sciencedirect.com/science/article/pii/S0950584915000646?via%3Dihub

Poonam, & Kumar, N. (2020). Experimental and kinetic study of removal of lead (Pb+2) from battery effluent using sweet lemon (Citrus limetta) peel biochar adsorbent. Environment, Development and Sustainability, 22(5), 4379–4406. doi: 10.1007/s10668-019-00389-2

PSA. (2015). Foreign Trade Statistics of the Philippines. PSA. Retrieved from http://www.psa.gov.ph/sites/default/files/Volume%20I%20-%20IMPORTS_FTS%202015%20e-Book_as%20of%2003-18-17.pdf

PSA. (2019a). Major Fruit Crops Quarterly Bulletin: January - March 2019. PSA. Retrieved April 16, 2020, from https://psa.gov.ph/sites/default/files/Major%20Fruit%20Crops%20Quarterly%20Bulletin%2C%20January-March_1.pdf

PSA. (2019b). Major Fruit Crops Quarterly Bulletin: April - June 2019. PSA. Retrieved April 16, 2020, from https://psa.gov.ph/sites/default/files/Major%20Fruitcrops%20Quarterly%20Bulletin%2C%20April%20-%20June%202019_0.pdf

PSA. (2019c). Major Fruit Crops Quarterly Bulletin: July - September 2019. PSA. Retrieved April 16, 2020, from https://psa.gov.ph/sites/default/files/Major%20Fruitcrops%20Quarterly%20Bulletin%2C%20July%20-%20September%202019_2.pdf

PSA. (2019d). Major Fruit Crops Quarterly Bulletin: October - December 2019. PSA. Retrieved April 16, 2020, from https://psa.gov.ph/sites/default/files/Major%20Fruitcrops%20Quarterly%20Bulletin%2C%20October-December%202019_1.pdf

Sahetya, T. J., Dixit, F., & Balasubramanian, K. (2015). Waste citrus fruit peels for removal of Hg(II) ions. Desalination and Water Treatment, 53(5), 1404–1416. doi:10.1080/19443994.2013.852483

Saini, J., Garg, V.K., & Gupta, R.K. (2020). Green synthesized SiO2@OPW nanocomposites for enhanced Lead (II) removal from water. Arabian Journal of Chemistry, 13(1), 2496-2507. doi: 10.1016/j.arabjc.2018.06.003

Siddiqui, N., Masum, A.A., Uddin, M.R., Mandal, S., Sengupta, M., Islam, M.M., & Mukhopadhyay, S. (2019). Elucidating the chemical and biochemical applications of Citrus sinensis-mediated silver nanocrystal. Journal of Biomolecular Structure and Dynamics, 37(18), 4863-4874. doi: 10.1080/07391102.2018.1559763

Sujitha, M.V., & Kannan, S. (2013). Green synthesis of gold nanoparticles using Citrus fruits (Citrus limon, Citrus reticulata and Citrus sinensis) aqueous extract and its characterization. Spectrochimica Acta - Part A: Molecular and Biomolecular Spectroscopy, 102, 15-23. doi: 10.1016/j.saa.2012.09.042

Sun, Y., Li, H., Li, G., Zhou, W. Yue, Q. & Li, X. (2016). Characterization and ciprofloxacin adsorption properties of activated carbons prepared from biomass wastes by H3PO4 activation. Bioresource Technology, 217, 239-244. doi: 10.1016/j.biortech.2016.03.047

Tran, H. N., You, S. J., & Chao, H. P. (2016). Effect of pyrolysis temperatures and times on the adsorption of cadmium onto orange peel derived biochar. Waste Management and Research, 34(2), 129–138. doi:10.1177/0734242X15615698

Wang, Y., Wang, S.-L., Xie, T., & Cao, J. (2020). Activated carbon derived from waste tangerine seed for the high-performance adsorption of carbamate pesticides from water and plant. Bioresource Technology, 316, 123929. doi: 10.1016/j.biortech.2020.123929

Wei, Q., Chen, Z., Cheng, Y., Wang, X., Yang, X., & Wang, Z. (2019). Preparation and electrochemical performance of orange peel based-activated carbons activated by different activators. Colloids and Surfaces A: Physicochemical and Engineering Aspects, 574, 221-227. doi: 10.1016/j.colsurfa.2019.04.065

Wei, Y., Fang, Z., Zheng, L., Tan, L., & Tsang, E.P. (2016). Green synthesis of Fe nanoparticles using Citrus maxima peels aqueous extracts. Materials Letters, 185, 384-386. doi: 10.1016/j.matlet.2016.09.029

Wu, Y., Cha, L., Fan, Y., Fang, P., Ming, Z., & Sha, H. (2017). Activated Biochar Prepared by Pomelo Peel Using H3PO4 for the Adsorption of Hexavalent Chromium: Performance and Mechanism. Water, Air, and Soil Pollution, 228(10). doi:10.1007/s11270-017-3587-y

Yoon, K., Cho, D. W., Bhatnagar, A., & Song, H. (2020). Adsorption of As(V) and Ni(II) by Fe-Biochar composite fabricated by co-pyrolysis of orange peel and red mud. Environmental Research, 188. doi:10.1016/j.envres.2020.109809

Zafar, S. (2020, July 23). Agricultural Wastes in the Philippines. Retrieved January 24, from: https://www.bioenergyconsult.com/agricultural-resources-in-philippines/

Zeng, R., Tang, W., Feng, Y., Liu, M., Huang, B., & Wu, A. (2013). Adsorption of bisphenol-A by using carbonized pomelo peel. Chinese Journal of Environmental Engineering, 7(10), 3797-3801.

Zhang, B., Wu, Y., & Cha, L. (2020). Removal of methyl orange dye using activated biochar derived from pomelo peel wastes: performance, isotherm, and kinetic studies. Journal of Dispersion Science and Technology, 41(1), 125–136. doi: 10.1080/01932691.2018.1561298

Zhao, T., Yao, Y., Li, D., Wu, F., Zhang, C., & Gao, B. (2018). Facile low-temperature one-step synthesis of pomelo peel biochar under air atmosphere and its adsorption behaviors for Ag(I) and Pb(II). Science of the Total Environment, 640–641, 73–79. doi:10.1016/j.scitotenv.2018.05.251

Effervescent Water Coagulant from *Citrofortunella Microcarpa* Scraps for Water Treatment

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Abstract: As the Philippines experiences increasing alerts in water pollution, this study aims to create a Calamansi-based effervescent water coagulant to increase the accessibility of purified water to Filipinos. The study makes use of Citrofortunella microcarpa (Calamansi), a small citrus fruit abundant in the Philippines. Calamansi has a big contribution in the production of agricultural waste as the fruit is mainly utilized for its pulp; therefore, the researchers focused on the usage of Calamansi's peels and seeds, given their ability to absorb minute particles and to kill bacteria. Disposed Calamansi scraps were powderized and mixed with other components to form an eco-friendly effervescent water coagulant. The researchers assessed the efficacy of the Calamansi coagulant by comparing it to Ferric chloride ($FeCl_3$), an existing chemical water coagulant, and testing ten trials of each sample in a contaminated soil-water mixture. The group's findings suggest that the effervescent Calamansi coagulant presented a higher efficacy in water treatment than $FeCl_3$, with its pH, electrical conductivity (EC), total dissolved solids (TDS), and salinity readings all within the standard range. The Calamansi coagulant accumulated more residue than the $FeCl_3$ sample. The study demonstrates that Calamansi seed and peel waste offer a great alternative to chemical-based coagulants in water treatment.

Key Words: water treatment; bath bomb; calamansi; coagulation; adsorption

1. INTRODUCTION

The Philippines is surrounded by numerous bodies of water; however, water shortage has been a prominent issue in the country due to pollution, climate change, and the El Niño phenomenon (World Health Organization, 2019). This water crisis forces Filipinos to consume contaminated water at higher rates, with almost seven million drinking from unsafe water and 24 million having no access to improved sanitation (water.org, n.d.). Further, the severity of water pollution in the Philippines contributes to the rapid increase of agricultural waste.

Citrofortunella microcarpa, commonly known as Calamansi, is a small citrus fruit predominantly cultivated in the Philippines and used as a condiment in Filipino cuisine. Calamansi is one of the main contributors to Philippine agricultural waste, as consumers focus on the fruit's affordability and versatility rather than the adsorbent quality of its scraps. Adsorption is a vital process in water treatment which adheres layers of molecules to the surface of a liquid or solid in contact ("What is adsorption?", 2016).

To address the influx of water contamination and agricultural wastes in the Philippines, the group aims to design an eco-friendly, portable, and accessible Calamansi-based water coagulant with a bath bomb's effervescent formula. Coagulation is a common water treatment technique, involving the adsorption of large amounts of organic compounds and suspended particles (Safe Drinking Water Foundation, n.d.). This coagulant intends to purify polluted water along the marginalized communities in Manila (near polluted riverbanks) and allow them access to clean water supply.

In this study, the group was able to further comprehend water purification through the process of coagulation. The researchers collected Calamansi scraps and created an effervescent Calamansi coagulant as a cheaper substitute for other coagulants in the market. Moreover, they were able to determine the amount of Calamansi peels needed to create an impurity coagulant in the form of a bath bomb, to which they compared Ferric chloride ($FeCl_3$), an existing chemical-based water coagulant, by testing the efficacy of both coagulants in contaminated water. Four tests namely, pH, electrical conductivity (EC), total dissolved solids (TDS), and salinity, were conducted to determine the quality of the water tested. The researchers used comparative analysis, correlation analysis, and regression analysis to analyze the retrieved data.

The study includes several limitations in accordance with the quarantine protocols. The final

product is not applicable for large bodies of water and is only tested on controlled basins. With this, the final product is only currently capable of coagulation, as further directives must be approached to achieve total purification.

2. METHODOLOGY

2.1. Literature review

The researchers reviewed past studies and approaches as experimental guides. The group examined a similar study conducted by Dollah et al. (2019) involving the investigation of *Citrus aurantiifolia* (key lime) and *Citrus microcarpa* (kasturi lime) waste as natural coagulants for water treatment, and modified the previous study's setup by incorporating bath bomb technology. Data gathered were corroborated through experimental trials; after which, the group integrated the coagulation process in water treatment.

2.2. Calamansi scraps collection

Disposed Calamansi scraps were gathered and accumulated for two weeks. After two weeks, the Calamansi peels and seeds were sun-dried for one week to eliminate the moisture content. Once the peels turned brittle and observed a light brown color and the seeds hardened with no apparent color change, the scraps were then ground using a mortar and pestle until a powdery finish was achieved.

2.3. Coagulant formulation

The powdered Calamansi scraps were transferred to another container with baking soda and citric acid, following the 2:1 ratio, and were mixed before transferring into the mold which is 4 cm in diameter. The mixture sat in the mold for 15 hours until the coagulant hardened. This procedure was then repeated 9 more times to create ten coagulants with varied compositions (Table 1).

Table 1. *Amount of Calamansi scraps, citric acid, and baking soda added per trial*

Trials	Calamansi Scraps (g)	Citric Acid (g)	Baking Soda (g)
1	0.5	14.8	29.7
2	1.0	14.7	29.3
3	1.5	14.5	29.0
4	2.0	14.3	28.7
5	2.5	14.2	28.3
6	3.0	14.0	28.0
7	3.5	13.8	27.7
8	4.0	13.7	27.3
9	4.5	13.5	27.0
10	5.0	13.3	26.7

2.4. Experimentation

The researchers assessed the efficacy of the coagulants by comparing the Calamansi and the Ferric chloride ($FeCl_3$) samples. For the first experimental setup, the coagulants were tested in contaminated water. Quarantine protocols have restricted the researchers from collecting contaminated water from rivers; therefore, a soil-water mixture, composed of 1 L of tap water and 50 g of soil, was used as a substitute. Electrical conductivity (EC), pH, total dissolved solids (TDS), and salinity tests were first conducted on the soil-water mixture before starting the overall experiment. Then, the Calamansi coagulants were dropped into the soil-water mixture and were left untouched for one hour to allow the residues to settle. The water was then filtered, and the residue was separated from the water. The residues were then sun dried to eliminate the moisture content present in them and were weighed afterward. The four water tests were then again conducted to the water. The same procedure was applied to the second experimental setup. The only difference was that Ferric chloride ($FeCl_3$) was used instead of the Calamansi coagulant (Table 2).

Table 2. *Amount of Ferric chloride ($FeCl_3$) per trial*

Trials	Ferric chloride (g)
1	0.5
2	1.0
3	1.5
4	2.0
5	2.5
6	3.0
7	3.5
8	4.0
9	4.5
10	5.0

2.5. Data Analysis

For a successful trial, the result of the readings should be within standard ranges (Table 3). The results were analyzed via correlation and regression to determine and predict the relationship between the amount of fruit peels and the rate of absorption. Furthermore, a comparative analysis was applied to compare the Calamansi coagulant and the Ferric chloride ($FeCl_3$) samples.

Table 3. *Ranges to be considered*

Water Quality Tester	Range of Required Reading
Water pH Tester	6.5 pH – 8.5 pH 7 pH at 25°C
Electrical Conductivity Test	200 to 800 µS/cm
Total Dissolved Solids Test	50 – 250 ppm
Salinity Test	Less than or equal to 500 ppm

3. RESULTS AND DISCUSSION

3.1. Comparative Analysis

Based on the ranges of required reading, the Calamansi coagulants were more successful than the Ferric chloride ($FeCl_3$) in impurity removal. Since none of the temperatures were at 25°C, the researchers disregarded this criterion (Table 4 & Table 5).

For the pH levels, the group opted to target the value range of 6.5 and 8.5. Only the Calamansi coagulant

with 0.5 g scraps is an outlier, having a pH of 6.4. Otherwise, all of them exceeded 6.5. On the other hand, the Ferric chloride trials were all acidic, ranging from 2.4 to 3.15 (Table 4 & Table 5).

The Calamansi coagulant trials also concurred the needed criteria in the electrical conductivity test. All Calamansi coagulant trials exceeded 200 µS/cm, having 210 µS/cm and 238 µS/cm as the highest and lowest values respectively. All Ferric chloride ($FeCl_3$) trials surpassed the highest standard value of 800 µS/cm; only Trial 1 had the lowest value of 634 µS/cm (Table 4 & Table 5).

Prior to the experimentation, the TDS test for both the Ferric chloride ($FeCl_3$) and Calamansi coagulant have already reached the target ppm, obtaining levels ranging from 82-124 ppm. The results showed little to no change after the Calamansi coagulant trials were conducted, but have grown significantly with the use of Ferric chloride ($FeCl_3$), with values increasing to 317-2040 ppm. All but Trials 1 and 2 greatly exceeded the targeted values (Table 4 & Table 5).

Salinity levels of the Ferric chloride ($FeCl_3$) and Calamansi coagulant before the experiment exhibit the same values as the TDS test, obtaining a target level of less than 500 ppm. For the Calamansi coagulant trials, their salinity levels increased to 121-135 ppm, except for Trial 2 whose salinity decreased to 107. All levels were within the acceptable range. On the other hand, Ferric chloride ($FeCl_3$) trials spiked identically to their TDS results, far surpassing the targeted value, except for Trials 1 and 2 whose values were still within range (Table 4 & Table 5).

While there was no standard for the amount of residue removed, the Calamansi coagulant was shown to have removed greater amounts of residue, with a minimum of 0.65 g removed to a maximum of 4.58 g. The Ferric chloride ($FeCl_3$) managed to remove, at the least, only 0.03 g and at the most, 1.43 g (Table 4 & Table 5).

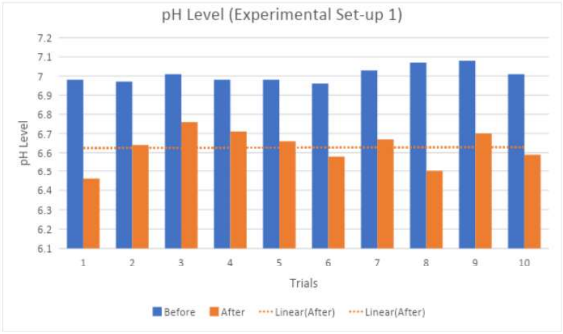

Figure 1. *pH Level (Experimental Set-up 1)*

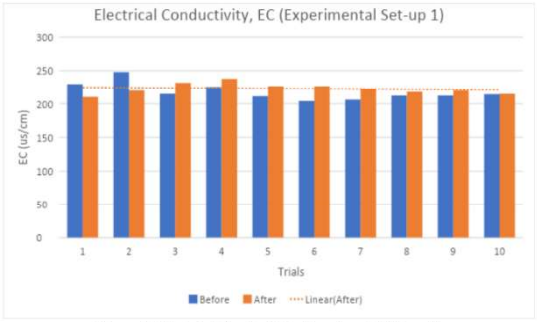

Figure 2. *Electrical Conductivity (Experimental Set-up 1)*

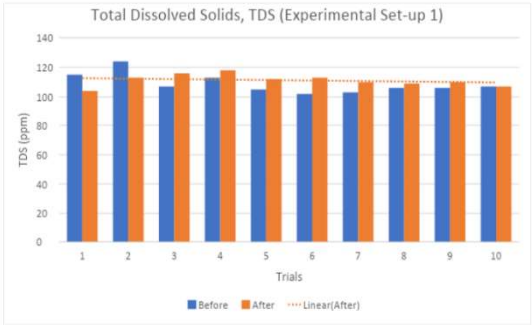

Figure 3. *Total Dissolved Solids (experimental Set-up 1)*

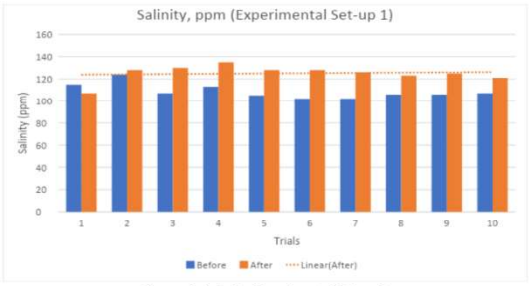

Figure 4. *Salinity (Experimental Set-up 1)*

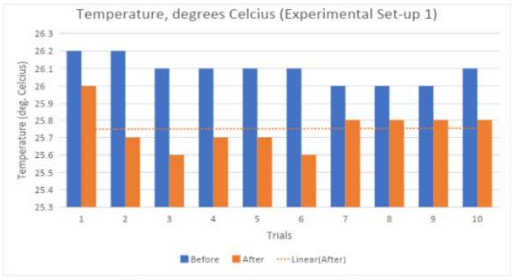

Figure 5. *Temperature (Experimental Set-up 1)*

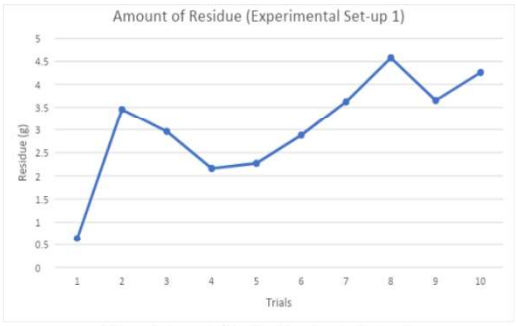

Figure 6. *Amount of Residue (Experimental Set-up 1)*

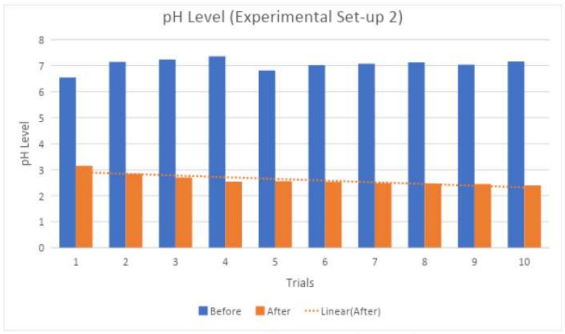

Figure 7. *pH Level (Experimental Set-up 2)*

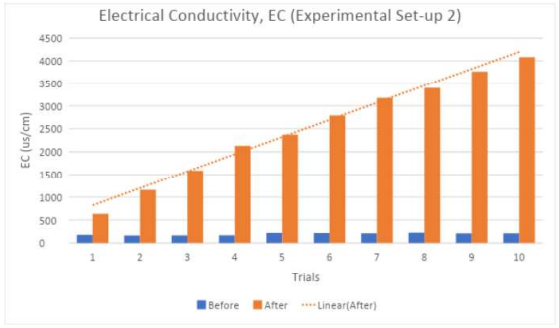

Figure 8. *Electrical Conductivity (Experimental Set-up 2)*

Figure 9. *Total Dissolved Solids (Experimental Set-up 2)*

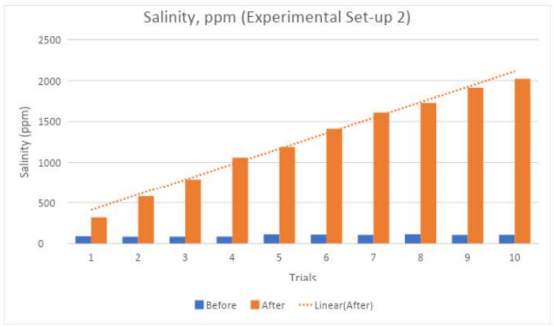

Figure 10. *Salinity (Experimental Set-up 2)*

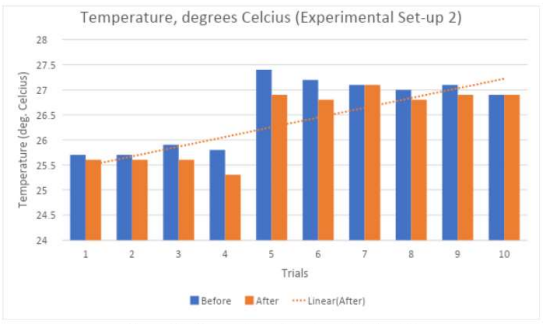

Figure 11. *Temperature (Experimental Set-up 2)*

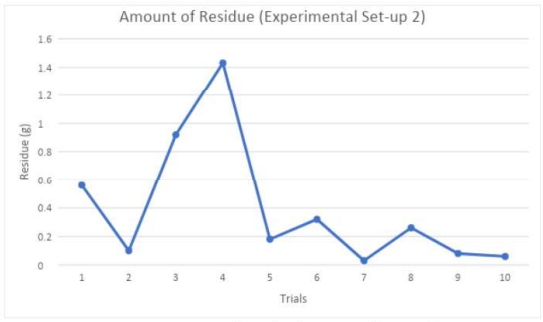

Figure 12. *Amount of Residue (Experimental Set-up 2)*

3.2. Correlation and Regression Analysis

The grams of Calamansi peels have weak correlations with the pH levels, electrical conductivity, total dissolved solids, and salinity. Each of these correlations garnered coefficients of 0.017, -0.16, -0.23, and 0.11, respectively. Since these values are closer to 0 than 1, they have small correlations with the grams of Calamansi peels used. In line with this, the regression coefficients are very low. They garnered values of 0, 0.24, 0.053, and 0.011, respectively.

The relationship between the grams of residue and the grams of Calamansi peels has a high degree of positive correlation, having a coefficient of 0.75. However, the regression coefficient is weak, having a value of 0.56.

On the other hand, the correlation between the grams of Ferric chloride ($FeCl_3$) and the pH levels is a strong negative one, garnering a value of -0.87. The regression coefficient garnered is 0.75.

The relationships of the grams of Ferric chloride ($FeCl_3$) with electrical conductivity, total dissolved solids, and salinity are strong positive correlations. The correlation coefficients and regression coefficients of these three relationships are 0.99.

A moderate correlation is formed between the grams of residue accumulated and the grams of Ferric chloride ($FeCl_3$) used. The correlation coefficient of this relationship is -0.48, while the regression coefficient is 0.23.

Discussion

The formulation of the Calamansi coagulant with the highest efficacy utilized 4.0 g of powderized Calamansi waste which, when mass produced, can greatly benefit our environmental impact. Its compact size of 4 cm in diameter and weight of approximately 45 g makes it easy to bring anywhere. Since Calamansi fruit is an important fruit crop in the Philippines, having produced 14.86 thousand metric tons in the first quarter of 2019 (Araneta, 2020), it can be easily grown and utilized for various purposes.

Comparing both results with the standard range for purified water, the Calamansi coagulant formulated was shown to be more effective. The amount of residue accumulated by the Calamansi coagulants were also greater than the Ferric chloride ($FeCl_3$) coagulants. Its pH levels, EC, TDS, and salinity showed little to no changes after experimentation and were all within the standard. Each of their correlations with the Calamansi garnered coefficients close to 0, resulting in a weak correlation and regression. It, however, showed strong positive correlation and moderate to high regression with the amount of residue. Meanwhile, the results of the Ferric chloride ($FeCl_3$) were either too low or too high for the standard. Each of the readings showed strong positive correlations with Ferric chloride ($FeCl_3$), except for the pH levels which showed strong negative correlation, however, its correlation with the amount of residue was only moderate.

4. CONCLUSIONS

The efficacy of the Calamansi coagulants formulated by the researchers as coagulants for water treatment were investigated and compared with Ferric chloride ($FeCl_3$), an existing chemical water purifier. The coagulant was composed of crushed and powderized seeds and peels of Calamansi mixed with baking soda and citric acid. Ten trials each were conducted for the coagulant and Ferric chloride ($FeCl_3$).

The researchers were able to successfully conduct the experiment. Results showed that the Calamansi coagulant was able to eliminate more residue than the Ferric chloride ($FeCl_3$) coagulant, despite the former having little effect on the water quality. Given that the contaminated water was already within the standard range, the Calamansi coagulant removed the contaminant (soil) successfully, and is thus more effective. Out of the ten trials of the coagulant, Trial 8 which used 4.0 g of Calamansi waste accumulated the most residue while still within the standard range. All trials from the Calamansi and Ferric chloride samples resulted in brown tinted water rich in Iron. The experiment only executed water coagulation and required flocculation, clarification, and filtration to achieve total water purification.

The researchers were able to produce an eco-friendly, portable, and accessible water coagulant through Calamansi waste utilization. Succeeding studies may explore further modifications on the current design to produce a highly-effective, organic effervescent water purifier from Calamansi scraps.

5. ACKNOWLEDGMENTS

The team would like to express their gratitude to their beloved family and friends for their continuous support. They would also like to thank their research mentors, Dr. Archie Maglaya and Professor Melchizedek Alipio, for the teachings and knowledge they bestowed upon them in creating the research paper. They are also grateful to their research advisor, Professor Gian Lim, for constantly guiding them on our chosen topic and sharing his insights that helped the team write this paper. The paper would not be made possible without them. Lastly, the group would like to thank God for protecting them from harm and giving them the strength to overcome any adversities that came their way while doing this study.

6. REFERENCES

Aquaread. (n.d.). Salinity. https://www.aquaread.com/parameters/salinity

Araneta, G. (2020). Research on calamansi peels receives 750k DOST funding. Retrieved From https://region9.dost.gov.ph/news/899-research-on-calamansi-peels-receives-570k-dost-funding

Dollah, Z., Abdullah, A. R. C., Hashim, N. M., Albar, A., Badrealam, S., & Mohd Zaki, Z. Z. (2019). Citrus fruit peel waste as a source of natural coagulant for water turbidity removal. Journal of Physics: Conference Series, 1349, 012011. https://doi.org/10.1088/1742-6596/1349/1/012011

Kent Ro Systems. (n.d.). What are Total Dissolved Solids (TDS) & How to Reduce Them?https://www.kent.co.in/blog/what-are-total-dissolved-solids-tds-how-to-reduce-them/

Lenntech (n.d.). Water conductivity. https://www.lenntech.com/applications/ultrapure/conductivity/water-conductivity.htm#:~:text=Pure%20water%20is%20not%20a,the%20concentration%20of%20ions%20increases.

Oram, B. (n.d.). The pH of water. https://water-research.net/index.php/water-treatment/tools/the-ph-of-water#:~:text=The%20pH%20scale%20ranges%20from%200%20to%2014.&text=In%20general%2C%20a%20water%20with,groundwater%20systems%206%20to%208.5.

Safe Drinking Water Foundation. (n.d.). Conventional water treatment: Coagulation and filtration. https://www.safewater.org/fact-sheets-1/2017/1/23/conventional-water-treatment

Safe Drinking Water Foundation. (n.d.). TDS and pH. Retrieved from https://www.safewater.org/fact-sheets-1/2017/1/23/tds-and-ph

Water.org. (n.d.). Philippines. https://water.org/our-impact/philippines/

What Is Adsorption? (2016). Fluence. https://www.fluencecorp.com/what-is-adsorption/

World Health Organization. (2019). Water shortage in the Philippines threatens sustainable development and health. https://www.who.int/philippines/news/feature-stories/detail/water-shortage-in-the-philippines-threatens-sustainable-development-and-health

Survey on Traditional Mangrove Crab Identification Methods of Filipino Fishermen

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De La Salle University Integrated School, Manila

Abstract: The Philippines is one of the largest producers of mangrove crabs in the industry, but only three of the four Scylla species exist in the country. As one of the largest mangrove crab exporters, Filipino crab farmers must distinguish their harvest before catching them for crab farming since the growth and needs of crabs depend heavily on their species group. To determine the accuracy of widely used local traditional methods, survey questions were distributed to 34 respondents around the Philippines through selected online platforms. Data gathered included local methods for identifying mangrove crabs based on traditional ecological knowledge and experiences of the local fishers interviewed. The study found that 70.58% of those polled identify the species of crabs by looking at their claws and 55.88% observe the color of the crabs. Furthermore, 41.17% of respondents consider the width and size of the shell, while 11.76% examine the crabs' carapace. Unique methods to certain regions were reported, including observation of minor features and behavior of the crabs and reliance on texture, weight, and season. Difficulty in species identification of juvenile crabs has been reported but was also possible when the crabs turn 2-3 months old or grow to the size of a 5-peso coin or 5 centimeters. Feeding schedules and consistent pond management are also said as crucial tasks in growing mangrove crabs. The fishermen voiced out concerns and opinions regarding the technology development and government policies in the crab industry.

Key Words: Philippines; mangrove crabs; Scylla serrata; species identification; traditional methods

1. INTRODUCTION

The Philippines, alongside Indonesia, Thailand, and Vietnam, remains one of the top exporters for mangrove crabs in the Southeast Asian region; as of 2018, it is estimated that over 18,100 tonnes of mangrove crabs have been exported from the Philippines to the global market all
over the world (Yxtung, 2020). Now, mangrove crab industries are significantly affecting the

Philippines' economy as it was known to be the world's second-largest producer of mangrove crabs in the year 2013 for producing over sixteen thousand tonnes of mangrove crabs, valuing around 5.2 billion pesos (Quinitio & Parado-Estepa, 2017). Additionally, as of the year 2018, a total of 20, 762 metric tonnes of mangrove crabs (Aquaculture production, 2018). In the Philippines, three out of the four mangrove crab species, under the genus Scylla, are known, namely S. serrata, S. olivacea, and S. tranquebarica (Keenan et al., 1998). Mangrove crabs grow not continuously but mature through the stages of molting, which is the shedding of the old exoskeleton of the shell and replacing it with a new and protective layer (Shelli & Lovatelli, 2011). Molting lets the mangrove crab develop from the early larval stage to the megalopae to the juvenile stage and eventually to the sexually mature stage. This study focuses on the juvenile and adult stages and is based on environmental factors that may take 5-12 days from the megalopae stage (Meynecke & Richards, 2014).

In species identification, there are a lot of ways to identify the type of mangrove crab captured. In morphological techniques, crabs are classified through frontal lobe spine shape, carapace features, inner carpus spine, and shape of the cheliped dactyl prominences. However, mangrove crabs' physical parts only have minimal differences and are very hard to see through the naked eye. As a result, morphometric methods and molecular markers were introduced to improve ccuracy. These techniques take a long time to execute and require many samples to experiment on, so it is not feasible for fishers to perform these methods (Hoq & Alam, 2018). Even though there are many studies about the taxonomy of mangrove crabs, there is still not enough research conducted to prove the traditional methods of fishers to differentiate species of genus Scylla. Additionally, people have not yet found a way to efficiently determine mangrove crab species without gadgets and

equipment.

This research's main objective is to determine the different traditional methods fishers use to identify mangrove crabs here in the Philippines. The researchers also aim to identify the similarities and differences of species identification methods used by crab farmers in several localities from Luzon, Visayas, and Mindanao and determine which methods are commonly used by them.

2. METHODOLOGY

2.1 Sampling and Data Collection

In this research, the respondents were primarily mangrove crab growers and traders from different regions in the Philippines. All participants in the study came from Regions and V in Luzon, Regions VI and VIII in the Visayas, and Regions IX, X, and CARAGA in Mindanao, all with high productions of mangrove crabs. The target number of respondents in this research was 30 respondents from the specified regions all over the country, and 34 respondents participated in the research. The data was gathered through the use of online platforms, with the duration of the survey running from November 2020 to January 2021. Data from the survey was used to assess the efficacy of crab fishers' species identification methods. The survey was conducted through Google Forms and was distributed through Facebook as the researchers joined in private groups with local mangrove crab farmers. Messenger was also utilized for private messages, especially for follow-ups from target participants. Since internet connection is required on the mentioned platforms, text messaging and calls were also considered as backup plans. Text loads were provided to some of the respondents to communicate their responses and other concerns to the researchers

2.2 Survey Questions

The survey questions were divided into the following groups:.

A. On mangrove crab production - The questions address how much mangrove crabs are produced and exported in the local and international trading and the effect of misidentification on production success.

B. On species identification of mangrove crabs - Questions in this group mainly focus on the features or parts the fishers check to identify the mangrove crabs, the methods used in species identification, and their importance.

C. On environmental changes affecting harvest, catch, and production - These questions mainly delve into any changes that can affect the harvest and production of mangrove crabs and how and why such changes affect harvest and production.

D. On general mangrove crab fishing and farming practices - These questions focus on learning about the daily routine of a mangrove crab fisher during certain periods and the routines done to ensure a higher increase in harvesting the mangrove crabs.

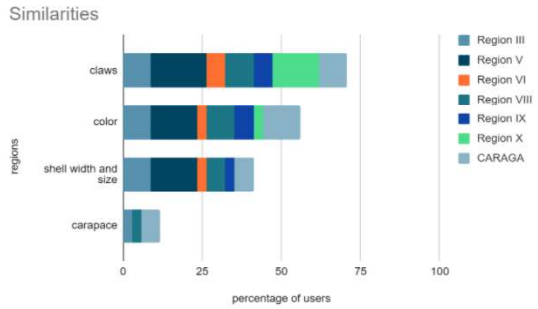
2.3 Data Analysis

The study utilized both qualitative and quantitative research. The qualitative approach gave an in-depth understanding of the different species identification crab fishers use to identify Scylla serrata while the quantitative approach aimed to evaluate the effectiveness of the methods by comparison of production rates even in environmental fluctuations. The data collected was used to assess the different species identification methods from Luzon, Visayas, and Mindanao and check the differences and similarities of these such methods. Moreover, the data mainly focused on the frequency of crab farmers using a certain species identification method and also cross-referenced the common and unique traditional methods mentioned with the scientifically discovered proved species identification, both locally and internationally. Opinions and statements of fishers regarding the importance and acceptance of knowledge in mangrove crab farming were also part of the processed data. The researchers assessed this information by comparing the responses about the methods used by the fishers to study the effectiveness of each considering the environmental factors in their respective localities and utilized the results to know if fishers around the Philippines widely use the efficient methods in order to determine how the accuracy and knowledge of the methods impact the country's overall crab trading and production rates. Additionally, the insights and statements collected from the crab farmers were summarized for the researchers to explore more possibilities of new knowledge and lifestyles in mangrove crab farming for future studies conducted by other researchers in the same field.

3. RESULTS AND DISCUSSION

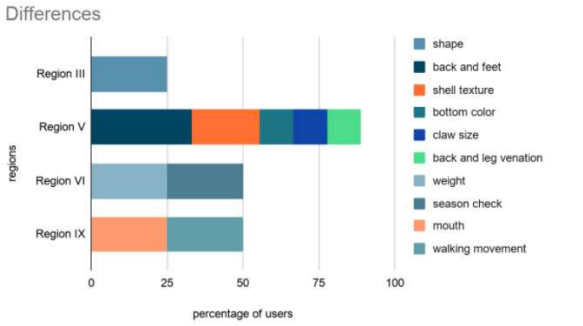
In the Philippines, three out of the four mangrove crab species, under the genus Scylla, are known, namely S. serrata, S. olivacea, and S. tranquebarica (Keenan et al., 1998). As one of the largest producers of mangrove crabs in the industry, it is vital that crab farmers need to distinguish their harvest before farming to avoid over-harvesting. Although numerous studies about the taxonomy of mangrove crabs have been conducted, there is still not enough research involving the traditional methods of fishers in differentiating the different species of genus Scylla without gadgets and equipment efficiently.

This is why the researchers have decided to survey 30 Filipino mangrove crab farmers from Regions III, V, VI, VIII, IX, X, and CARAGA to determine the various traditional methods fishers use in identifying mangrove crabs in the Philippines. With this, the researchers have further analyzed what similarities and differences their respective methods have from each other and which among these obtained methods are most commonly used.



Graph 1. *Similarities of Species Identification Methods*

Graph 1 reveals that 70.58% of the respondents stated that they identify crabs species by observing their claws. According to them, the claws of Scylla serrata are usually larger than other species, and that the edges of their claws have more visible sharp "edges" or spine, and its color varies from dark green to purple. It also appears that 55.88% of the respondents observe the color of the crabs. The farmers pointed out that the chelae color of Scylla serrata is normally dark green or blue green. Scylla olivacea has a reddish brown hue, while Scylla tranquebarica is a vibrant purple, and Scylla paramamosain, which only 2.94% of the respondents are familiar with, has a light green color. White spots occur on the claws of the Scylla serrata and the back of its shell, according to 5.88% of respondents. Moreover, the graph indicates that observation of the width and size of the shell is 41.17%, S. olivacea is said to have a carapace diameter of 20.8-140.0 mm. S. tranquebarica has a carapace that measures 40.0-195.0 mm, while S. serrata has a carapace that measures 24.4-172.0 mm. Seasonal variations, on the other hand, will affect this. 41.17% of the respondents use this approach to assess the breadth and height of the shell. Another way to differentiate adult crab species is to search for inner carpus spines and the cheliped's dactyl prominence shape, which is blunt in S. olivacea. While only 11.76% of the respondents observe the crabs' carapace to identify chelipeds, search for their relative sizes and spins. Many fishers use various unique methods that are not found in other regions surveyed and instead base their species identification on mangrove crabs' appearances. This includes observing the crab's shape, checking the crab's back and feet, observing the color of the crab's bottom, sizing the claws, observing the venation at the back and the legs, and finally, checking the mouth of the crab. Some fishers can also determine the crab species by feeling the texture of the shells, weighing the crab, depending on the season, and observing how the crab walks. The percentage of users performing the aforementioned methods with their specific originated regions are illustrated in the graph below:



Graph 2. *Differences of Species Identification Methods*

However, the most precise approach is to identify the polygonal patterns on the thighs among these methods. However, the crabs' burrowing habits can cause them to change shape (Vince-Cruz Abeledo, Ting & Ablan-Lagman, 2018). Observing the white spots on the back of the shell is another practice that was not listed, suggesting that farmers have traditional ecological knowledge that has not been recorded or researched. The carpus spine, frontal spine, propodus spine, polygon patterns on chelipeds and pereopods, and carapace coloration, according to Hoq & Alam (2018), are used to classify mangrove crab species, especially those belonging to the genus Scylla. According to Lebata, Vay, Primavera, Walton, & Biñas (2007), the different groups of mangrove crabs under the genus Scylla are morphologically differentiated through color patterns. Meynecke, et al. (2010) discussed seasonal variations and environmental disparities that influence crab preferences, but they were not used as a mechanism for species identification.

Aside from the traditional methods, the researchers also considered the differences in identifying juvenile species and adult species. Crab farmers from Region III, V, VIII, IX, and CARAGA found it challenging to identify juveniles until they turn 2-3 months old; because as these crabs turn into adults, sometimes they turn out to be different species. In connection to this, respondents from Regions V and X continued to expound that once juvenile crabs grow into the size of a 5 peso coin or 5 cm, they will be identifiable through their claws and color. Besides differentiating juveniles from adult species, the researchers also concluded that when it came to pond management, all respondents believed

in doing site security surveys both for theft and biohazards twice a day. Moreover, all of the respondents believed in the importance of checking their ponds' water condition, perimeter fence, pests, dike, and surface to see if there are any issues present. Furthermore, the respondents were also very particular about maintaining their ponds salinity and pH level for crab growth since salty ponds are more favored by crabs, but excess salt may also cause them to grow slowly. Lastly, the crab farmers also mentioned how water temperature, level, and cleanliness significantly affect production.

4. CONCLUSIONS

Survey forms were distributed to 34 local fishers from Regions III, V, VI, VIII, IX, X, and CARAGA of the Philippines. The researchers found that methods across regions showed similarities in species identification, and some techniques are unique to specific regions through quantitative and qualitative data analysis. The most common practice in the Philippines for identifying mangrove crab species is through observation of the claws followed by observing the color, both of which are common in all surveyed regions. On the other hand, most reported unique methods come from Region V, including checking the crab's back and feet, feeling the shell's texture, observing the color of the bottom, and checking for venation on the back and the legs. Observation of the carapace pattern and checking the width and size of the shells are techniques done by a portion of the surveyed population and are methods reflected in published papers. Dependence on the season was used to determine the crab species and was discussed in a published paper but not as a method of species identification. Traditional ecological knowledge is said to be preserved after seeing that the observation of white spots on the shells is done across different regions and is not mentioned in any studied articles as well as other methods that can be found only in certain regions. Fishers from five out of the seven regions surveyed expressed how it was much more difficult, and to some impossible, to identify langaw-langaws or fly-sized crablets. In contrast, some fishermen from CARAGA and Region VI were confident that fly-sized crablets were identifiable by looking at their colors and the season. The fishermen were quite particular about the pond's management, particularly its water condition, depth, temperature, and security. They also highlighted the importance of maintaining a one-meter depth, a consistent feeding schedule, ensuring that the crabs are fed and monitored regularly, and frequently renewing the pond's water. Lastly, the researchers were also able to collect some of the fishermen's concerns and responses, like how they agreed that harsh and unpredictable weather conditions like rising sea levels could affect the growth of crabs. They also raised their concern on current government policies, illegal fishing, theft, and how they ultimately want to gain support from Local Government Units. Fishers also voiced their queries on how they want to apply the latest technology to help them be more knowledgeable and have an overall easier time identifying different crab species. 30 out of the 34 respondents were willing to learn an easier method of species identification as long as it does not compromise accuracy.

5. ACKNOWLEDGMENTS

The researchers would like to show their most profound appreciation to Doctor Chona Camille Vince-Cruz Abeledo, the group's research adviser, and Miss Hilarie Orario, assistant research adviser, for supervising the group throughout the research process. The researchers would also like to extend their greatest gratitude to the following people who translated the survey questionnaires and answers from respondents: Jaron Acha, Betina Grace Tan and Jewel Alexei Buot Image for the Bisaya translation, Divine Laciste, Kyna Dominique Palattao, and Amalia Ediezca for the Ilocano version, and Joanna Nicole Wang for the translation in Ilonggo.

6. REFERENCES

Abeledo, C. C.-C. (2018). A feast of (crab) kings [Image]. Retrieved from SHE-ENSYA:

https://sheensya.wordpress.com/2018/05/10/a-feast-of-kings/

Alberts-Hubatsch, H., Lee, S. Y., Meynecke, J.-O., Diele, K., Nordhaus, I., & Wolff, M. (2015). Life-history, movement, and habitat use of Scylla Serrata (Decapoda, Portunidae): Current

knowledge and future challenges. Hydrobiologia, 763(1), 5–21. https://doi.org/10.1007/s10750-015-2393-z

Aldon, E. T., & Dagoon, N. J. (1997). The market for mudcrab. SEAFDEC Asian Aquaculture, 19(3), 11-13.

Allan, G. (2004). Mud Crab Aquaculture in Australia and Southeast Asia. Australian Centre For Industrial Agricultural Research.

Aquaculture Production. (2018). Bureau of Fisheries and Aquatic Resources. BFAR On-line Information

System.
https://www.bfar.da.gov.ph/profile?id=14&fbclid=IwAR0ppdgQaTwhIf%09ad Q4nGs

Balasubramanian, C. P., & Chandini, G. (2014). Diversification in coastal aquaculture: mud crabs. In Training manual on health management practices for finfish and shellfish of brackishwater environment (pp. 12-29). Central Institute of Brackishwater Aquaculture.

Bandibas, M. B. (2015). Crab biodiversity under different management schemes of mangrove ecosystems. Global Journal of Environmental Science and Management, 2(1), 19-30. http://dx.doi.org/10.7508/gjesm.2016.01.003

Basconcillo, J., Lucero, A., Solis, A., Sandoval, Jr., R., Bautista, E., Koizumi, T., & Kanamaru, H. (2016). Statistically Downscaled projected changes in seasonal mean

temperature and rainfall in Cagayan Valley, Philippines. Journal of the Meteorological Society of Japan. Ser. II, 94A(0), 151-164. https://doi.org/10.2151/jmsj.2015-058

Berkes, F., Colding, J., & Folke, C. (2000). Rediscovery of traditional ecological knowledge as

adaptive management. Ecological Applications, 10(5), 1251-1262. https://doi.org/10.1890/1051-0761(2000)010[1251:roteka]2.0.co;2
Castrence-Gonzales, R., Gorospe, J. G., Torres, M. A. J., Vicente, H. J., Roa, E. C., &

Demayo, C. G. (2018). The Fishery of the Mangrove Crabs, Scylla spp in Three Selected

Areas of the Philippines. Transactions on Science and Technology, 5(2), 155-170.

Choo, J., Zent, E. L., & Simpson, B. B. (2009). The importance of traditional ecological knowledge for palm-weevil cultivation in the Venezuelan Amazon. Journal of Ethnobiology, 29(1), 113-128.

Crear, B., Hart, P., Thomas, C., & Barclay, M. (2002). Evaluation of commercial shrimp grow-out pellets as diets for juvenile southern rock lobster, Jasus edwardsii. Journal of Applied Aquaculture, 12(3), 43-57. https://doi.org/10.1300/j028v12n03_05

Davis, J. L., Eckert-Mills, M. G., Young-Williams, A. C., Hines, A. H., & Zohar, Y. (2005). Morphological conditioning of a hatchery-raised invertebrate, Callinectes sapidus, to
improve field survivorship after release. Aquaculture, 243(1-4), 147-
158. https://doi.org/10.1016/j.aquaculture.2004.09.027

De La Cruz, J. (2020). Expert warns crab farmers against 'fake' king crablets. Seafdec, https://www.seafdec.org.ph/2020/expert-warns-crab-farmers-against-fake-king-crablets/

Dissanayake, A., Galloway, T. S., & Jones, M. B. (2008). Physiological responses of juvenile and adult shore crabs Carcinus maenas (Crustacea: Decapoda) to pyrene exposure. Marine Environmental Research. https://doi.org/10.1016/j.marenvres.2008.07.006.

Estampador, E. P., (1949). Studies on Scylla (Crustacea: Portunidae) I. Revision of the genus. The Phillipine Journal of Science, 78, 95–109.

Fazhan, H., Waiho, K. & Ikhwanuddin, M. (2017). Non-indigenous giant mud crab, Scyllaserrata (Forska1, 1775) (Crustacea: Brachyura: Portunidae) in Malaysian coastal waters: a call for caution. Mar Biodivers Rec 10, 26 (2017). Marine Biodiversity Records. https://doi.org/10.1186/s41200-017-0128-8

Fazhan H, Waiho K, Quinitio E, et al. (2020). Morphological descriptions and morphometric discriminant function analysis reveal an additional four groups of Scylla spp. PeerJ. https://doi.org/10.7717/peerj.8066
Fielder, D.F. & Heasman, M.P. (1978). The mud crab. A Queensland Museum Booklet.

Queensland Museum.

Fisheries Statistics of the Philippines 2017-2019. (2020). Philippine Statistics Authority. https://psa.gov.ph/sites/default/files/Fisheries%20Statistics%20of%20the%20Philippines%2C%202017-2019.pdf

Fisheries Statistics of the Philippines 2016-2018. (2019). Philippine Statistics Authority. https://psa.gov.ph/sites/default/files/Fisheries%20Statistics%20of%20the%20Philippines%2C%202016-2018.pdf

Fuseya, R. & S. Watanabe. (1996). Genetic variability in the mud crab genus Scylla (Brachyura:

Portunidae). Fisheries Science, 62, 705–709.

FAO (2015). Global Forest Resources Assessment 2015: Desk Reference. UN Food and Agriculture Office, http://www.fao.org/forest-resources-assessment/past-assessments/fra-2015/en/

Google Forms. (2018). Google Tools Meets Middle School, 127-142.

doi:10.4135/9781506360188.n7

Hoq, E., & Alam, M. S. (2018). Morphometric identification of mud crabs of the genus Scylla available in Bangladesh waters. Bangladesh Journal of Fisheries, 30(2), 19– 206

Houde, N. (2007). The six faces of traditional ecological knowledge: challenges and opportunities for Canadian co-management arrangements. Ecology and Society, 12(2).

Inglis, J. (Ed.). (1993). Traditional ecological knowledge: Concepts and cases. IDRC.

J.-O. Meynecke, R. G. Richards, (2014) A full life cycle and spatially explicit individual-based model for the giant mud crab (Scylla serrata): a case study from a marine protected area. ICES Journal of Marine Science, 71(3), 484–498. https://doi.org/10.1093/icesjms/fst181

Kathirvel, M. & Srinivasagam, S. (1992). Resource and Exploitation of Mud Crab Scylla serrata (Forskal) in India. BOBP, Madras (India): 85–94.

Keenan, C., Davie, P. & Mann, D. (1998). A revision of the genus Scylla De Haan, 1833 (Crustacea: Decapoda: Brachyura: Portunidae). The Raffles Bulletin of Zoology 46: 217-245.

Lebata, M. J., Vay, L. L., Primavera, J. H., Walton, M. E., & Biñas, J. B. (2007). Baseline assessment of fisheries for three species of mud crabs (Scylla spp.) in the mangroves of Ibajay, Aklan, Philippines. Bulletin of Marine Science.

Leland, J. C., Bucher, D. J., Southern Cross University., & Fisheries Research and Development Corporation. (n.d.). Direct age determination with validation for commercially important
Australian lobster and crab species: Western, Eastern,Southern and ornate rock lobsters, and crystal, giant and mud crabs.

Le Vay, L., Ut, V. N., & Jones, D. A. (2001). Seasonal abundance and recruitment

in an estuarine population of mud crabs, Scylla paramamosain, https://doi.org/10.1023/A:1017511002066

Meynecke, J.-O., Lee, S. Y., Grubert, M., Brown, I., Montgomery, S., Gribble, N., . . . Gillson, J. (2010). Evaluating the environmental drivers of mud crab (Scylla serrata) catches in Australia.

Molt. (n.d.) [Image]. Retrieved from New World Encyclopedia:

https://www.newworldencyclopedia.org/entry/Molt

Moreau, E. (2020). Facebook Messenger: Everything You Need to Know. Lifewire. https://www.lifewire.com/facebookmessenger-4103719

Naim, D. M., Nor, S. A. M., & Mahboob, S. (2020). Reassessment of species distribution and occurrence of mud crab (Scylla spp., Portunidae) in Malaysia through morphological and molecular identification. Saudi Journal of Biological Sciences, 27(2), 643–652. https://doi.org/10.1016/j.sjbs.2019.11.030

Nakashima, D., & Roué, M. (2002). Indigenous knowledge, peoples and sustainable practice.

Encyclopedia of global environmental change, 5, 314-324.

P. J. Smith , W. R. Webber , S. M. McVeagh , G. J. Inglis & N. Gust (2003) DNA

and morphological identification of an invasive swimming crab, Charybdis japonica, in New Zealand waters. New Zealand Journal of Marine and Freshwater Research, 37:4, 753-762

Paterson, B. D., & Mann, D. L. (2011). Recent Advances and New Species in Aquaculture. Mud Crab Aquaculture. https://doi.org/10.1002/9781444341775.ch4

Pritt, B. S. (2015). Molecular diagnostics in the diagnosis of parasitic infection. Methods in Microbiology. https://doi.org/10.1016/bs.mim.2015.05.001

Province of Lanao del Norte. (2016). Gov't. plans to make Lanao Del Norte the "Crab capital of the Philippines". https://lanaodelnorte.gov.ph/2016/02/17/govt-plans-to-make-lanao-del-norte-thecrab-capital-of-the-philippines/

Quinn, N. J. & Kojis, B. L., (1987). Reproductive Biology of Scylla Spp. Bulletin of Marine Science 41, 234–241.

Quinitio, E. T., & Parado-Estepa, F. D. (2017). Development of a sustainable mangrove crab industry through science-based research. Fish for the People, 15(1), 47-51.

Rinkevich, S., Greenwood, K., & Leonetti, C. (2011). Traditional ecological knowledge for application by Service scientists. US Fish and Wildlife Service.

Saylor, C. R., Alsharif, K. A., & Torres, H. (2017). The importance of traditional ecological knowledge in agroecological systems in Peru. International Journal of Biodiversity Science, Ecosystem Services & Management, 13(1), 150-161.

Silbiger, N., & Munguia, P. (2008). Carapace color change in Uca pugilator as a response to temperature. Journal of Experimental Marine Biology and Ecology, 355(1), 41-46. https://doi.org/10.1016/j.jembe.2007.11.014

Shelley, C., & Lovatelli, A. (2011). Mud crab aquaculture: a practical manual. FAO Fisheries and

aquaculture technical paper, (567), I. https://doi.org/10.1002/9781444341775.ch4 Taylor, M. L. (1984). New species of mud crab found in Western Australia. FINS, 17(2), 15-18. Triño, A. T. (2000). Aqua-mangrove integrated farming: Shrimp and mud crab culture in coastal

and inland tidal flats with existing reforested or natural growth of mangroves. Technologies in Mangrove-Friendly Aquaculture. Final Report of and Papers Presented to the On-Site Training on Mangrove-Friendly Aquaculture, Hai Phong City, Socialist Republic of Vietnam, 19-30 April 1999 (pp. 157-188). Aquaculture Department, Southeast Asian Fisheries Development Center.

Vincecruz-Abeledo, C. C., & Lagman, M. C. A. (2018). A revised dichotomous key for the mangrove crab genus Scylla De Haan, 1833 (Brachyura, Portunidae). Crustaceana, 91(7), 847-865. https://doi.org/10.1163/15685403-00003798

Vince Cruz-Abeledo, C. C., Ting, K., & Ablan-Lagman, M. C. (2018). Identification of a species diagnostic character for instar and juvenile mud crabs (Genus Scylla). Aquaculture, 491, 205-209. https://doi.org/10.1016/j.aquaculture.2018.03.035

What are Facebook Groups? (n.d.). Big Commerce. https://www.bigcommerce.com/ecommerce-answers/what-are-facebook-groups/

Williams, M. J., & Primavera, J. H. (2001). Choosing tropical portunid species for culture, domestication and stock enhancement in the Indo-Pacific. Asian Fisheries Science, 14(2), 121-142.

Wu, Y. (2017). Periphyton and Its Study Methods. In Periphyton. https://doi.org/10.1016/b978-0-12-801077-8.00001-6

Yxtung (2020, August 16). Overview of the Mud (Mangrove) Crab industry in the Philippines (Q3-2019) | Industry Report. https://www.ras-aquaculture.com/post/overview-of-the-mud-mangrove-crab-industry-in-the-philippines-q3-2019-industry-report

Fish waste as a resource: An approach to lessen the impact of improper solid waste management in the Philippines

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Abstract: Improper solid waste management of fish waste contributes to the pollution leading the Comprehensive National Fisheries Industry Development Plan to declare that the Philippine aquaculture industry is unsustainable. The utilization of waste promotes a circular economy, whereby products are reused indefinitely in order to eliminate waste and boost sustainability in the fish industry. This study consists of surveys and interviews with fish vendors to determine the most efficient methods of reusing and disposing fish waste, and which of these are feasible within the Philippines, specifically Metro Manila. The data gathered could be useful in the creation of policies recommending ways on repurposing fish waste and promoting a circular economy. From the responses gathered, wet market fish stalls in Metro Manila produce 1.8 tons of fish waste a year, wherein the majority claimed that it was managed by being collected by garbage collectors and segregated; however, the protocols and practices of the interviewed wet markets were inconsistent. As implementation of protocols are not strictly enforced, current waste management methods remain ineffective in reducing solid waste. Therefore, educating those in the fish industry, enacting methods to recycle fish waste, and recommending them to LGUs would prove effective in developing a circular economy while providing another source of income for the fish industry.

Key Words: fish waste; waste management; valorization; sustainability; wet market

1. INTRODUCTION

A circular economy follows the principle of reducing the usage of raw materials, reusing materials to create new products, and recycling existing ones; it minimizes hazardous impacts to the environment without stopping economic growth (Johansson & Henriksson, 2020). In the 35,000 tons of municipal solid waste being generated every day, 15 to 60% of the uncollected waste is found polluting bodies of water in the Philippines (Plaza, 2017). Despite the approval of RA 9003 or "Ecological Solid Waste Management Act of 2000" aimed to institute sustainable development by creating a comprehensive solid waste management (SWM) program; however, local government units (LGUs) have been unable to comply with the standards that the republic act requires (Castillo & Otoma, 2013). Due to improper waste disposal, the Comprehensive National Fisheries Industry Development Plan (CNFIDP) declared the Philippine aquaculture industry as unsustainable wherein fish waste such as bones, fins, skin, and scales, is one of the causes.

This study seeks to identify the actual amount of fish waste generated in the wet markets of Metro Manila, the existing SWM plans being implemented, and to find methods of converting fish waste into useful products to contribute to the development of a circular economy. The valorization of fish by-products play an essential role in conserving marine resources, and solutions should be implemented to avoid the pointless discarding of valuable biomass (Lopes et al., 2015). This will help alleviate excessive solid waste production, promote a circular economy, and provide new sources of useful material such as animal feed, fertilizer, biopolymer extracts, and collagen for the utilization and usage of other special fields within the food, medicinal, cosmetic, and agricultural industries.

2. METHODOLOGY

2.1 Sampling and Data Collection Methods

Purposive sampling was used in selecting the 40 fish vendors who manage stalls in the wet markets of Metro Manila. Their perspectives about the processes of waste disposal, their knowledge of SWM policies, and possible uses for fish waste byproducts were obtained from interviews and survey questionnaires, while the average of fish waste produced in the Philippines every year, along with the frequency of its valorization after disposal were

acquired through extensive literature from various studies using 71 books, academic journals, and theses, collectively. Interviews were conducted with the help of family members and friends, who are able to go outside following quarantine protocols, by way of face to face verbal surveys in Metro Manila wet markets. Php 50.00 of prepaid load was given to each participant days after conducting the interview. Guide questions were given to the participants a few minutes prior which had given them ample time to prepare their answers. The overall interview process lasted from late November to late December.

The interviewees were asked to provide personal information such as job position, job experience (e.g. years in current job), and province or city of origin. They were given the choice to provide their name or age as long as they were aware of the risks and confidentiality of the study. The participants were interviewed on the same day and their responses were recorded and transcribed.

2.2 Data Analysis Strategy

The Framework Method was the data analysis strategy used for this study (Gale et al., 2013). Firstly, the data collected were manually categorized and grouped based on the similarities of the responses. Secondly, the organized data were illustrated into a framework showing the full process of fish waste disposal and currently practiced valorization methods. The framework was then used for cross-referencing to identify loopholes in current disposal practices and policies such as where the unused fish waste ends up and how it is handled. Following the identification of these issues, methods of reusing fish waste that Southeast Asian industries can profit from were determined. These can serve as a basis for the creation of a policy paper which implements a circular economy through an improved solid waste management system by the Philippine fish industry.

3. RESULTS AND DISCUSSION

3.1 Results

The data from the surveys state that the majority of fish waste produced in the wet market are innards, gills, and scales that are produced on a daily basis (Fig. 4.3.1a and Fig. 4.3.1b).

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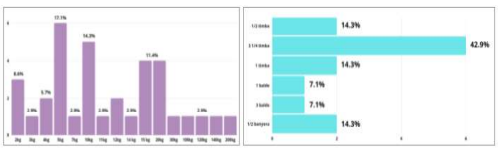

Fig. 4.3.1a *Weight of Fish Waste produced (kilograms), and b. Weight of Fish Waste produced (containers)*

With the amount of fish waste produced, 40% of respondents stated that their customers ask to acquire the fish waste for free, while some opt to buy it (22.5%). However, 37.5% of the respondents stated that fish waste isn't acquired from their stalls at all. In the stalls wherein fish waste is actually obtained, most customers buy around 1 to 2 kg of fish waste (Fig. 4.6.1a and Fig. 4.6.1b).

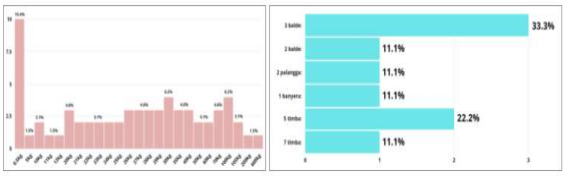

Fig. 4.6.1a. *Weight of Fish Waste thrown out (kilograms) and b. Weight of Fish Waste thrown out (containers)*

For fish waste that is thrown, 58.1% of the responses claim the waste is taken by garbage collectors or dump trucks, followed by the waste being given away (19.4%). Under SWM methods, the majority responded that waste produced by the vendors' stalls is collected by waste collectors (45%) and segregated (42.5%) while the rest stated it was maintained, unmanaged or given away, or that they did not know. Almost half of the respondents state that government units are responsible for managing wastes produced by vendors' stalls.

Most of the targeted wet markets implement policies like keeping the area clean (24.4%), placing waste proper containers (24.4%), and practicing proper disposal (15.6%) and segregation (13.3%). However, 20% claim that no such protocols are being implemented.

Regarding sanctions charged, the majority of the respondents (72.5%) stated that no penalties were imposed in their wet markets, while others (22.5%) claimed that penalties were given. These include being fined (55.6%), being given memos (22.2%), and other means of penalties accordingly.

The summary of responses for the possible uses for fish waste were animal food (63.6%) and fertilizer (11.4%). Several respondents also answered that there were no other uses for fish waste (9.1%) or that they did not know (9.1%).

3.2 Discussions

From the responses of the fish vendors, the specific parts of dead fish frequently being thrown were deemed as having little to no commercial value (Ahuja et al., 2020), hence being considered useless and labelled as "fish waste." This data supports the claim that the public market is the source that generates the most amount of solid waste (Environmental Management Bureau, 2016) as they produce fish waste on a daily basis, accumulating roughly 1.8 tons of fish waste a year. There are customers who obtain 1.5kg of fish waste everyday on

average, where 62.5% of them opt to utilize the fish waste, meaning each customer is able to repurpose around half a ton of fish waste annually and consequently reduce the amount of solid waste produced.

Among the 10 wet markets, five had inconsistent practices as there were varying practices in each, even though responses show that there were existing implementations in these markets. On the other hand, two among these have inconsistent practices and implementations as responses exhibit that only some practice them while a few are not aware or claim that there are none. While responses from one market were consistently observing one practice showing consistent presence of implementation, responses from another were consistently claiming there were no implementations. SWM methods in these markets correspond to the SWM program under RA 9003 where waste segregation and collection of solid waste are listed to manage solid waste (Aquino et al., 2013). Aligned with this is the assistance of LGUs in implementing SWM systems (Castillo & Otoma, 2013). Since more than half of the respondents gave the responsibility to market management or the store owner, it can be said that the LGUs have failed in leading the implementation of this program.

Although penalties are supposed to be imposed according to RA 9003 and Presidential Act No. 825, the majority of respondents claimed that there are none or were found to be unaware of the penalties. This proves that SWM is ineffective due to insufficient efforts by government agencies in implementing such penalties (Ngoc & Schnitzer, 2009). Despite the consequences per violation, this data implies that there is inadequate cooperation from citizens or fish vendors in waste collection methods (Environmental Management Bureau, 2018).

While a smaller percentage of fish vendors are unfamiliar with the alternate uses of fish waste or believe they have no uses, a significant portion managed to offer their knowledge related to repurposing their waste. Regarding utilization processes, results of this study show that 8 out of 10 fish vendors within Metro Manila have knowledge on repurposing fish waste as feed, fertilizer, leftovers, and clothing designs as their method of reducing the waste they produce.

Amongst the given alternative uses of fish waste obtained from the interview data, other unmentioned uses such as sources for biofuels and biopolymer extracts were found through extensive research. In this case, the methods of creating animal feed, fertilizer, leftovers, clothing designs, biofuels, and biopolymer extracts from fish wastes were further investigated. First, there are two types of animal feed that can be reprocessed from fish waste — fish silage, a wet by-product liquefied by enzymes and acids (Zynudheen & Binsi, 2018), and fish meal, a by-product that is minced, cooked, and pressed to separate the solid cake from the liquid phase (Plazzota & Manzocco, 2019). Second, seeing that fish waste is rich in nutritive soil elements, decomposes rapidly, and is compatible with organic production systems, fish waste is a suitable material as fertilizer (López-Mosquera et al., 2011; Illera-Vives et al., 2015). Third, leftover fish parts can be used in meals such as chowder, stew, stock and more. Fourth, clothing such as leather can be produced from fish skin, an ancient tradition practiced by indigenous Arctic groups (Palomino et al., 2019). Fifth, through the method of fish waste conversion with transesterification — wherein the biomass reacts with alcohol — a nontoxic, pollution-free, and biodegradable biofuel can be created (Knothe et al., 2015). Lastly, since seafood by-products are a great source of biopolymers, certain extracts like chitin, chitosan, and collagen can be obtained depending on the method of extraction on a specific type of fish waste (Diez-Pascual, 2019). The methods to extract chitin, chitosan, and collagen include centrifugation, N-deacetylation and deacytylation, and demineralization, respectively (Korma et al., 2016; Majekodunmi, 2016).

4. CONCLUSIONS

Throughout the research, the following objectives were accomplished:

The current state of fish waste management within the wet markets of the Philippines was observed by identifying the amount and frequency of waste produced, SWM practices, and the extent of the fish vendors' knowledge in fish waste valorization methods.

Methods of repurposing fish waste produced by wet markets were compiled and practices feasible in the Philippines and Southeast Asia were determined.

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6. REFERENCES

Ahuja, I., Dauksas, E., Remme, J. F., Richardsen R., & Løes, A. (2020). Fish and fish waste-based fertilizers in organic farming—with status in Norway: A review.

Waste Management, 115, 95-112. https://doi.org/10.1016/j.wasman.2020.07.025

Aquino, A. P., Derequito, J. A. P., Festejo-Abeleda, M. A. (2013, December 9). Ecological solid waste management act: Environmental protection through proper solid waste practice. https://ap.fftc.org.tw/article/588#:~:text=Waste%20mismanagement%20has%20serious%20environmental,garbage%20problems%20in%20the%20country.

Castillo, A., & Otoma, S. (2013). Status of solid waste management in the Philippines. https://www.jstage.jst.go.jp/article/jsmcwm/24/0/24_677/_pdf.

Diez-Pascual, A. M. (2019). Synthesis and applications of biopolymer composites. International Journal of Molecular Sciences, 20(9), 1-7. https://doi.org/10.3390/ijms20092321

Environmental Management Bureau. (2016). National Solid Waste Management Strategy 2012-2016. https://nswmc.emb.gov.ph/wp-content/uploads/2016/07/NSWM-Strategy-2012-2016.pdf

Environmental Management Bureau. (2018). National solid waste management report. https://emb.gov.ph/wp-content/uploads/2019/08/National-Solid-Waste-Management-Status-Report-2008-2018.pdf

Gale, N.K., Heath, G., Cameron, E., Rashid, S., & Redwood, S. (2013). Using the framework method for the analysis of qualitative data in multi-disciplinary health research. BMC Medical Research Methodology, 13(117), 1-8. https://doi.org/10.1186/1471-2288-13-117

Illera-Vives, M., Seoane Labandeira, S., Brito, L.M., López-Fabal, a., López-Mosquera, M.E. (2015). Evaluation of compost from seaweed and fish waste as a fertilizer for horticultural use. Scientia Horticulturae, 186, 101-107. https://doi.org/10.1016/j.scienta.2015.02.008

Johansson, N. & Henriksson, M. (2020). Circular economy running in circles? A discourse analysis of shifts in ideas of circularity in Swedish environmental policy. Sustainable Consumption and Production, 23, 148-156. https://doi.org/10.1016/j.spc.2020.05.005

Knothe, G., Krahl, J., & Van Gerpen, J. (Eds.). (2015). The biodiesel handbook. Elsevier.

Korma, S. A., Kamal-Alahmad, Niazi, S., Ammar, A., & Alyousef, H. (2016). Production, classification, properties and application of chitosan. International Journal of Research in Agricultural Sciences, 3(3), 2348-3997.

Lopes, C., Antelo L. T., Franco-Uria, A., Alonso, A. A., & Pérez-Martín, R. (2015). Valorisation of fish by-products against waste management treatments – Comparison of environmental impacts. Waste Management, 46, 103-112. https://doi.org/10.1016/j.wasman.2015.08.017

López-Mosquera, E., Fernández-Lema, E., Villares, R., Corral, R., Alonso, B., & Blanco, C. (2011). Composting fish waste and seaweed to produce a fertilizer for use in organic agriculture. Procedia Environmental Sciences, 9, 113–117. https://doi.org/10.1016/j.proenv.2011.11.018

Majekodunmi, S. O. (2016). Current development of extraction, characterization and evaluation of properties of chitosan and its use in medicine and pharmaceutical industry. American Journal of Polymer Science, 6(3), 86-91. http://article.sapub.org/10.5923.j.ajps.20160603.04.html

Ngoc, U. N., & Schnitzer, H. (2009). Sustainable solutions for solid waste management in Southeast Asian countries. Waste Management, 29(6), 1982-1995. https://doi.org/10.1016/j.wasman.2008.08.031

Palomino, E., Káradóttir, K., Rhame, L., & Boon, J. (2019). Indigenous arctic fish skin clothing traditions: Cultural and ecological impacts on fashion higher education. https://www.researchgate.net/publication/334224302_Indigenous_Arctic_Fishskin_clothing_traditions-_Cultural_and_ecological_impacts_on_Fashion_Higher_Education_Cumulus-Rovaniemi

Plaza, A. B. (2017, October 13). Ditch NIMBY to fix Philippines' municipal solid waste problem. https://blogs.adb.org/blog/ditch-nimby-fix-philippines-municipal-solid-waste-problem

Plazzota, S. & Manzocco, L. (2019). 10 - food waste valorization. Saving Food: Production, Supply Chain, Food Waste, and Food Consumption, 279-313. https://doi.org/10.1016/B978-0-12-815357-4.00010-9

Zynudheen, A. A. & Binsi, P. K. (2018). Fish processing waste: Valuable raw material for silage, foliar spray and animal feed preparation. http://drs.cift.res.in/bitstream/handle/123456789/4486/Fish%20processing%20waste.pdf?sequence=1

Paper Review for Application of Thermally Treated Eggshell Waste: Systematic Approach

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Abstract: The amount of eggshell waste continues to rise due to the increased consumption of eggs; thus, finding methods to repurpose these waste materials would be beneficial. The estimated number of eggshell wastes in the Philippines for 2019 is 63.28 thousand metric tons. Moreover, eggshells also exhibit potential to have various applications due to their polycrystalline structure and calcite crystal content. The performance of eggshells in these applications can be maximized through thermal treatment, which involves exposing the eggshells to high temperatures for a period of time. Thus, this study aims to develop a framework using systematic mapping approach to evaluate the application of calcined eggshells. Through this method, relevant papers were collated, screened, analyzed, and evaluated. The findings showed that the application of calcined eggshells can be classified into seven general utilizations: catalysis, adsorption, additives, hydroxyapatite synthesis, bacteria removal, biogas production, and biomass gasification. Additionally, the resulting data indicated that chicken eggshells were the most used eggshell type for these applications. It was also noted that the usual temperature and time for thermal treatment ranges from around 500-1000°C for about 2-4 hours. Overall, the results suggest the possibility for eggshells, given the significant eggshell waste production in the country, to be utilized in different applications through thermal treatment.

Key Words: eggshell waste; thermal treatment; calcination; systematic mapping approach; waste utilization

1. INTRODUCTION

Eggshells are agricultural wastes that accumulate in landfills. The high concentration of waste causes environmental pollution (Abdulrahman et al., 2014). The increase in demand for eggs contributes to the increase in consumption of eggs. The United States Department of Agriculture (2020) stated that the consumption per year is around 13.4kg per person. The rise in egg production contributes to the high concentration of waste. Eggshell waste utilization helps reduce solid waste dumps in landfills because of its efficiency. Eggshells are composed of 94% calcium carbonate, 4% organic matter, 1% magnesium carbonate, and 1% calcium phosphate (Mohadi et al., 2016). Eggshells exhibit calcite crystals and polycrystalline calcium carbonate (Hincke et al., 2012). Calcination involves subjecting raw materials to extremely high temperatures which enhances the calcium carbonate content of eggshells (Wu et al., 2015). Ahmadzadeh-Hakimi et al. (2017) state that Scanning Electron Microscopy (SEM), Fourier-Transform Infrared Spectroscopy (FTIR), and X-ray Diffraction (XRD) are utilized for characterization of eggshells. Characterization is performed to analyze the efficiency of calcined eggshells. Mohadi et al. (2016) states that the overall performance of calcined eggshells was highly effective compared to that of raw eggshells.

A systematic approach was used in this paper review to evaluate the relevance of the research topic. The study is limited to conducting a desktop study to determine its performance based on the significant results of existing literature from different sites. Sites used for the research were Scopus, Google Scholar, and Science Direct. The performance of calcined eggshell waste will be evaluated based on its properties and applications. The general objective of the study is to evaluate the application of thermally-treated eggshell waste through a systematic mapping approach. It is narrowed into three specific objectives, which are: 1) to formulate a framework for systematic mapping of the utilization of thermally-treated eggshell waste; 2) to evaluate the performance of thermally-treated eggshell wastes to its intended application, and; 3) to assess the properties of calcined

eggshell wastes that affect its performance. The study will examine the studied waste utilization and benefits as an adsorbent, catalyst, additive, bacteria removal, biogas production, hydroxyapatite synthesis, and biomass gasification. It will concentrate on the trend, calcination, and characterization of eggshell waste used to evaluate its performance in different functions.

2. METHODOLOGY

2.1. Research Framework

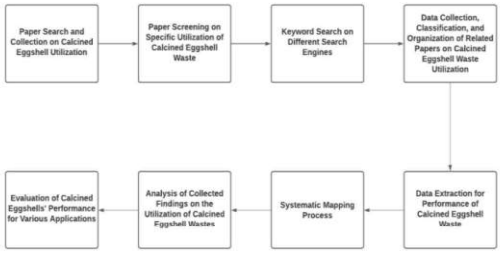

Fig 2.1. *Research Flow*

The research flow presented in Fig. 2.1 consists of ten steps. First, the formulation of the research questions was the initial point of the research. Then, the scopes and limitations were reviewed to analyze the restrictions of the research. Afterwards, paper search and collection were carried out to find significant research evidence. The gathered papers were screened to obtain optimum results. Furthermore, keywords were used to identify the scope of the papers being reviewed. Data collection, classification, and organization were employed to achieve a thorough synthesis of the papers. Moreover, information extracted from different papers were analyzed and evaluated for the calcined eggshells. Mapping process was used via the systematic approach to answer the research questions. Additionally, findings of the analysis were organized for visualization of the results. Lastly, the performance of thermally-treated eggshells for each application was evaluated to determine efficiency of calcined eggshells.

2.1.2. Research Questions

For this study, the following research questions (RQs) were formulated to be answered by the systematic approach for the applications of thermally-treated eggshell waste: RQ1: Is thermal treatment being utilized for eggshell waste?

RQ2: What are the applications of thermally treated eggshell wastes?

RQ3: What is the performance of thermally treated eggshell wastes to its intended application?

RQ4: What are the properties of thermally treated eggshell wastes that affect its performance?

2.2. Paper Search and Screening

The search for relevant papers related to the research questions was performed using the following search engines and databases: SCOPUS, ResearchGate, Google Scholar, and ScienceDirect. Then, during the initial paper search in these databases, the results were filtered with the following keywords as shown in Table 2.1.

Table 2.1. *Keywords Used in the Initial Paper Search*

	Keyword		Keyword
K1	"Eggshells"	K6	"Calcined eggshell"
K2	"Eggshell" + "Waste"	K7	"Calcined waste eggshell"
K3	"Waste eggshell"	K8	"Eggshell" + "Utilization"
K4	"Thermally treated eggshell"	K9	"Eggshell" + "Application"
K5	"Eggshell" + "Thermal treatment"	K10	"Eggshell" + "Adsorption"

2.3. Data Collection, Organization, and Analysis

The extraction of relevant information is necessary to answer the defined research questions. The collected papers were further screened as only relevant papers related to the study would be used for the paper review. Moreover, the significant performance, eggshell type, temperature, specific utilization, and general utilization were extracted from various papers and recorded in excel to achieve an organized data sheet. All papers were organized by placing its significant information, which is author, date published, journal abbreviation, type of eggshell, temperature of thermal treatment, duration of thermal treatment, significant results, highest performance, analysis used, and utilization. The group utilization was divided into different groups, which are Adsorbent, Bacteria Removal, Catalyst, Biomass Gasification, Additives, and Hydroxyapatite Synthesis. Since some sources did not state the type of eggshells used, the eggshell source for the unspecified eggshells were grouped as well.

3. RESULTS AND DISCUSSION

3.1 Philippine Egg Production, Waste Generation, and Eggshell Types

The increase in egg production per year has contributed to the increase in eggshell waste. As presented in Fig. 3.1, the amount of chicken eggs has

gradually increased for the past three years. During the year 2019, the production of both chicken and duck eggs are higher compared to 2017 and 2018. Moreover, the abundance of chicken eggs in the Philippines significantly outweigh that of duck eggs. This signifies the high supply and demand of chicken eggs in the country as they are one of the staple foods.

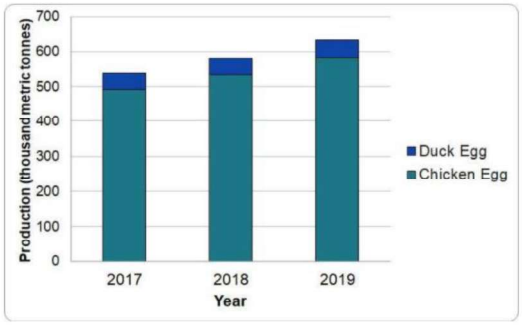

Fig. 3.1. *Chicken and Duck Egg Production in the Philippines*

It was determined that the shell is said to be 10% of the egg's total weight (Hunton, 2005). It was estimated that eggshell weighs 6g for every 60g egg (average weight). The projected eggshell waste for 2017, 2018, and 2019 were computed by multiplying the total egg supply to the percentage of eggshell per egg. The computed projected eggshell wastes for those years were 53.78 thousand metric tonnes, 58.05 thousand metric tonnes, and 63.28 thousand metric tonnes, respectively. As shown by Fig. 3.2, there has been an increase in eggshell projection which is relative to the egg production in the country.

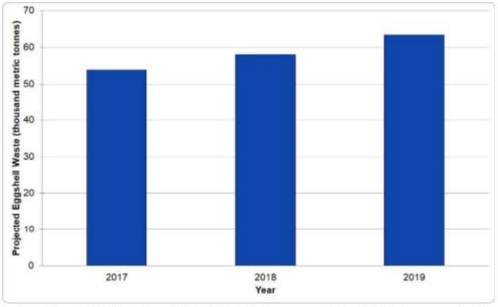

Fig. 3.2. *Eggshell Waste from 2017-2019 (Note: computed as 10% of egg production)*

Based on the data collected, there are three primary types of eggshells: quail eggshells, duck eggshells, and chicken eggshells. In Fig. 3.3, chicken eggshells rank the highest with 34 papers due to their abundance and accessibility. However, the number of unspecified eggshells remains higher with 52 papers. The type of eggshells used in some studies were not specified; however, their sources were mentioned. Figure 3.4 below shows the percentage of the different sources of unspecified eggshells. It depicts that waste eggshells were collected from street food stalls, bakeries, breakfast shops, food markets, poultry farms, and restaurants. Some studies sourced out from restaurants due to the large number of eggshell wastes from consumption. Despite identifying the study's source of eggshell waste, 53.8% remain to be unstated.

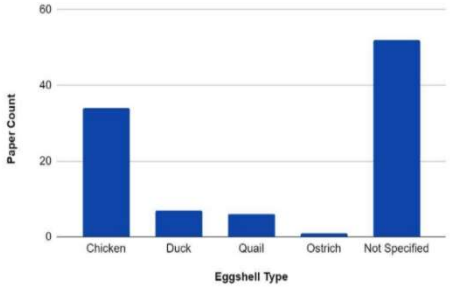

Fig. 3.3. *Paper Count on the Eggshell Type Utilized*

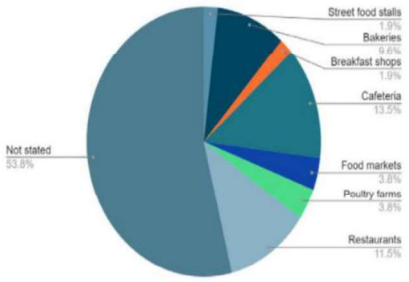

Fig. 3.4. *Sources of Unspecified Eggshells*

3.2. Thermal Treatment

Calcium carbonate content of eggshells are further maximized by the application of thermal treatment. The high temperature of calcination triggers the conversion of calcium carbonate calcium oxide and calcium hydroxide (Wu et al., 2015). Based from Fig. 3.5, the optimum calcination temperature used by many studies range from 500-1000℃ for a duration of 2-4h. Awogbemi et al. (2020) stated that a calcination at 90℃ affected the pore size, surface area, and thermal decomposition of eggshells. XRD patterns show that samples sintered beyond 1100℃ shows a gradual disappearance of the ß-TCP phase that is transformed to hydro (Wu et. al., 2015). Agbabiaka et al. (2020) found that a calcination temperature of 1000℃ showed a hydroxyapatite structure, meaning a high purity rate. Furthermore, Mohadi et al. (2016)

states that metal oxide formation and calcination temperature are directly proportional.

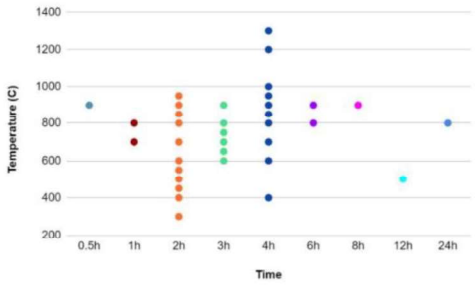

Fig. 3.5. *Corresponding Time and Temperature for Calcination from Various Studies*

3.3. Utilization, Application, and Performance

General Utilization, Specific Application, and Overall Performance

Thermally treated eggshell wastes have multiple utilizations: adsorption, catalyst, bacteria removal, biogas production, biomass gasification, hydroxyapatite synthesis, and additives. In Table 3.1, a total of 100 papers were used in this study to analyze each utilization. Based on different studies, chicken eggshells were more often used than other eggshell types. The performance of eggshells from various papers were assessed and analyzed in order to determine the efficiency of eggshells as an alternative product.

Table 3.1. *Eggshell Waste Utilization Paper Count*

General Utilization	Paper Count
Catalyst	47
Adsorption	25
Additives	14
Hydroxyapatite Synthesis	11
Bacteria Removal	1
Biogas Production	1
Biomass Gasification	1

Catalysis

Catalysts accelerate the chemical reaction between substances and improves the yield. The thermally-treated eggshells were used mainly for biodiesel production. The reaction process present in the studies was transesterification. Due to the calcium carbonate content in eggshells, the eggshell-derived catalyst showed great stability and high effectiveness. The majority of the studies utilized chicken eggshells as a catalyst. As shown in Fig. 3.6, the results for the biodiesel yield range from 75-97.98%. This shows the efficiency of calcined eggshells as a catalyst for biodiesel production.

Fig. 3.6. *Biodiesel Yield of Eggshell-Derived Catalyst*

Adsorption

The presence of contaminants in water has adverse effects on human health and the environment. Eggshells were found to be effective adsorbents due to the calcium carbonate content and porous structure. As presented in Fig. 3.7, the overall efficiency of calcined eggshells for the adsorption of different contaminants ranged from 50-99.5%. Amongst the contaminants, phosphorus was the most prevalent due to its abundance in wastewater.

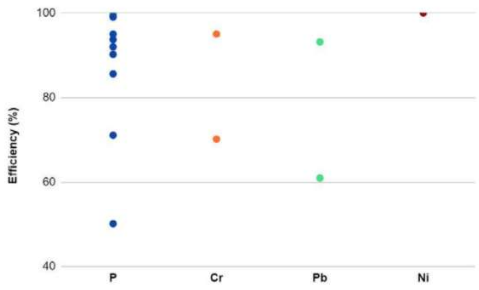

Fig. 3.7. *Efficiency of Calcined Eggshells on Corresponding Contaminants*

Additive

The thermally treated eggshells were combined with other products to enhance the quality and capability of the final product. In Fig. 3.8, the temperatures through which the highest performance of calcined eggshells as additives are exhibited. Specifically, a calcination temperature of 800℃ was commonly used by multiple studies for this application. The calcination temperature is vital in

obtaining optimal performance. The eggshell type used in these studies were not specified.

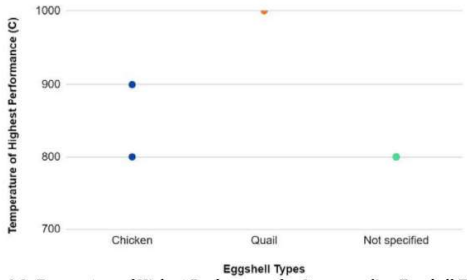

Fig. 3.8. *Temperature of Highest Performance for Corresponding Eggshell Types*

Hydroxyapatite Synthesis

The calcium carbonate present in eggshells can be converted to crystalline hydroxyapatite. Eggshells were found to have high thermal stability which is advantageous for hydroxyapatite synthesis. Calcination was performed to aid in calcium oxide formation and produce high quality hydroxyapatite (Ummartyotin & Tangnorawich, 2015). In Fig. 3.9, the Ca/P ratio is optimal as it ranges from 1.56-2.44. The results were limited because most studies use chicken eggshells in the study. Oladele et al. (2019) state that calcination is a factor that improved the synthesis of hydroxyapatite.

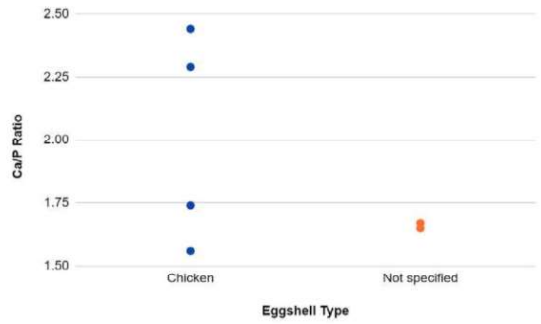

Fig. 3.9. *Ca/P Ratio of Hydroxyapatite with Corresponding Eggshell Type*

Other Utilizations (Bacteria Removal, Biogas Production, and Biomass Gasification)

As abundance of human pathogen and antibiotic resistance genes within landfills has become a great threat to human health, bio sorbents from agricultural wastes provide economic and environmental benefits towards the prevention of its dissemination. Ye et. al (2017) stated that eggshells treated from sulfate and calcination provided a significant result of showing its high capacity in absorbing E. coli with gentamicin-resistance gene. Furthermore, the study stated that its optimal absorption from eggshells led to the increase of pathogenic bacteria, which shows great purification efficiency.

Biogas production is a good renewable energy source which requires various materials as a biogas source. Kivuyo et. al (2017) studied that pre-treating substrates, such as banana pulp, with calcined eggshells exhibit an efficient degradation of lignocellulosic substrate. The calcium carbonate content of eggshells allows the improvement of biogas yield as it assists in hydrolysis. Furthermore, a higher efficiency in converted organic compounds was achieved which led to the increase in pH and methane content.

According to the study conducted by Salaudeen et al. (2018), calcined eggshells can act as a potential CO2 sorbent involved in biomass gasification. The increase in carbonation temperature improves the carbonation conversion. The gathered data from the study shows that around 76.41% of conversion was reached in the first calcination-carbonation cycle. However, due to the sintering and attrition, the conversion reduced with increasing cycles.

4. CONCLUSIONS

Due to the continuous increase of eggshell waste production, methods to repurpose these wastes must be implemented to minimize its contribution to filling up landfills. Eggshells reveal the potential of becoming a useful material for various processes because of their composition and morphology. For calcined eggshells, the thermal treatment process further increases their functional capacity. Thermal treatment parameters such as time and temperature also influence the performance of eggshells. After the collation of papers, the application of eggshell was grouped into seven general utilizations: catalyst, adsorption, additive, hydroxyapatite synthesis, bacteria removal, biogas production, and biomass gasification. Chicken eggshells were found to be the most used eggshell type in papers that specified the eggshell type used due to their abundance. Meanwhile, the data showed that the usual temperature and time for the calculation of eggshells ranges from 500-1000°C and about 2-4 hrs. Overall, the performance of eggshells for various applications indicate optimum efficiency as it ranges from 50-99.5%.

5. REFERENCES

Abdulrahman, I., Tijani, H., Mohammed, B., Saidu, H., Yusuf, H., Jibrin, M., & Mohammed, S. (2014). From garbage to biomaterials: an overview on eggshell based hydroxyapatite. Journal of

Materials, 1-6. https://doi.org/10.1155/2014/802467

Agbabiaka, O., Oladele, I., Akinwekomi, A., & Adediran, A. (2020). Effect of calcination temperature on hydroxyapatite developed from waste poultry eggshell. Scientific African, 8. https://doi.org/10.1016/j.sciaf.2020.e00452

Ahmadzadeh-Hakimi, K., Keshmirizadeh, E., & Modarress, H. (2017). The activation of eggshell by chemical and thermal treatment for removal of acid blue 92 dye from aqueous solutions. Analytical Chemistry Letters, 7(3), 369-382. https://doi.org/ 10.1080/22297928.2017.1322535

Awogbemi, O., Inambao, F., & Onuh, E. (2020). Modification and characterization of chicken eggshell for possible catalytic applications. Heliyon, 6(10). https://doi.org/10.1016/ j.heliyon.2020.e05283

Hincke, M., Nys, Y., Gautron, J., Mann, K., Rodriguez-Navarro, A., & McKee, M. (2012). The eggshell: structure, composition, and mineralization. Frontiers in Bioscience, 17, 1266-1280.https://www.researchgate.net/publication/269791417_The_eggshell_structure_composition_and_mineralization

Hunton, P. (2005). Research on eggshell structure and quality: An historical overview. Brazilian Journal of Poultry Science, 7(2), 61-71. https://doi.org/10.1590/S1516-635X2005000200001

Kivuyo, L., Njau, K., & King'ondu, C. (2017). Eggshells – assisted hydrolysis of banana pulp for biogas production. African Journal of Environmental Science and Technology, 11(1), 71https://www.researchgate.net/publication/315633769_Eggshells_assisted_hydrolysis_of_banana_pulp_for_biogas_production

Mohadi, R., Anggraini, K., Riyanti, F., & Lesbani, A. (2016). Preparation calcium oxide from chicken eggshells. Sriwijaya Journal of Environment, 1(2), 32-35. https://doi.org/ 10.22135/sje.2016.1.2.32-35

Oladele, I., Agbabiaka, O., Adediran, A., Akinwekomi, A., Balohun, A. (2019). Structural performance of poultry eggshell derived hydroxyapatite based high density polyethylene bio-composites. Heliyon, 5(10), 1-7. https://doi.org/10.1016/j.heliyon.2019.e02552

Salaudeen, S., Tasnim, S., Heidari, M., Acharya, B., & Dutta, A. (2018). Eggshell as a potential CO2 sorbent in the calcium looping gasification of biomass. Waste Management, 80, 274-284. https://doi.org/10.1016/j.wasman.2018.09.027

Ummartyotin, S. & Tangnorawich, B. (2015). Utilization of eggshell waste as raw material for synthesis of hydroxyapatite. Colloid and Polymer Science, 293, 2477-2483. https://link.springer.com/article/10.1007/s00396-015-3646-0

United States Department of Agriculture. (2020, March). Philippine Broiler Market Trends and Prospects. https://www.fas.usda.gov/data/philippines-philippine-broiler-market-trends-and-prospects

Wu, S., Hsu, H., Hsu, S., Chang, Y., & Ho, W. (2015). Effects of heat treatment on the synthesis of hydroxyapatite from eggshell powders. Ceramics International, 41(9). https://doi.org/ 10.1016/j.ceramint.2015.05.006

Ye, M., Sun, M., Chen, X., Feng, Y., Wan, J., Liu, K., Tian, D., Liu, M., Wu, J., Schwab, A., & Jiang, X. (2017). Feasibility of sulfate-calcined eggshells for removing pathogenic bacteria and antibiotic resistance genes from landfill leachates. Waste Management, 63, 275-283. https://doi.org/10.1016/j.wasman.2017.03.005

Effect of Different Amounts of Volcanic Ash from the Taal Volcano Eruption to the Growth of *Ocimum basilicum* (Basil)

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Abstract: Volcanic eruptions have a tremendous impact on an area that often leads to the destruction of the environment, human injuries, and even death. However, this research emphasizes one specific outcome unique to volcanic eruptions. The study aims to shed light upon the beneficial applications of volcanic ash to determine whether or not volcanic ash has advantageous botanical properties that could potentially enhance the growth of Ocimum basilicum (basil). In 8 weeks, four different concentrations (VA-0, VA-0.5, VA-1, and VA-2) of volcanic ash-loam soil composition were tested on basil plants. Three parameters were utilized to measure the plant's growth: plant height, leaf count, and leaf surface area. Pot VA-1 achieved the highest plant height and leaf count increase among the four concentrations. As for the leaf surface area, VA-1 and VA-2 both yielded the highest growth from week 1 to week 8. Results support a beneficial relationship between volcanic ash and acid-loving plants.

Key Words: volcanic ash; basil; concentration; growth; acid-loving plants

1. INTRODUCTION

Every so often, volcanic activity occurs. Mt. Pinatubo, known for its global scale effect, has affected and devastated thousands of humans and other species, such as plants. Volcanic eruptions have a tremendous impact on an area that often leads to the destruction of the environment, human injuries, and even death. However, this research emphasizes one specific outcome unique to volcanic eruptions. Ash clouds will cover the atmosphere, leading to an abundant amount of volcanic ash everywhere when a volcanic eruption occurs. Depending on the magnitude of the explosion, its range or eruption radius may vary drastically. However, volcanic ash is commonly depicted as a terrible substance for the environment. Since it is heavy and acts as a sun-resistant layer over plants, it strongly hinders photosynthetic activities and transpiration from commencing.

In the field of botany, ash could potentially have effects that could change the way people grow plants and vegetables. With a composition of high sulfur levels, integrating ash into the soil could prove beneficial to acid-loving plants. According to the Natural Resources Conservation Service (NRCS), acid-loving plants prefer pH soil levels of 6.5 and below. Due to the ash's elevated sulfur levels and low pH levels, non-acidic plants may not survive. In contrast, acid-loving plants may thrive from their low pH nature. Acid-loving fruits grow more efficiently on soils with a pH level of 4.0 to 5.0. In contrast, some acid-loving vegetables will prefer a pH soil level of 4.5 to 5.5. In addition to this, soils following a volcanic eruption yield the most fertile and productive soil (Fiantis et al., 2019). Individual plants grown in such soils could thrive and develop into healthy, high-yield plants.

Along with a volcanic eruption comes the adverse effects such as the destruction of acres of land, bodies of water engulfed by ash, thousands of crops perishing, and hundreds of homes rendered uninhabitable, to name a few. The aftermath of such events led to stockpiles of ash left on the streets. The problem is that all that ash was rendered useless by disposing of it rather than looking for ways to make use of its unique composition. As of today, volcanic ash is an excellent material for the structural integrity of bricks compared to cement usage (Salamah & Maryudi, 2016). Volcanic ash could potentially open many doors to new developments in different areas. With the utilization of the excess volcanic ash, the growth of acid-loving plants could improve. As studies have shown, the composition of volcanic ash leads to its high acidic nature. This brings the research to its hypothesis: volcanic ash aids in making the soil acidic to benefit the growth of acidic-loving plants.

The primary goal of the study is to undergo a substantial experimentation process to prove that unfiltered volcanic ash has botanic advantages. This study focused on plant development through natural means; hypothesized results could pave the way for future researchers to perform their trials with variables unique to their experiment. To achieve the projected outcome of this research, the researchers' general objective in conducting this study is to determine the effect of utilizing volcanic ash on basil's growth.

The findings of the study can be used as supporting evidence towards volcanic ash's overall knowledge, a resource regarded as pollution. This will be benefiting the agricultural sector as this could be used as an excellent addition to loam soil when growing acid-loving plants. This innovative, costless, and inventive soil composition with volcanic ash could drastically reduce the expenses of those looking to grow acidic-loving plants when choosing an efficient soil composition. Furthermore, this provides a framework for further studies regarding volcanic ash's feasibility as soil, making this particular soil composition evidence-based. If the research is successful, the addition of volcanic ash will prove an effective way to maximize available resources, making volcanic ash a more sought-after product when growing acid-loving plants. The effects of the volcanic ash from the Taal Volcano eruption are to be tested. However, because of the method of gathering the volcanic ash, it may not be considered pure. The height difference was determined using an initial and final measurement for each setup containing different volcanic ash concentrations. It could signify a change in development in the plant. The researchers only used four different concentrations of volcanic ash which includes a blank setup that serves as the control (0% volcanic ash), a 25% volcanic ash concentration composition, a 50% volcanic ash concentration composition, and a pure (100%) volcanic ash composition. Each of the concentrations yielded a certain pH level that was attained through averaging all the readings from time 0 to week 8. The pH levels are the following: 8.0 for VA-0, 6.5 for VA-0.5, 6.1 for VA-1, and 6.0 for VA-2. To ensure a pure reaction between the loam-volcanic ash soil composition, the researchers chose to avoid using chemicals such as aftermarket fertilizers and pesticides.

2. METHODOLOGY

Table 1. *Materials Used*

Qty.	Item	Description	Price (₱)
16	Pot	16 identical pots measuring D:11in, H:9in.	₱960
16	Basil seedlings	X weeks old seedlings	₱1,120
14 kg	Volcanic ash	Volcanic ash was harvested during the Taal eruption and different amounts (g) will be used in 2/4 setups.	₱0
80 kg	Loam	Each member gets 10 kg of loam. Loam will be used because it is the most basic form of garden soil	₱560
4	Jollic pH indicator	Each member will receive identical pH level indicators for measurement of soil acidity with their respective trials.	₱976
1	Escali gram scale Model: Pana#V136	To be used for mass concentration calculations to be done by one member.	₱0
4	Anti-pest plant netting	To minimize or eradicate pest infestations, net usage will protect the plant.	₱766
4	Ruler	To measure the growth height of the plant in centimeters	₱0
		Total:	₱4,382

The research design formulates three different parameters that manifest plant growth. With the gathered data from 8 weeks of experimentation, each trial in each parameter has changed between the initial and the preceding week. The increasing parameters may help the amount of sunlight the plants receive hence providing more glucose or food for the plant to grow. Each pot gaining varying results on different parameters shows that each parameter benefits from the volcanic ash concentration.

There are sixteen pots in total. Since there are four members in the group, each member received and tended to 4 pots throughout the experimentation period. The pot was filled up to a certain point with the soil used (loam) to determine how much soil the pot can hold in grams, and once filled, the soil's weight was recorded. Each pot contained a different volcanic ash and soil concentration, while similar basil plants were planted in each pot. To meet the optimal pH level that basil thrives in (5.5-6.5 pH), every member of the research group was tasked to measure the loam soil's pH level in all of the assigned pots, respectively. Weight per weight percentage allowed the researchers to express the concentration of the solution. As for how the measurements were taken for the three parameters, namely plant height, leaf count, and leaf surface area, tools such as a ruler and ImageJ software were utilized to gather the data needed over eight weeks effectively. However, only the plant height and leaf count were recorded for eight consecutive weeks. The data taken for the leaf surface area was only an initial and final measurement, time zero and week eight, respectively.

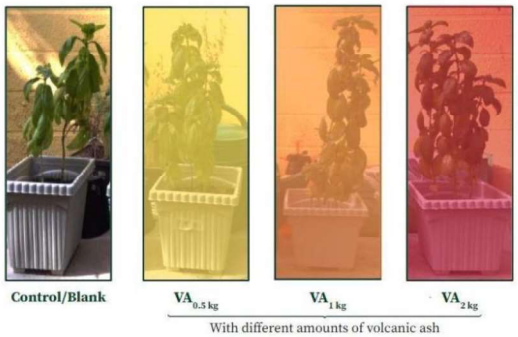


Figure 1. *Research Design Showing Three Different Parameters per Trial*

3. RESULTS AND DISCUSSION

As the researchers observed, the plant height had an average increase of 2 cm per week for VA-0, 1.9 cm per week for VA-0.5, 2.8 cm per week for VA-1, and 2.5 cm per week for VA-2. The average increase of the height of the plant was taken through finding the slope yielded by the trendline of each graph (Fig. 3.0-3.3). From this data that the members have gathered,

it can be concluded that VA-1 has the highest average increase which is 2.8cm per week. For leaf count (Fig. 5), it is shown in the graph that VA-0 has a continuous increase of leaves as weeks pass by. For VA-0.5 it reached its peak on week 5 and plateaued shortly after. VA-1 had a constant number of leaves within week 2 to week 5 and showed a sudden significant increase in number of leaves. Throughout eight weeks, the number of leaves of VA-2 shows an inconsistent increase and decrease in the number of leaves. The researchers took pictures of the basil leaves and used ImageJ to measure, analyze, and process the images to gain more accurate results. With this application, we were able to measure the area and compare the initial leaf area to week 8 area to know how much it has increased and to determine which pot has the highest area value. Starting from the pot which has the lowest average surface leaf area, VA-0.5 with 13.76 cm2, VA-0 with 17.95 cm2, VA-2 with an area of 22.71 cm2, and the pot with the highest leaf area, was VA-1 with an area of 24.93 cm2.

3.1 Plant Height

For the first week, there was a sudden increase in height for all trials with a ΔT range of 6-8 cm. It was hypothesized that the sudden increase might be natural plant growth since the initial height (time 0) was based on seedlings, or newly germinated seeds. Pot VA-1 averaged 2.8 cm of growth per week. Being the highest out of all four concentrations, pot VA-2 came in second with an average growth per week of 2.5 cm. The experimentation period ended at week 8 with pot VA-1 being the tallest plant with an average height of 31.7 cm; which may prove the presence of a snowball effect on the height of the basil. The second tallest plant is VA-2,; which could prove that a more concentrated amount of volcanic ash is potentially beneficial to the height of acidic plants. Adding to this, pot VA-0.5 resulted in having the lowest height with a total average height of 23.7 cm.

Table 3.3. *Summary table of plant height*

		y = mx + b		Growth Rate
No	Sample	Linear Equation	R^2	Slope
1	VA-0	y = 2.0050x + 11.496	0.8120	2.0050
2	VA-0.5	y = 1.9877x + 10.108	0.8488	1.9677
3	VA-1	y = 2.8562x + 10.302	0.9113	2.8562
4	VA-2	y = 02.5825x + 9.9956	0.9477	2.5825

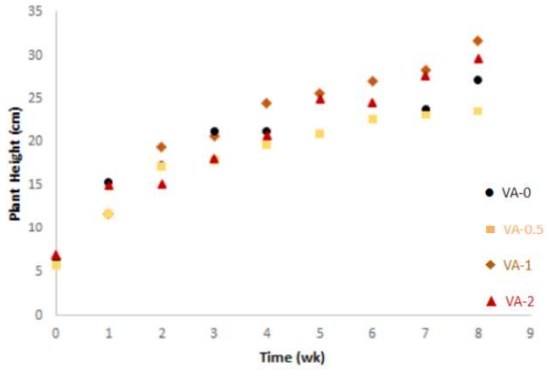
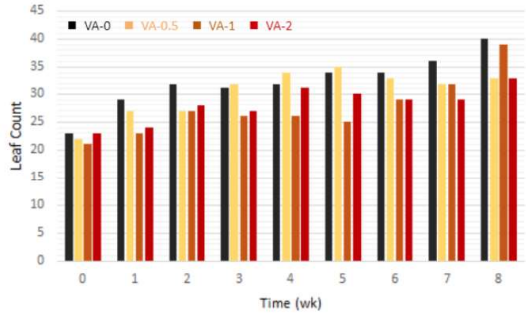


Figure 4.0. *Combined Height of Basil Plants in a Span of Eight Weeks*

3.2 Leaf Count

The basis behind including basil leaf count in the parameters is the concept of "more leaves means more sites for glucose production". The pot that ended with the highest leaf count is VA-0 ; which had 40 leaves in average of all three trials. From week 0 to week 8, there was an increase of 17 leaves. The second plant with the highest leaf count is VA-1. It had 39 leaves in average of all three trials and had an increase of ~18 leaves from week 0 to week 8. Though VA-0 ended with the highest number of leaves, it had a lower increase of leaves from initial to final as compared to VA-1. As observed, VA-1 has the highest increase of leaf count with 18 leaves, with VA-0 being second to that. The researchers hypothesized that since VA-1 is the tallest, its height had an effect on the number of leaves increased since a higher plant height equates to more exposure to sunlight. This proves that leaf count is directly related to the plant height or the amount of exposure to sunlight the plant receives.



3.3 Leaf Surface Area

Similar to the leaf count, the size of the leaf plays a role in how much glucose could actually be produced by the plant; for the main goal of this research was to prove volcanic ash's positive effects on basil's growth. At time 0, VA-1 had the highest initial leaf surface area. It was able to maintain its lead ending with a highest final leaf surface area of 24.932 cm2. VA-1 also had the highest change in leaf surface

area out of all the pots. There is a small difference between the increase in surface area from week 0 to week 8 of VA-1 and VA-2 with both numbers rounding up to 16.5 cm2. With this, we are able to say that a higher concentration of volcanic ash in the soil composition will lead to a high leaf surface area increase as compared to VA-0 and VA-0.5.

4. CONCLUSIONS

This research had the aim to shed light upon the beneficial applications of volcanic ash; which is determining whether or not volcanic ash has advantageous botanical properties that could potentially enhance the growth of Ocimum basilicum (basil). VA-1 benefitted the most from its concentration in terms of growth, the highest slope in leaf count increase, the highest plant height, and the biggest leaf surface area. With this, having a pH level of 6.1, VA-1 yields the best overall results. The results of this study indicate a positive relationship between a volcanic ash soil composition and the growth of acidic-loving plants. Specifically, 1kg of volcanic ash in loam soil has the biggest effect on the growth rate of Ocimum basilicum (Basil). Further studies can make use of different acidic-loving plants. This gives the research more space to justify the benefits of a volcanic ash composition on acidic-loving plants. Furthermore, a particular location to experiment in will benefit the results by providing uniform treatment to the plants. The gathering of ash could also be improved to achieve accurate conclusions about the correlation between acid-loving plants and the effects of volcanic ash.

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6. REFERENCES

Albert, S. (2019). How to plant, grow, and harvest basil. Harvest to Table. https://harvesttotable.com/how_to_grow_basil/

Al-Maskari, M.Y. & Hanif, Muhammad Asif & Al-Maskri, A.Y. & AlAdawi, Samir. (2012). Basil: A natural source of antioxidants and neutraceuticals.

Bilal, A. & Jahan, Nasreen & MAKBUL, SHAIKH & Bilal, S.N. & Habib, S. & Hajra, S.. (2012). Phytochemical and pharmacological studies on Ocimum basilicum. Int J Curr Res Rev. 4. 73-83.

Cash, Philip & Stanković, Tino & Štorga, Mario. (2016). An Introduction to Experimental Design Research. 10.1007/978-3-319-33781-4_1.

Dorel, M., Roger-Estrade, J., Manichon, H., & Delvaux, B. (2006). Porosity and soil water properties of Caribbean volcanic ash soils. Soil Use and Management, 16(2), 133–140. doi:10.1111/j.1475-2743.2000.tb00188.x

Fiantis, Dian & Ginting, Frisa & Gusnidar, & Nelson, M. & Minasny, Budiman. (2019). Volcanic Ash, Insecurity for the People but Securing Fertile Soil for the Future. Sustainability. 11. 3072. 10.3390/su11113072.

Grosshans, R., Viswanathan, B., Gass, P., & Grieger, L. (2019). Sustainable Watersheds for Carbon Offsets: Biomass harvesting for phosphorus capture, habitat renewal and carbon emissions reductions (pp. 14-16, Rep.). International Institute for Sustainable Development (IISD). doi:10.2307/resrep22001.6

Hamasaki, Randall & Valenzuela, Hector & Tsuda, Dick & Uchida, Janice. (1994). Fresh Basil Production Guidelines for Hawai'i.

Hossain, K.. (2006). High strength blended cement concrete incorporating volcanic ash: Performance at high temperatures. Cement and Concrete Composites. 28. 535-545. 10.1016/j.cemconcomp.2006.01.013.

J. Michael Geist. (1976). Orchardgrass Growth on Nitrogen and Sulfur Fertilized Volcanic Ash Soil. Journal of Range Management, 29(5), 415-418. doi:10.2307/3897155

Kogge, Kome & Kogge, Enang & Yerima, Bernard & Gille Raoul, Lontsi. (2018). Models relating soil pH measurements in H 2 O, KCl and CaCl 2 for volcanic ash soils of

Cameroon. Geoderma Regional. 14. e00185. 10.1016/j.geodrs.2018.e00185.

Kokkini, Stella & Karousou, Regina & HANLIDOU, Effie. (2003). HERBS | Herbs of the Labiatae. 10.1016/B0-12-227055-X/00593-9.

Lansing, John & Kremer, James & Pollard (Gerhart), Vanda & Kremer, Patricia & Arthawiguna, Alit & Surata, Sang & Suprapto, & Suryawan, Ida & Arsana, I. & Scarborough, Vernon. (2001). Volcanic fertilization of Balinese rice paddies. Ecological Economics. 38. 383-390. 10.1016/S0921-8009(01)00173-2.

McCauley, A., Jones, C., & Olson-Rutz, K. (March 2017). Soil PH and Organic Matter, 1-16.

Makri, Olga & Kintzios, Spiridon. (2008). Ocimum sp. (Basil): Botany, Cultivation, Pharmaceutical Properties, and Biotechnology. Journal of Herbs, Spices & Medicinal Plants. 13. 123-150. 10.1300/J044v13n03_10.

Moles, Angela & Warton, David & Warman, Laura & Swenson, Nathan & Laffan, Shawn & Zanne, Amy & Pitman, Andy & Hemmings, Frank & Leishman, Michelle. (2009). Global patterns in plant height. Journal of Ecology. 97. 923 - 932. 10.1111/j.1365-2745.2009.01526.x.

Nakagawa, Mitsuhiro & Ohba, Tsukasa. (2002). Minerals in Volcanic Ash 1: Primary Minerals and Volcanic Glass. 6.

Nanzyo, Masami. (2002). Unique properties of volcanic ash soils. Glob. Environ. Res.. 6.

Salamah, Siti & Maryudi, Maryudi. (2016). Utilization of Kelut's Volcanic Ash as the Aggregate Mixture of Concrete Brick. Key Engineering Materials. 718. 196-200. 10.4028/www.scientific.net/KEM.718.196.

Singletary, Keith. (2018). Basil: A Brief Summary of Potential Health Benefits. Nutrition Today. 53. 92-97. 10.1097/NT.0000000000000267.

Shoji, Sadao & Takahashi, Tadashi. (2002). Environmental and agricultural significance of volcanic ash soils. Global Environmental Research. 6.

Shoji, S., Nanzyo, M., & Dahlgren, R. (2006). Volcanic ash soils: genesis, properties, and utilization. Amsterdam: Elsevier.

Soti, P., Jayachandran, K., Koptur, S., & Volin, J. (2015). Effect of soil pH on growth, nutrient uptake, and mycorrhizal colonization in exotic invasive Lygodium microphyllum. Plant Ecology, 216(7), 989-998. Retrieved April 10, 2020, from www.jstor.org/stable/24557827

Tsuyuzaki, S., & Del Moral, R. (1995). Species Attributes in Early Primary Succession on Volcanoes. Journal of Vegetation Science, 6(4), 517-522. Retrieved April 30, 2020, from www.jstor.org/stable/3236350

Ugolini, Fiorenzo & Dahlgren, Randy. (2002). Soil development in volcanic ash. Global Environ. Res. Engl. Ed.. 6.

On the Effects of N-P-K Fertilizer to the Electricity Generated by *Aloe barbadensis miller*

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Abstract: Nowadays, electricity is a pressing conflict due to the increase in demand by the populace. Thus, energy prices have also increased, making it considerably inaccessible to several population members. Considering this, the researchers have studied the type of N-P-K fertilizer that can improve the efficiency of producing electricity from a living plant. There were four experimental setups of Aloe barbadensis miller that were utilized in the experiment. Every variable and component of each setup was constant, except the type of fertilizer that was added to the soil. The first setup did not have any fertilizer, the second group had Nitrogen-based (N-P-K 21:0:0), the third group had Phosphorus-based (N-P-K 0:22:0), and the fourth group had Potassium-based (N-P-K 0:0:50). The researchers gathered data on electricity generated in the Aloe vera derived from a capacitor using a multimeter every 12 hours for 16 days. Descriptive statistics and repeated measures of ANOVA statistical tests were utilized to perform the data analysis. Results showed that the setup with potassium-based fertilizer had produced significantly greater electricity ($p < .05$) among the four setups whose differences were insignificant ($p > .05$). Time had a moderate but negligible effect on the electricity produced by the Aloe vera. It is advised to increase the time taken to observe the plant if further research will be done on the topic.

Key Words: aloe vera; electricity generation; nitrogen-based fertilizer; phosphorus-based fertilizer; potassium-based fertilizer

1. INTRODUCTION

Electricity has become an integral part of human life in the modern era. It affects one's capability of acquiring education, communicating with others, and cooking food without destroying the ecosystem (Löfquist, 2020). In the Philippines, electricity has become a necessity in every household due to the importance of electrical appliances as assets to most of the population (Reyes et al., 2012). Yet, over 2.3 million homes in the Philippines still lack access to electricity (National Electrification Administration, 2019), and 59 million people in the country have no access to clean cooking (Renewable Energy Policy Network for the 21st Century, 2020).

Considering the insufficient electricity supply, previous research utilized accessible natural resources, such as plants, to create potential energy sources. Ying and Dayou (2016) found that plants can generate electricity by transmuting sunlight into electricity based on photosynthesis. The study shows the conversion of chemical energy to electrical energy by embedding a pair of electrodes into the plant's leaves. Bundschuh, Yusaf, Maity, Nelson, Mamat, and Mahlia (2014) studied the capability of algae-biomass being used as fuel for electricity and agriculture. This source was expected to provide a new power generation system for the low-power electrical equipment used in forestry. However, the voltage was weak which caused great difficulty in the application. Despite these previous studies concerning generating sustainable energy, they have only been able to generate sustainable energy with low voltage.

The objective of this study is to create sustainable energy from organic life and to produce an adequate amount of electricity. Previous studies have shown that generating sustainable energy from living plants is possible; however, it cannot naturally produce an adequate amount of electricity that can be used instantaneously (Bundschuh et al., 2014). Thus, the researchers of this study will examine which of the different N-P-K fertilizers will improve the efficiency of energy production of the plant.

2. Literature Review

Figure 1. *Conceptual Framework of the Study*

Figure 1 presents the possibility of how the different N-P-K fertilizers may directly affect the electricity generated by the *Aloe vera* plant. It is known that the primary nutrients of the fertilizer – Nitrogen, Phosphorus, and Potassium – directly influence the plant's process of photosynthesis (Bolfarini et al., 2016; Gierth & Mäser, 2007). Since ATP, the energy of the plant, is produced in the photosynthesis process, the N-P-K can possibly have a significant effect on the electricity produced by plants. This study aims to see whether plants can produce enough electricity when N-P-K fertilizer is added to their soil.

Specifically, the study aims to answer the following:

a. What is the electricity produced by the *Aloe vera* plants after introducing the N-P-K fertilizers for 16 days?

b. Is there a significant difference in the electricity produced by the *Aloe vera* plant with different N-P-K fertilizers observed in a 48-hour interval for 16 days?

2. METHODOLOGY

2.1. Research Design

The experimental research design was suitable for this study since it required experimentation on the electricity produced by plants in response to the added N-P-K fertilizers with varied ratios of Nitrogen, Phosphorus, and Potassium.

3.2. Data Gathering Procedures

Before data gathering, the researchers accomplished a Research Ethics Checklist and letter of approval. Once approved, they began with the acquisition of materials sourced from online stores. In this experiment, the four Aloe vera samples, sourced from a mother plant from a farm, were divided into four experimental setups. The first setup, the control group, was treated with no fertilizer. For the second, Nitrogen-based fertilizer (N-P-K 21:0:0) was treated to the plant. For the third, Phosphorus-based fertilizer (N-P-K 0:22:0) was added. Lastly, the fourth setup was treated with Potassium-based fertilizer (N-P-K 0:0:50).

Figure 2. Experimental setups (from left to right: Nitrogen-based, Potassium-based, Phosphorus-based, No fertilizer)

As shown in Figure 2, each setup had six pairs of Zinc (Zn) anode and Copper (Cu) cathode embedded on two leaves of the Aloe vera plant (Chong et al., 2019). A 4.7 uF 400V Aluminum Electrolytic capacitor was connected to store the electricity generated by the plants. A digital multimeter was used to measure the voltage stored in the capacitor. It was set to have a maximum measurement of 2.000 Volts.

Upon completing the experimental setups, the researchers began recording the electricity generated by each experimental design using the digital multimeter connected to the capacitor. The recording of observations occurred every 12 hours within 16 days. Throughout the experimentation, the plants were watered regularly and were exposed to sunlight to maintain its prime condition.

After obtaining all needed observations, the researchers began to organize their raw data in preparation for the data analysis.

3. RESULTS AND DISCUSSION

Two primary data analysis procedures were performed using IBM SPSS version 24. The first is Descriptive statistics (Mean and Standard Deviation), which was used to find the average electricity produced by the sample per setup. The second is repeated measures of Analysis of Variance, which was used to determine if there is a significant difference between the setups as time passes.

3.1. What is the electricity produced by the Aloe vera plants after introducing the N-P-K fertilizers for 16 days?

Table 1. Descriptive Statistics of Electricity Produced by Aloe vera plants treated with different N-P-K fertilizers

		No Fertilizer		Nitrogen-based		Phosphorous-based		Potassium-based	
Time	N	M	SD	M	SD	M	SD	M	SD
1	4	1.266	.596	1.383	.082	1.393	.585	1.092	.503
2	4	1.076	.485	1.302	.352	1.447	.168	1.234	.156
3	4	1.456	.143	1.016	.671	1.523	.346	1.614	.13
4	4	1.555	.052	1.353	.211	1.227	.087	1.622	.081
5	4	1.079	.107	1.253	.02	1.009	.065	1.512	.099
6	4	1.052	.067	1.369	.121	1.033	.025	1.39	.062
7	4	1.412	.148	1.422	.185	1.237	.145	1.476	.097
8	4	1.148	.034	1.198	.07	1.171	.063	1.387	.078

Table 1 presents the electricity generated by the Aloe vera plants treated with different N-P-K

fertilizers observed in a 48-hour time interval. A total of 128 valid cases were examined with an equal number of recorded observations per N-P-K fertilizer type (4).

The visualization of the differences in the electricity produced in each setup is shown below:

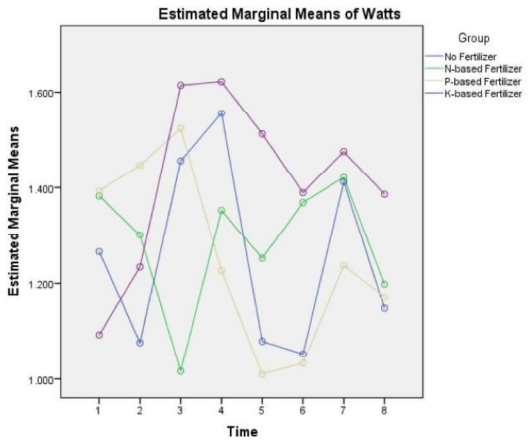

Figure 3. Means Plot of Estimated Marginal Means of Watts

As shown in Figure 3, the electricity produced by the majority of fertilizer groups tended to hit their peaks between and around the end of the second and third intervals, with the outlier being the nitrogen-based fertilizer hitting the rise between the sixth and seventh-time interval. A previous study concluded that organic sources of fertilizer helped improve the quality of the Aloe vera (Saha et al., 2003). This shows that by improving the quality of the plants with fertilizer, the generated electricity by the plant increased.

The P-based fertilizer setup produced the most electricity throughout the first and second-time intervals with a continuous rise in electricity production. Phosphorus contributes largely to plant product yield in agriculture since it influences the plant's ability to utilize water in its system and other micronutrients in the plant's soil (Valkama et al., 2009). However, it also decreases the Nitrate stored in the plant (Wang & Li, 2004). With this, the plant is likely to have been influenced by having more nutrients and water to utilize.

The K-based fertilizer setup produced the most electricity among the four setups during the third-time interval and onwards. Potassium in plants increases the rate at which the plant with damage repairs itself and maintains the ionic homeostasis (Wang et al., 2013). The nature of the experiment setup made the K-based fertilizer's role more significant since the plants became weak to hold the copper and zinc plates for as long as they had. Additionally, the level of K in the soil could influence the plant's uptake of N-P-K elements in the ground (Baque et al., 2006).

5.2. Is there a significant difference in the electricity produced by the Aloe vera plant with different N-P-K fertilizers observed in a 48-hour interval for 16 days?

The analysis of the results generated by the Repeated Measures of ANOVA is presented in two ways. The discussion of the assumptions is given first, then followed by the main outcome.

Table 2. *Normality Test*

	Kolmogorov-Smirnov[a]		
	Statistic	df	Sig.
t1	.172	16	.200*
t2	.164	16	.200*
t3	.179	16	.179
t4	.189	16	.129
t5	.155	16	.200*
t6	.240	16	.014
t7	.079	16	.200*
t8	.170	16	.200*

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

The normality test was performed using Kolmogorov-Smirnov, and Table 2 shows that the collected data for the seven observations are normal ($p > 0.05$) except during time 6 ($p = 0.014$).

Table 3. *Mauchly's Test of Sphericity[a]*

Measure: Electricity Generated							
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Time	.000	88.714	27	.000	.381	.622	.143

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a. Design: Intercept + Group
Within Subjects Design: Time
b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Sphericity is a condition where the variances between the differences between the related groups are equal. And since the Repeated Measures of ANOVA is susceptible to violating this assumption, Mauchly's Test of Sphericity was performed and shown in Table 3. Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi 2(27) = 88.714$, $p < .0005$, and therefore, a Greenhouse-Geisser correction was used since $\epsilon < 0.75$.

Table 4. *Tests of Within-Subjects Effects*

Measure: Electricity Generated							
Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Time	Sphericity Assumed	.956	7	.137	1.895	.080	.136
	Greenhouse-Geisser	.956	2.666	.358	1.895	.156	.136
Time * Group	Sphericity Assumed	2.534	21	.121	1.675	.052	.295
	Greenhouse-Geisser	2.534	7.999	.317	1.675	.143	.295
Error (Time)	Sphericity Assumed	6.052	84	.072			
	Greenhouse-Geisser	6.052	31.995	.189			

Partial eta squared can be cited as a measure of effect size: f^2 is Cohen's effect size: .02 = small, .15 = moderate, .35 = large.

Also, there was no significant effect of time on the generated electricity by Aloe vera with different N-P-K fertilizers, $F(2.666, 31.995) = 1.895$, $p > 0.05$.

Table 4 presents that the use of fertilizer had a nearly moderate effect on the electricity generated by the Aloe vera over time (partial $\eta 2 = 0.136$); however, this is not significant $F(2.666, 31.995) = 1.895$, $p > 0.05$.

The significance of time to the affected electricity caused by the addition of different N-P-K fertilizers ratios is likely because the time of the experiment was too short. The total number of days taken to conduct the experiment in other related studies is greater compared to this. A study by Lazcano, Gómez-Brandón, Revilla, and Domínguez (2012) had three months of fertilizer exposure for the plant before data gathering, considered as 'short-term'. Another study by Valkama, Uusitalo, Ylivainio, Virkajärvi, and Turtola (2009) had up to twelve months of application of fertilizer. Another independent research by Saïdou, Janssen, and Temminghoff (2003) had three years to test the effects of the fertilizer on the plants. Based on these three studies, the time of experimentation was significantly shorter than the aforementioned studies.

Table 5. *Tests of Between-Subject Effects*

Measure: Electricity Generated
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	217.408	1	217.408	5026.975	.000	.998
Group	.561	3	.187	4.326	.028	.520
Error	.519	12	.043			

Partial eta squared can be cited as a measure of effect size: f^2 is Cohen's effect size: .02 = small, .15 = moderate, .35 = large.

Table 5 presents that there is a significant difference in the electricity generated by Aloe vera when treated with different fertilizers, $F(2.666, 31.995) = 1.895$, $p < 0.05$. The effect of the differences in the fertilizers applied to the soil where the Aloe vera is planted is large (partial $\eta 2 = 0.520$).

Table 6. *Multiple Comparisons*

Measure: Electricity Generated
LSD

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
No Fertilizer	N-based Fertilizer	-.03122	.051991	.559	-.14450	.08206
	P-based Fertilizer	.00053	.051991	.992	-.11275	.11381
	K-based Fertilizer	-.16025*	.051991	.009	-.27353	-.04697
N-based Fertilizer	P-based Fertilizer	.03175	.051991	.553	-.08153	.14503
	K-based Fertilizer	-.12903*	.051991	.029	-.24231	-.01575
P-based Fertilizer	K-based Fertilizer	-.16078*	.051991	.009	-.27406	-.04750

Based on observed means.
The error term is Mean Square (Error) = .005.
**. The mean difference is significant at the .05 level.*

Post-hoc Test using LSD was performed to determine which of the N-P-K fertilizers show a significant difference in the electricity generated by Aloe vera. As shown in Table 6, only the following different N-P-K fertilizers show a significant difference: No fertilizer and K-based fertilizer, N-based fertilizer and K-based fertilizer, P-based Fertilizer and K-based fertilizer, $p < .05$.

Previous studies have studied the effect of potassium on the plant. Grzebisz, Gransee, Szczepaniak, and Diatta (2013) experimented with the effects of potassium fertilization on water supplies and nitrogen to a plant during its critical stages of growth. The plant's access to potassium during mild water-deficiency stress stimulates water uptake through the root cells. This results in an extension of development, giving it access to various mineral elements such as nitrogen and water, which are essential for plant growth. Wang, Zheng, Shen, and Guo (2013) found that potassium (K) has several biological components that strengthen the plant's growth and metabolism. Lower K concentrations can further depress the plant resistance to drought stress and K absorption; this is due to its weakness in terms of water uptake. One of the advantages, as discussed in the study, is that it stimulates photosynthesis. It also regulates protein synthesis, enhances damage repair and water uptake, and maintains ionic homeostasis.

4. CONCLUSIONS

This study discovered the significant relationship of potassium to the electricity produced by the plant. Yet, the researchers cannot discern the effect that fertilizer would have on electricity throughout a specific period. Despite these findings, there are numerous limitations to this study. The data gathering period for the researchers was only limited to 16 days because of time constraints. Moreover, each experimental setup utilized only one Aloe vera sample. Hence, the results of the research may not have been precise.

Furthermore, other variables that may have affected the Aloe vera plant's electrical yield were not observed and manipulated. This includes the condition of the environment, weather, material of the electrodes, plant type, and soil type. The researchers recommend that the duration of experimentation be conducted for a more extended period. Studying fertilizers with other N-P-K ratios with more potassium content can provide more information on the specific type of fertilizer that could generate a significantly more tremendous amount of energy. Future studies may research other possible factors that may affect and improve the efficiency of electricity generation in plants.

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6. REFERENCES

Baque, M. A., Karim, M. A., Hamid, A., & Tetsushi, H. (2006). Effects of fertilizer potassium on growth, yield and nutrient uptake of wheat (Triticum aestivum) under water stress conditions. South Pacific Studies, 27(1), 25-35.

Bolfarini, A. C. B., Leonel, S., Leonel, M., Tecchio, M. A., Silva, M. D. S., & Souza, J. M. A. (2016). Growth, yield and fruit quality of 'Maçã' banana under different rates of phosphorus fertilization. Australian Journal of Crop Science, 10(9), 1368–1374. doi: 10.21475/ajcs.2016.10.09.p7892.

Bundschuh, J., Yusaf, T., Maity, J. P., Nelson, E., Mamat, R., & Mahlia, T. I. (2014). Algae-biomass for fuel, electricity and agriculture. Energy, 78, 1–3. doi: 10.1016/j.energy.2014.11.005.

Chong, P.L., Singh, A.K., Kok, S.L. (2019) Characterization of Aloe Barbadensis Miller leaves as a potential electrical energy source with optimum experimental setup conditions. PLOS ONE 14(6): e0218758. https://doi.org/10.1371/journal.pone.0218758

Gierth, M., & Mäser, P. (2007). Potassium transporters in plants - Involvement in K+acquisition, redistribution and homeostasis. FEBS Letters, 581(12), 2348–2356. doi:10.1016/j.febslet.2007.03.035.

Grzebisz, W., Gransee, A., Szczepaniak, W. and Diatta, J. (2013), The effects of potassium fertilization on water-use efficiency in crop plants. Z. Pflanzenernähr. Bodenk., 176: 355-374. https://doi.org/10.1002/jpln.201200287.

Lazcano, C., Gómez-Brandón, M., Revilla, P., & Domínguez, J. (2012). Short-term effects of organic and inorganic fertilizers on soil microbial community structure and function. Biology and Fertility of Soils, 49(6), 723–733. doi:10.1007/s00374-012-0761-7.

NEA (2019). NEA'S 2020 PROPOSED BUDGET TO CONTINUE FUNDING ELECTRIFICATION PROJECTS. Retrieved from https://www.nea.gov.ph/ao39/458-nea-s-2020-proposed-budget-to-continue-funding-electrification-projects-masongsong.

REN21 (2020). Renewables 2020 Global Status Report. REN21 Secretariat, Paris.

Reyes, C. M., Tabuga, A. D., Asis, R. D., & Datu, M. B. G. (2012). Poverty and agriculture in the Philippines: Trends in income poverty and distribution. PIDS DPS, (2012-09).

Saha, R., Palit, S., Ghosh, B. C., & Mittra, B. N. (2003). Performance of Aloe vera as influenced by organic and inorganic sources of fertilizer supplied through fertigation. In III WOCMAP Congress on Medicinal and Aromatic Plants-Volume 2: Conservation, Cultivation and Sustainable Use of Medicinal and 676 (pp. 171-175).

Saïdou, A., Janssen, B. ., & Temminghoff, E. J. . (2003). Effects of soil properties, mulch and NPK fertilizer on maize yields and nutrient budgets on ferralitic soils in southern Benin. Agriculture, Ecosystems & Environment, 100(2-3), 265–273. doi:10.1016/s0167-8809(03)00184-1.

Valkama, E., Uusitalo, R., Ylivainio, K., Virkajärvi, P., & Turtola, E. (2009). Phosphorus fertilization: A meta-analysis of 80 years of research in Finland. Agriculture, Ecosystems & Environment, 130(3-4), 75–85. doi:10.1016/j.agee.2008.12.004.

Wang, M., Zheng, Q., Shen, Q., & Guo, S. (2013). The Critical Role of Potassium in Plant Stress Response. International Journal of Molecular Sciences, 14(4), 7370–7390. doi:10.3390/ijms14047370.

Wang, Z., & Li, S. (2004). Effects of Nitrogen and Phosphorus Fertilization on Plant Growth and Nitrate Accumulation in Vegetables. Journal of Plant Nutrition, 27(3), 539–556. doi:10.1081/pln-120028877.

Ying, C. Y., & Dayou, J. (2016). Modelling of the electricity generation from living plants. Jurnal Teknologi, 78(6).

A Life Cycle Assessment of Disposable Medical Masks and its Impacts Towards the Environment in the Context of the COVID-19 Pandemic

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Abstract: This study is about the Life Cycle Assessment of Disposable Medical Masks and its Environmental Impacts in the context of the COVID-19 pandemic in the Philippines. Prior to the study, the researchers have noticed that there was an increase in demand for disposable medical masks as a response to the COVID-19 pandemic. The overall objective of the study was to assess the environmental impacts of the life cycle of disposable medical masks in the context of three variables which are energy consumption, waste production, and pollution. The impacts were assessed using related literature and gathered data from respective respondents through the dissemination of online questionnaires among 5 different focus groups. The results from the surveys have shown that the production of healthcare waste has doubled in the past year and is mainly composed of disposable medical masks. In addition, answers from the surveys have shown that the majority of households improperly dispose of their masks by not complying with the set guidelines of the Department of Health. After data collection and discussion, the researchers have observed the connections between the increase in demand for masks and the damaging of the environment in relation to the three variables. To conclude, the researchers have disproved the initial null hypothesis.

Key Words: life cycle assessment; disposable medical mask; environmental sustainability; Personal Protective Equipment; COVID-19

1. INTRODUCTION

1.1 Rationale

At the beginning of the pandemic, the world turned its focus to prioritizing safety and health that the state of the environment was neglected. With this, many environmental advocates and organizations have been bringing attention to the rise in energy consumption from the production and disposal of medical masks. In addition, a more pressing environmental concern was brought up due to the improper disposal of medical masks. After use, the mask cannot be recycled due to the risk of contamination therefore, it is needed to be disposed of (Parkinson, 2020). Without proper disposal, masks end up in landfills and even in the ocean causing damage to marine life and worsening the issue of general pollution (Kassam, 2020). The several issues brought up by these articles show the overall severity of the environmental situation caused by disposable medical masks.

1.2. Statement of the Problem

The study assessed the Life Cycle of Disposable Medical Masks and its Impacts towards the environment in the context of the COVID-19 pandemic.

Specifically, the research answered the following questions:

1. What is the Life Cycle of Disposable Medical Masks?
2. What are the proper and improper methods/processes in the disposal of medical masks?
3. What are the impacts of the production processes of disposable medical masks towards the environment?
    a. Energy consumption
    b. Production waste
4. What are the impacts of the disposal of disposable medical masks towards the environment?
    a. Energy consumption
    b. Waste production
    c. Pollution

1.3. Hypothesis

The increasing rate of utilization of disposable medical masks has no significant impact towards the environment in the context of the COVID-19 pandemic.

2. METHODOLOGY

2.1. Type of Research and Research Design

A descriptive research design was chosen to show the analysis of the life cycle of the masks in determining its effects towards the environment. It was used to justify the presented realities which were obtained through the answered survey forms of the chosen respondents in relation to the LCA of disposable medical masks.

2.2. Samples and Sampling Technique

To select respondents for data collection in the LCI phase, the researchers have utilized a convenience sampling technique. This was used because of the lack of availability of the respective respondents given the ongoing COVID-19 pandemic. Each focus group consisted of a certain number of respondents, again, depending on the availability of respondents in the ongoing pandemic disregarding the factors of age and sex. The five focus groups were based on their profession and expertise in the main focus of this research: environmentalists, medical practitioners, waste management officers, mask consumers and mask distributors.

The first focus group consists of environmentalists required to have knowledge about key environmental issues such as waste pollution and overconsumption of energy. The second focus group consists of medical practitioners with a minimum of 5 years of experience serving in their medical field and knowledge about the coronavirus. The third focus group is composed of waste management officers with respective expertise on the presence of waste pollution and waste production, specifically in terms of PPE, perspectives, and data regarding PPE pollution and the environmental effects of the disposal process. The fourth focus group is composed of mask distributors willing to disclose information regarding their rates of supply and demand of sales with respect to the ongoing COVID-19 pandemic. Lastly, the fifth focus group was mask consumers utilizing disposable medical masks as a preventive measure from getting the virus; their questions were focused on their rate of consumption on a monthly basis and their disposal process after usage.

2.3. Research Instrumentations

The researchers utilized five different surveys wherein one was adapted from past studies to gather and collect data. The first survey was a five-item questionnaire given to environmentalists created by the researchers to gather information about effects caused by the life cycle of disposable medical masks from an environmental perspective.

The second instrument given to medical practitioners was a seven-item survey to understand the purpose and effectiveness of a mask in hindering the spread of the COVID-19 virus. The third instrument is a seven-item survey disseminated among mask sellers which focuses on the rate of sales of different types of masks in Metro Manila during the COVID-19 pandemic. The fourth instrument was a five-item survey focused on the consumption rate of masks and means of their disposal which is administered to mask consumers in Metro Manila. This survey was focused on their consumption rate of their preferred types of masks and their means of disposal after usage.

The last survey that was given to HCWM officers was an adapted and shortened version of the Health-Care Waste Management Rapid Assessment Tool. This was developed by the WHO, and its goal is to promote safe and appropriate practices in the field of HCWM ("Health-care waste management rapid assessment tool", 2016). Its purpose is to understand the processes and the overall situation regarding the HCWM system.

2.4. Procedures

Preparation of Adapted Survey Questionnaire
The researchers designed a survey fit to the specifications of the study which highlighted the given variables, and this was done specifically for the respondents under the category of medical practitioners and environmentalists. Aside from the designed surveys which have been disseminated to medical practitioners, environmentalists, mask distributors, and mask consumers, an adapted Health Care Waste Management (HCWM) assessment was utilized for the chosen Waste Management Officers. Afterward, a confidentiality conforme has been made for respondents to be assured of the compliance towards the Data Privacy Act of 2012, to be signed prior to answering the designed survey.

Administration of the test to the respondents

Firstly for the chosen available medical practitioners, environmentalists, mask distributors, mask consumers, and waste management officers, all were given a confidentiality conforme to answer prior the survey. Afterwards, questionnaires were administered to the respondents.

2.5 Statistical Treatment

The researchers made use of Descriptive Statistics as its statistical treatment in this study. It was used to thoroughly describe and indicate the manners on how the life cycle of disposable medical masks impact the environment, specifically in the context of the COVID-19 pandemic. Through the obtained data, the statistical analysis of this was focused on the evaluation of the answers of the respondents and used as one of the basis of the

conducted study.

3. RESULTS AND DISCUSSION

3.1 Problem 1

What is the life cycle of a disposable medical mask?

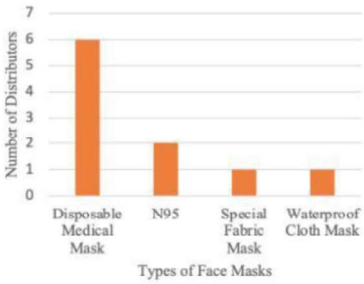

Figure 1. Types of Face Masks Sold

There are three main phases of the life cycle of disposable medical masks: production, usage, and disposal. The researchers decided to give focus to only the production and disposal phases. Within the production phase, there are four sub-processes that occur accordingly: (1) Acquisition of raw materials, (2) Transportation of materials, (3) Production line, (4) Distribution to the sellers. The generic type of surgical face masks that 85.7% of all respondents from the distributors' focus group sell are commonly made up of 3 non-woven layers (see figures 1 and 2) which all serve a purpose in providing the mask's filtration efficiency. These layers are produced in one of two procedures: spun bond or melt-blown (Chua et al, 2020).

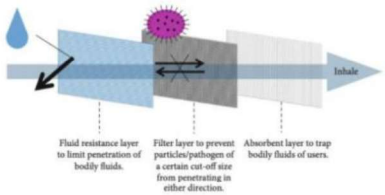

Figure 2. *Layers of a Disposable Medical Mask (Chua et al., 2020)*

In the disposal phase of the cycle, 6 sub-processes occur accordingly: (1) Initial segregation, (2) Storage, (3) Collection, (4) Transportation, (5) Treatment, (6) Final Disposal (DENR-EMB, 2020). The first process is the most crucial since it decides whether the HCW will undergo proper disposal or not. As seen in figure 3, results from the surveys showed that 71.4% of HCW are disposed of in the wrong waste container. The other 29.6% get stored and transported by DENR certified transportation companies to treatment facilities.

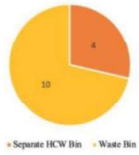

Figure 3. *Disposable Methods of Medical Practitioners and Consumer*

All the results and discussions done under this research problem can be consolidated into figure 4.1 and 4.2.

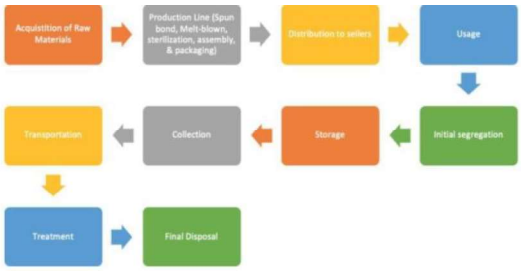

Figure 4.1. *Life Cycle of Disposable Medical Masks*

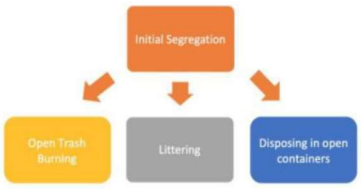

Figure 4.2 *Improper Disposal Method of Disposable Medical Masks*

3.2. Problem 2

What are the proper and improper methods/processes in the disposal of medical masks?

One respondent observed that the most common yet improper means of disposal include open trash burning, littering, and disposal in open-containers (figure 4.2). Each method creates their own negative effect on the state of the environment. Out of these three, the one that was frequently admitted by the survey respondents was the disposal in open-containers as seen in table 1. The waste coming from this process often ends up in open and unsecured dumping grounds which have become a commonplace for households to recover and recycle the objects found (Ferronato & Torretta, 2019). The continuation of these practices causes infections and viruses to be spread more rapidly.

3.3. Problem 3

What are the impacts of the production processes of disposable medical masks towards the environment?

Table 1. Improper Disposal Methods of Consumers and Medical Practitioners

Consumer/Medical Practitioner	Disposal Methods of Medical Masks
Consumer 1	"Put it in a bin filled with used masks"
Consumer 2	"I just throw it in the trashcan"
Consumer 3	"we just throw it in the trash can"
Consumer 4	"Usually, they are placed in our non-biodegradable waste basket after the straps/elastic has been cut off."
Consumer 5	"I throw them in my trash bin just like normal trash."
Consumer 6	"We cut it in the middle and roll it up before tossing it in the trash"
Consumer 7	"Honestly, I just throw it in the nearest trash bin."
Consumer 8	"By throwing it in the garbage."
Medical Practitioner 1	"Tear and throw in wastebasket"
Medical Practitioner 2	"for surgical mask put it in a garbage can but for special mask like Philips Fresh air mask with N95 clean it with alcohol and the n95 component can be replace after more than 5 usage"

As presented in figure 4, 92.9% of masks in the distributor's inventory is sold and this leads to the increase of product demand from consumers and suppliers.

To further discuss, two t-test: Two-Sample Assessing Unequal Variances was utilized to analyze the relationship between mask distributors and consumers. First, it computed a value of P(t<=t)=0.697503595 which shows there is no significant difference between the two variables; this indicates the increase of sales of masks because of the demand and need of the product in the context of the pandemic. Second, a value of P(t<=t)=0.500136489 indicates the significant difference between the targeted amount of sales and supplies. This implies the gap between the masks being supplied to distributors and consumed by the general public; there is a possible overproduction of masks which can create waste. As said by a mask distributor, the shelf life of a mask lasts from 3-5 years before considered "expired" or ineffective of use. The excess in inventory can lead to the expiration of product and ineffective usage.

3.4. Problem 4

What are the impacts of the disposal of disposable medical masks towards the environment?

The usage of disposable medical masks is the most effective type to be used as a preventive measure for the virus because of the filtration from the exposure of aerosol spray with proper usage. Although according to figure 5, the usage also required proper disposal after usage as a health precaution, yet PPE is not classified under waste disposed of using proper methods of disposal.

Figure 5. *The Division of Waste Undergoing Proper and Improper Treatment according to Environmentalists*

The improper disposal of these disposable medical masks results in certain aspects in energy consumption, waste production, and pollution which lead to severe repercussions that negatively affect the environment.

Energy Consumption

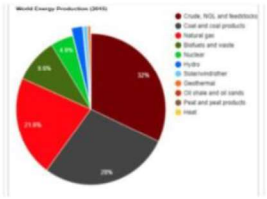

Figure 6. *Energy Production and Usage as of 2015 (Hanania et al., 2020)*

Based on figure 6, the second most utilized is non-renewable energy such as coal/coal products which are used to generate electricity that runs the technology to properly dispose of clinical waste, and with the increase of usage, the required energy is bound to have a direct relationship as well.

Waste Production

The improper disposal has led to the increase of waste in relation with the rate of demand and supply of PPE, and the added criteria of usage and disposal of this mask. The 3-ply masks are only effective up to six hours of usage then a replacement is needed. With the given condition, each individual consuming these masks must comply for maximum protection.

Especially for frontliners and the general public who are constantly exposed to the possibility of being infected. This circumstance has led to the doubling of healthcare waste wherein most do not undergo proper disposal.

Pollution

With the increase of the rate of waste production, 100% of these wastes are categorized to undergo the improper disposal (refer to figure 5). Under the category of improper waste, one specific process evident amidst the pandemic is discarding of masks in landfills which is shown to be borderline sustainable (refer to figure 7).

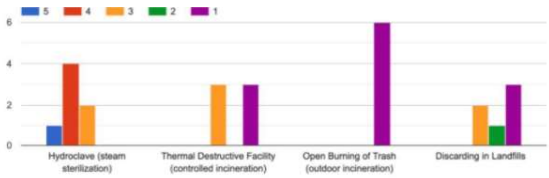

Figure 7. *Level of Sustainability of Various Disposal Processes according to Environmentalists*

Referring to figure 8, the disposal process of these medical masks greatly impact the environment in terms of pollution and this is highly evident in the present context of the improper disposal of masks.

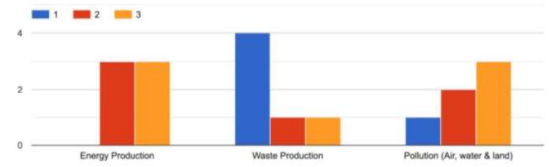

Figure 8. *Casualties of Environmental Issues regarding the Life Cycle of Disposable Masks (1 - highest impact and 3 equivalents to the latter)*

As seen in figure 9, the disposal process of the medical masks is the least sustainable portion of the life cycle and this is because of the three factors which are energy consumption, waste production and pollution as explained respectively.

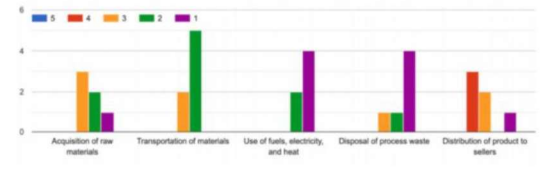

Figure 9. *Sustainability of each Process in the Life Cycle of Medical Masks (5 equivalents to being the most Sustainable and 1 equivalents to the latter)*

4. CONCLUSIONS

4.1. Summary of Findings

The following are the summary of the results that the researchers gathered from the surveys of the study:

Disposable medical masks are the most utilized type of mask for the prevention of COVID-19 to spread. Therefore, 85.7% of mask distributors focus their attention on selling disposable medical masks as compared to cotton masks, N95's, and etc.

The production rate of disposable medical masks is higher than the consumption rate of the general public of this product. Therefore, the likeliness of product expiration is higher.

Among the mask consumers and medical practitioners, 71.4% of respondents improperly dispose of their medical face masks by placing them in regular waste bins rather than special color-coded waste bins specifically meant for healthcare waste.

A total of 100% in the HCWM officer focus group agree that open burning, littering, and disposal in open landfills are common improper means of disposal. The most sustainable process, yet still improper out of the three is littering.

In terms of waste production, the usage of disposable medical masks in the ongoing pandemic has been a factor leading to the increase of medical waste by 100%.

A total of 66.7% of environmentalists agree that the overall life cycle of disposable medical masks has the most impact on waste production, while 16.7% mentioned pollution received the highest impact.

4.2. Conclusions

The following conclusions are drawn based on the summary of findings:

While there is no significant difference between the number of masks sold and consumed, there is a significant difference between the number of masks supplied to these distributors and their sales.

The overall life cycle gravely impacts environmental issues such as waste production, pollution, and energy consumption (arranged from most impacted to least impacted)

Most processes involved in the life cycle of disposable medical masks compromise the environmental sustainability of the product.

4.3. Recommendations

Having considered the summary of findings and conclusions in this chapter, the following recommendations are forwarded:

Future researchers are advised to look into and compare disposable medical masks to other variants to assess the suitability for prevention in the COVID-19 pandemic. In addition, to give medical disposable masks a point of comparison in terms of environmental sustainability.

To have a stronger foundation of data and information, the researchers suggest making use of a wider range of participants particularly in the HCWM

officers and mask manufacturers.

As brought up by one mask distributor, it is recommended to focus on the different levels of mask quality with regards to their respective price ranges to have an understanding of the value of materials involved in the life cycle assessment and to make an informative decision upon purchase.

Due to the lack of time and resources under the circumstance of the ongoing COVID-19 pandemic, the researchers advise to conduct an experiment in order to obtain empirical data and make use of this research paper as preliminary paper to further back up future results and findings.

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6. REFERENCES

2019 Novel Coronavirus. (2019). Who.Int. https://www.who.int/emergencies/diseases/novel-coronavirus-2019

Ansale, N. C. (2020). DENR REMINDS THE PUBLIC AGAINST BURNING OF THEIR GARBAGE. Denr.Gov.Ph. https://r8.denr.gov.ph/index.php/news-events/press-releases/1359-denr-reminds-the-publi c-against-burning-of-their-garbage

Ashifa, K. (2020). "More masks than jellyfish": coronavirus waste ends up in the ocean. The Guardian; The Guardian. https://www.theguardian.com/environment/2020/jun/08/more-masks-than-jellyfish-coron avirus-waste-ends-up-in-ocean

Barr, S., & Gallagher, S. (2020,). The new plastic bottle? How to dispose of face masks in an environmentally-safe way. The Independent. https://www.independent.co.uk/life-style/face-masks-coverings-dispose-throw-away-safe -environment-litter-single-use-a9612946.html

Batino, C., & Karunungan, L. (2020). Philippines Virus Cases Top 80,000; Singapore Exceeds 50,000. Bloomberg.Com, N.PAG-N.PAG. https://www.bloomberg.com/news/articles/2020-07-26/philippines-viru cases-top-80-000-singapore-exceeds-50-000

Batino, C., Jiao, C., & Aditya, A. (2020). Doctors See High Mortality in Virus Fight in Philippines, Indonesia. Bloomberg.Com, N.PAG-N.PAG https://www.bworldonline.com/doctors-see-high-mortality-in-virus-fight-in-philippines/indonesia/

Bernadas, J., & Ilagan, K. (2020). Journalism, public health, and COVID-19: some preliminary insights from the Philippines. Media International Australia, 177(1), 132–138. https://doi.org/10.1177/1329878x20953854

Bueza, M. (2020). IN CHARTS: COVID-19 cases in the Philippines. Rappler; Rappler. https://www.rappler.com/newsbreak/iq/charts-coronavirus-covid-19-cases-philippines

Bussemaker, N., & Felter, C. (n.d.). Which Countries Are Requiring Face Masks? Council on Foreign Relations. https://www.cfr.org/in-brief/which-countries-are-requiring-face-masks

Cabico, G. (2020). "Earth not healing": Medical waste piles up as COVID-19 cases rise. Philstar.com; Philstar.com. https://www.philstar.com/headlines/2020/08/15/2034986/earth-not-healing-medical-waste -piles-covid-19-cases-rise

Calonzo, A., & Lopez, D. (2020). Philippines Lets Malls Reopen Further While Virus DeathsRise— Bloomberg.https://www.bloomberg.com/news/articles/2020-10-05/philippines-lets-malls-reopen-furt her-while-virus-deaths-rise

Calonzo, A., & Lopez, D. (2020). Philippines Keeps Loose Covid Curbs in Capital Next Month. Bloomberg.Com, N.PAG-N.PAG. https://www.bloomberg.com/news/articles/2020-10-27/philippine-keeps-loose-covid-curb s-in-capital-through-november

CDC. (2020). Healthcare Workers. Centers for Disease Control and Prevention. https://www.cdc.gov/coronavirus/2019-ncov/hcp/non-us-settings/emergency-consideratio ns-ppe.html

Chua, M., Cheng, W., Goh, S., Kong, J., Li, B., Lim, J., Mao, L., Wang, S., Xue, K., Yang, L., Ye, E., Zhang, K., Cheong, W., Tan, B., Li, Z., Tan, B., & Loh, X. (2020). Face Masks in the New COVID-19 Normal: Materials, Testing, and Perspectives. Research, 2020, 1–40. https://doi.org/10.34133/2020/7286735

Cook, J., Nuccitelli, D., Green, S., Richardson, M., Winkler, B., Painting, R., Way, R., Jacobs, P., Skuce, A. (2013). Quantifying the consensus on anthropogenic global warming in the scientific literature. Environmental Research Letters, 8(2), 024024. https://doi.org/10.1088/1748-9326/8/2/024024

COVID-19 airway protection PPE overview. (2020). https://www.mckinsey.com/~/media/McKinsey/About%20Us/COVID%20Response%20 Center/PDFs/COVID-19-PPE-Ops-Airway-Protection.pdf

Das, O., Neisiany, R., Capezza, A., Hedenqvist, M., Försth, M., Xu, Q., Jiang, L., Ji, D., & Ramakrishna, S. (2020). The need for fully bio-based facemasks to counter coronavirus outbreaks: A perspective. Science of the Total Environment, 736, N.PAG-N.PAG. https://doi.org/10.1016/j.scitotenv.2020.139611

Deaths Rise. Bloomberg.Com, N.PAG-N.PAG. Declarations. (2020). Insurance Journal, 98(12), 12–13.

Department of Environment and Natural Resources, Environmental Management Bureau. (2020). Provincial Guidelines on the Hazardous Waste Management During the Extended Enhanced Community Quarantine Period (Report no. 2020-20).

Edmond, C. (2020). How face masks, gloves and other coronavirus waste is polluting our ocean. World Economic Forum. https://www.weforum.org/agenda/2020/06/ppe-masks-gloves-coronavirus-ocean-pollution/

Face Masks, Including Surgical Masks, and Respirators for COVID-19. (2020). FDA. https://www.fda.gov/medical-devices/coronavirus-covid-19-and-medical-devices/face-ma sks-including-surgical-masks-and-respirators-covid-19

Fadare, O., & Okoffo, E. (2020). Covid-19 face masks: A potential source of microplastic fibers in the environment. The Science of the Total Environment, 737, 140279. https://doi.org/10.1016/j.scitotenv.2020.140279

Ferronato, N., & Torretta, V. (2019). Waste Mismanagement in Developing Countries: A Review of Global Issues. International Journal of Environmental Research and Public Health, 16(6), 1060. https://doi.org/10.3390/ijerph16061060

Gambo, J., Ahmed, G., Hadejia, H., Idris, A., Babura, B., & Yusuf, Y. (2018). ASSESSING THE IMPACTS OF IMPROPER MEDICAL WASTE DISPOSAL AND RESIDENTS PERCEPTION OF THEIR DISPOSAL PRACTICES IN HADEJIA METROPOL. https://www.researchgate.net/publication/323368745_ASSESSING_THE_IMPACTS_OF _IMPROPER_MEDICAL_WASTE_DISPOSAL_AND_RESIDENTS_PERCEPTION_ OF_THEIR_DISPOSAL_PRACTICES_IN_HADEJIA_METROPOLIS_JIGAWA_STAT E_NIGERIA

GOVERNMENT PH. (2020). [PDF] RA 11469: Bayanihan to Heal As One Act | Downloadable. Government PH. https://governmentph.com/ra-11469/

Hanania, J., Heffernan, B., Jenden, J., Lloyd, E., Stenhouse, K., Toor, J., & Donev, J. (2020). Fuel—Energy Education. https://energyeducation.ca/encyclopedia/Fuel

Health Care Waste Management. (2014). IWMI. https://www.iwmiph.com/services/health-care-waste-management

Health-care waste management rapid assessment tool. (2016). World Health Organization. https://doi.org//entity/water_sanitation_health/facilities/waste/hcwmtool/en/index.html

Henneberry, B. (2020). How Surgical Masks are Made. Thomasnet.com; Thomas. https://www.thomasnet.com/articles/other/how-surgical-masks-are-made/

International Organization for Standardization. (2006). Environmental management — Life cycle assessment — Principles and framework (ISO 14040:2006). https://www.iso.org/standard/37456.html

Ivey, J. (2016). Demystifying Research. Is Descriptive Research Worth Doing? Pediatric Nursing, 42(4), 189–189.

Jahangiri, M., Cousins, R., & Gharibi, V. (2020). Let's get back to work: Preventive biological cycle management of COVID-19 in the workplace. Work, 66(4), 713–716. https://doi.org/10.3233/WOR-203217

Klemeš, J., Fan, Y., & Jiang, P. (2020). The energy and environmental footprints of COVID-19 fighting measures – PPE, disinfection, supply chains. Energy, 211, 118701. https://doi.org/10.1016/j.energy.2020.118701

Klöpffer, W., & Grahl, B. (2014). Life Cycle Assessment (LCA): A Guide to Best Practice. ResearchGate. https://www.researchgate.net/publication/285947771_Life_Cycle_Assessment_LCA_A_ Guide_to_Best_Practice

Ma, Y., Lin, X., Wu, A., Huang, Q., Li, X., & Yan, J. (2020). Suggested guidelines for emergency treatment of medical waste during COVID-19: Chinese experience. Waste

Disposal & Sustainable Energy, 2(2), 81–84. https://doi.org/10.1007/s42768-020-00039-8

Makato, T., Gamaralalage, P., Yugo Pratomo, I., Onogawa, K., Alversion, K., Honda, S., Ternald,

D., Diley, M., Fujioka, J., & Condrorini, D. (2020). Waste Management during the COVID-19 Pandemic From Response to Recovery. United Nations Environment Programme.

https://www.iges.or.jp/en/pub/waste-management-during-covid-19-pandemic-response-re

covery/en

Medical face mask production process. (n.d.). https://www.maskexpert.com/new/Medical-face-mask-production-process.html

MedTecs International Corporation Limited. (2019). Medtecs, Safeguarding Every Tomorrow. Medtecs.com.tw. http://www.medtecs.com.tw/en/

Metropolitan Manila Development Authority. (2019). Anti-littering. Mmda.gov.ph. https://mmda.gov.ph/20-faq/2384-anti-littering.html

Narvaez, D., Benedictos, E., & Mogol, G. (2004). Health Care Waste Management Manual.

DOH.

https://doh.gov.ph/sites/default/files/publications/Health_Care_Waste_Management_Man

ual.pdf

Niu, Z., Wang, T., Hu, P., Mei, J., & Tang, Z. (2020). Chinese Public's Engagement in Preventive and Intervening Health Behaviors During the Early Breakout of COVID-19: Cross-Sectional Study. Journal of Medical Internet Research, 22(8), e19995. https://doi.org/10.2196/19995

Nzediegwu, C., & Chang, S. (2020). Improper solid waste management increases potential for COVID-19 spread in developing countries. Resources, Conservation and Recycling, 161, 104947. https://doi.org/10.1016/j.resconrec.2020.104947

Parkinson, J. (2020). Coronavirus: Disposable masks "causing enormous plastic waste." BBC News; BBC News. https://www.bbc.com/news/uk-politics-54057799

Pfattheicher, S., Nockur, L., Böhm, R., Sassenrath, C., & Petersen, M. (2020). The Emotional Path to Action: Empathy Promotes Physical Distancing and Wearing of Face Masks During the COVID-19 Pandemic. Psychological Science (0956-7976), 31(11), 1363–1373. https://doi.org/10.1177/0956797620964422

Philippine Clean Air Act of 1999, 20 (1999). http://www.congress.gov.ph/legisdocs/ra_11/RA08749.pdf

Production of Disposable Surgical and Medical Face Mask. (n.d.). https://www.entrepreneurindia.co/Document/Download/Production%20of%20Disposable %20Surgical%20and%20Medical%20Face%20Mask-67739-.pdf

Coronavirus Resource Center. (2021). Harvard Health. https://www.health.harvard.edu/diseases-and-conditions/coronavirus-resource-center

Reusability of Facemasks During an Influenza Pandemic: Facing the Flu. (n.d.). https://doi.org/10.17226/11637

Riedy, C. (2016). Climate Change.

https://www.researchgate.net/publication/311301385_Climate_Change

Ritchie, H., & Roser, M. (2013). CO_2 and Greenhouse Gas Emissions. Our World in Data. https://ourworldindata.org/co2/country/philippines?country=~PHL

Rizan, C., Reed, M., & Bhutta, M. (2020). Environmental impact of Personal Protective Equipment supplied to health and social care services in... ResearchGate; unknown. https://www.researchgate.net/publication/345426529_Environmental_impact_of_Persona l_Protective_Equipment_supplied_to_health_and_social_care_services_in_England_in_t he_first_six_months_of_the_COVID-19_pandemic

Sangkham, S. (2020). Face mask and medical waste disposal during the novel COVID-19 pandemic in Asia. Case Studies in Chemical and Environmental Engineering, 2, 100052. https://doi.org/10.1016/j.cscee.2020.100052

Togoh, I. (2020). Overwhelmed By Coronavirus Coverage? Here's How It Started, And The Essential Information You Need. Forbes.Com, N.PAG. https://www.forbes.com/sites/isabeltogoh/2020/03/13/overwhelmed-by-coronavirus-cove rage-heres-how-it-started-and-the-essential-information-you-need/?sh=79bc7a406145

Yurasits, B. (2020). Five things you should know about disposable masks and plastic pollution. UN News. https://news.un.org/en/story/2020/07/1069151

Zhai, Z. (2020). Facial mask: A necessity to beat COVID-19. Building and Environment, 175, 106827. https://doi.org/10.1016/j.buildenv.2020.106827

A Systematic Review on Water Hyacinth *(Eichhornia crassipes)* as a Biosorbent of Cadmium

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Abstract: Water hyacinth has gained a noteworthy reputation as the worst invasive macrophyte for its alarming proliferation rates, threatening transportation and irrigation systems and ecosystem biodiversity. Sustainable efforts have found the plant to demonstrate efficiency in sequestering toxic heavy metals such as cadmium from marine environments. Cadmium presence in water, primarily caused by anthropogenic sources, poses public health risks due to its toxicity. Consequently, studies on the applications of Eichhornia crassipes and the removal of cadmium have become active research areas in recent decades. This review presents literature related to the Cd sorption capacity of water hyacinth biosorbents. The effects and optimization of parameters including treatment, temperature, pH, initial sorbate and sorbent concentration have been explored in classical and competitive adsorption models. Investigations on kinetics, equilibrium, and desorption studies have also been conducted. From the gathered literature, water hyacinth biosorbents show potential for industrial-scale applications, but its metal recovery and utilization in multi-metal and continuous sorption may require further evaluation.

Key Words: water hyacinth; biosorption; batch adsorption; cadmium; heavy metals

1. INTRODUCTION

Millions of cubic meters of untreated wastewater are disposed of in Manila Bay and Laguna Lake annually (International Water Association, 2018). Within these emissions are potential heavy metals that significantly impact the environment. Cadmium (Cd) is a naturally-occurring, heavy metal that bioaccumulates in organisms, causing adverse health effects such as cancer and toxicity in various organ systems (Rahimzadeh et al., 2017). Industrial effluents released from manufacturing processes are the primary anthropogenic pathway of Cd into the environment (Rao et al., 2010). Moreover, the Cd concentration of tap water sourced from Metro Manila reached 4.78ppm, exceeding the permissible concentration of 0.005ppm set by the WHO (Solidum & Solidum, 2012; World Health Organization, 2010).

To reduce its lethality, remediation techniques such as chemical precipitation, ion exchange separation, adsorption, filtration, reverse osmosis, solvent extraction, and electrochemical treatment have been developed, but most entail expensive operating costs (Wolowiec et al., 2019). Adsorption, however, has been preferred due to its low cost and high efficiency, particularly with the use of agricultural by-products (Lee et al., 2015).

Water hyacinth (Eichhornia crassipes) is regarded as the world's most invasive macrophyte for its alarming growth. It reduces oxygen levels in aquatic ecosystems and encourages diseases in nearby communities. Despite its disadvantages, its biomass has been reported by numerous valorization studies to be efficient in remediating polluted waters and removing toxic heavy metals like Cd. With the need for cost-efficient sustainable adsorbents, the high biomass production, tolerance to pollution, and adsorption capacity of water hyacinths qualify them as effective biosorbents (Priya & Selvan, 2017).

Through a systematic review of literature, relevant studies on Cd biosorption by E. crassipes were synthesized. Particularly, it aimed to evaluate the effects of sorbent treatments and experimental parameters, identify optimal conditions for Cd adsorption by water hyacinth (WH) biosorbents, and determine their applicability in industrial-scale operations.

The paper is solely centered on E. crassipes biomass as a sorbent of Cd. Different methodologies and adsorption systems were considered, where the biosorption capacity of WH was determined through real experiments. The relevance of output limited the reference articles to have been published within the last three decades.

2. METHODOLOGY

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, which include a screening process for articles from

electronic databases, i.e., Scopus, ScienceDirect, and PubMed, were implemented. The keywords used in the initial search include the following terms and their combinations: "water hyacinth" OR "Eichhornia crassipes" AND "cadmium" OR "Cd" AND "adsorption" OR "biosorption". Following established inclusion and exclusion criteria, twenty-nine studies on Cd sorption by WH were deemed eligible (Figure 1).

A data extraction form was utilized to summarize and obtain specific information from the studies. The following items were included: (a) identification data; (b) adsorption type; (c) adsorbent parameters; (d) experimental parameters; (e) maximum sorption capacity; and (f) desorption data. Studies that had consistencies in variables, methodology, and results were sorted and tabulated. Analyses involved the comparison of results, particularly the influence of treatments and parameters on the adsorption capacity of the WH biosorbents.

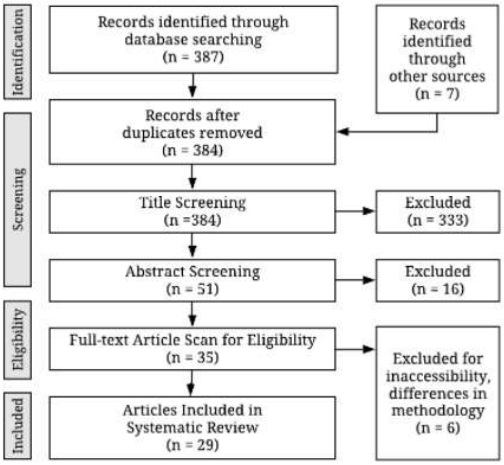

Figure 1. Adapted PRISMA screening process

3. RESULTS AND DISCUSSION

3.1 Classification of Sorbents

Three categories of sorbents were recognized in the studies: live, dried, and pyrolyzed WH biosorbents. Forty-eight percent were conducted using dried E. crassipes, while live biomass and biochar studies each comprised twenty-four percent of publications. One study conducted simulation studies (Soriano et al., 2016) which did not fit in any of the aforementioned classifications. All sorbent types exhibited effective Cd sorption capacity, with the highest removal rates for dried biomass, live water hyacinth and E. crassipes biochars being 99.9%, 100% and 99.24% respectively (Manju et al., 2016; Swain et al., 2014; Li et al., 2016).

3.2 Live Water Hyacinth Biomass for Cadmium Sorption

With the usage of live sorbents, phytoremediation studies precede the more common adsorption methods at present. Cd is primarily bound to WH via peptides (Romanova & Shuvaeva, 2015) while the cell wall and subcellular fractions of tissues account for most of the uptake (Fett et al., 1994b). Four studies applied live WH sorption for Cd removal (Table 1).

From the collated articles, untreated, raw and live E. crassipes biomass have been observed to perform well in terms of Cd sorption at near-neutral pH levels of 6.0-7.0. Acidic conditions have been found to be less ideal due to the binding competition between Cd2+ and H+ ions to WH adsorption sites. Similarly, Cd removal is most favorable in the absence of other metals; single-sorption systems produced the best Cd removal rates. (Hasan et al., 2007; Patel et al., 2014; Mishra & Tripathi, 2008). It was found that longer exposure times (≥10 days) led to higher Cd accumulations. Moreover, the highest percent removal was at minimum initial Cd concentrations. While modifications might improve the metal uptake of E. crassipes, cadmium, at high concentrations, bears toxic effects on WH and suppresses plant growth and absorption (Fett et al., 1994a; Mishra & Tripathi, 2008). At larger scales where Cd is prevalent, live sorbents are not as reliable for removal.

3.3 Application of Dried Water Hyacinth Biomass in Cadmium Removal

Table 1. Batch cadmium sorption using live WH biomass.

Biomass Part	Optimal Parameters	Removal/Sorption Capacity	Reference
Roots, Shoots	pH 7.0; 1.0 mg L^{-1} Cd(II); 16 days	92.0% – single 73.2% – binary (vs Zn)	Hasan et al. (2007)
Whole Biomass	2.0 mg L^{-1} metal concentrations; 12 days	0.31 mg g^{-1}; 85% – quinary (vs Cu, Cr, Zn, Fe)	Mishra & Tripathi (2008)
Whole Biomass	pH 6; 10 mg L^{-1} Cd	20.54%	Patel et al. (2014)
Whole Biomass	pH 6.7; 0.27 mg L^{-1} Cd; 15 days	100%	Swain et al. (2014)

The Cd removal behavior of dried water hyacinth roots, shoots, and whole biomass has also been studied in various conditions (Table 2). To maximize surface area and available sites for adsorption, the biomass is usually dried and crushed into powder. According to Khatoon et al. (2016), pretreatment of biosorbents may result in the opening of biopolymer rings, increasing porosity and stability,

ultimately improving the heavy metal removal efficiency of the sorbent.

The effects of different pretreatment factors, including drying temperature and sorbent size on the maximum adsorption of the WH have been taken into consideration. Modenes et al. (2011) observed greater adsorption capacity at the lower drying temperatures due to greater pore size contraction at high temperatures. Modenes et al. (2011) also found little variation in adsorption capacity of different sorbent particle sizes.

Table 2. Batch cadmium adsorption via dried WH biomass.

Biosorbent Treatment	Optimal Parameters	Removal/Sorption Capacity	Reference
Whole biomass, dried at 60°C		27 mg g^{-1} – quaternary (vs Pb, Cu, Zn)	Schneider et al. (1995)
Acid-treated biomass, oven-dried at 65°C for 12h	pH 7.10; 250 mg L^{-1} Cd; 3.5 g L^{-1} sorbent dose	87.54 mg g^{-1}	Mahamadi & Nharingo (2006)
Acid-treated roots, oven-dried at 65°C for 12h	pH 5.8; 300 mg L^{-1} Cd	4.0 mg L^{-1} – quaternary (vs K, Ca, Mg)	Mahamadi & Zaranyika (2007)
Whole biomass, dried at 70°C for 48h	30 mg L^{-1} Cd	1.98 mg g^{-1} – single; 1.96 mg g^{-1} – senary (vs Cu, Zn, Ni, Pb, Cr); ≈98%	Verma et al. (2008)
Ash, air-dried and oven-dried, burnt at 220°C	30 µg mL^{-1} Cd	28.41 µg g^{-1}	Mahmood et al. (2010)
Acid-treated roots, sun-dried for 2d, oven-dried at 65°C for 12h		9.92 mg g^{-1} – single 2.43 mg g^{-1} – binary (vs Pb); 6.42 mg g^{-1} – binary (vs Zn) 3.01 mg g^{-1} – ternary (vs Pb, Zn)	Mahamadi & Nharingo (2010)
Whole biomass, dried separately at 30°C, 50°C	pH 5.0 30°C drying temperature; non-uniform sorbent size; 30°C; 60 min contact time	0.667 meq g^{-1}, >60% – binary (vs Zn)	Modenes et al. (2011)
Roots, shoots, dried at 65°C for 48h	pH 5.0; 50 mg L^{-1} Cd; 5.0 g L^{-1} sorbent dose; 60 min contact time	79.65% – roots; 79.22% – shoots	Ibrahim et al. (2012)
Acid-washed whole biomass, oven-dried at 60°C for 24h	pH 6.0; 0.2 g mL^{-1} sorbent dose; 300 mg L^{-1} Cd; 45°C; 175 rpm	104.16 mg g^{-1}	Murithi et al. (2014)
Emericella nidulans-immobilized biomass, dried at 50°C	pH 6.0; 1% sorbent dose; 100 mg L^{-1} Cd; 120 min sorption time; 40°C	99.9%	Manju et al. (2016)
Roots, dried at 70°C	pH 6.0; 0.267 mmol L^{-1} Cd and 0 mmol L^{-1} Cu – binary;	5.43% – single 0.62% – binary (vs Cd) (in Cd/biomass Wt%)	Zheng et al. (2016)
Leaves, dried in shade for 3d	pH 8; 250 mg L^{-1} Cd	96%	Hassoon & Najem (2017)
Sodium-alginate microspheres, oven-dried at 105°C	96h sorption time	94.2%	Grenni et al. (2019)
Shoots, oven-dried at 60°C	pH 6.5; 5 g L^{-1} sorbent dose; 10 mg L^{-1} Cd; 60 min sorption time	21.6 mg g^{-1}	Li et al. (2020)

The studies on dried WH biosorption of Cd have determined different parameters to maximize adsorption rates. Several studies have found that a neutral acidity of pH 5.0 to 7.0 would be optimal for Cd adsorption due to a lower concentration of hydrogen ions competing for the sorption sites on the sorbent (Modenes et al., 2011; Manju et al., 2016; Zheng et al., 2016). Sorbent dose affects the electrostatic interactions between particles, and a ceiling of adsorptive capacity emerges at greater sorbent doses (Ibrahim et al., 2012). At 0.2 to 0.5mm, 5g L-1 of biomass reached maximum adsorption, while 1.0mm particle size plateaued at 0.2g mL-1; this signifies that the use of a smaller sorbent size requires less sorbent to reach the optimal amount (Ibrahim et al., 2012; Murithi et al., 2014; Li et al., 2020). Initial Cd concentration also affects the adsorption capacity of the biomass. With a greater amount of Cd ions present, the increased rate of adsorption reaction causes more amounts of the metal to be adsorbed but decreases the removal percentage of Cd (Mahamadi & Zaranyika, 2007; Mahamadi & Nharingo, 2006; Li et al., 2020; Murithi et al., 2014; Manju et al., 2016). The adsorption of Cd ions by WH consistently followed the pseudo-second-order model and fitted the Langmuir adsorption model. With the presence of other heavy metals, the competitive adsorption of Pb and Zn significantly hindered the adsorption of Cd, while Na, K, Mg and Ca had minimal to no impact (Mahamadi & Nharingo, 2010; Murithi et al, 2014).

3.4 Cadmium Biosorption via Water Hyacinth Biochar

The utilization of water hyacinth-derived biochars for Cd removal from aqueous solutions is relatively unexplored, with publications surfacing only recently (Table 3). However, it is a promising method to manage the invasive species and immobilize Cd effectively.

The heating temperature during biochar generation influences adsorption capacity. A pyrolysis temperature between 450ºC to 700ºC is found to be ideal (Zhang et al., 2015; Ding et al., 2016; Li et al., 2016). Ding et al. (2016) inferred that higher pyrolysis temperatures encouraged surface area and porous structure, but increasing the temperature beyond 600ºC causes the loss of oxygen-containing groups. Increasing temperature results in greater Cd removal, but extreme heat dissipates functional groups essential for adsorption. Zhou et al. (2019) recommended a heating rate of 15ºC min-1 for 2 hours, demonstrating a slow pyrolysis to be most effective.

Compared to dried and live biosorbents, WH biochars appear to be better accumulators of Cd at high and low initial concentrations in terms of adsorption capacity and metal removal. Higher concentrations of Cd require longer exposure times as presented by Zhang et. al (2015). Solution temperature heavily influences the adsorption behavior of biochars due to its endothermic characteristic (Ding et al., 2016; Liu et al., 2020),

wherein increasing the temperature during sorption encourages Cd sorption mechanisms to occur. Solution pH has been considered as one of the most influential factors to the adsorption capacity of biochars. The surplus of H+ at low pH levels (>2.50) overwhelmed and protonated the negatively-charged biochar surface, repelling Cd2+; thus, a moderate pH level of 5.0-6.0 has been deemed optimal (Ding et al., 2016; Li et al., 2016; Liu et al., 2020).

Table 3. Batch cadmium adsorption by WH biochars.

Biochar Treatment	Optimal Parameters	Removal/Sorption Capacity	Reference
Acid-washed biochar	450°C pyrolysis; 24h sorption time	70.313 mg g^{-1}	Zhang et al. (2015)
WH Biochar	450°C pyrolysis; pH 5.0; 100 mg L^{-1} Cd; 30°C	74.99 mg g^{-1}	Ding et al. (2016)
WH Biochar	700°C pyrolysis; 1.0 g L^{-1} sorbent dose; pH 5.0; 1mol L^{-1} Cd; 25°C	25.826 mg g^{-1}, 99.24%	Li et al. (2016)
Root biochar	500°C pyrolysis; 1.0 g L^{-1} sorbent dose;	39.81 mg g^{-1}, 96.24%	Li et al. (2018)
	100 mg L^{-1} Cd; 298K		
Roots, leaves biochar pellets immobilized with *Chlorella* sp.	pH 6.0; 10 mg L^{-1} Cd(II); leaf biochar pellet immobilized with *Chlorella* sp.; 119 µmol $m^{-2}s^{-1}$ illumination	13.81 mg g^{-1}, 92.45%.	Shen et al. (2018)
Stem biochar	400°C pyrolysis; 2h heating time; 15°C min^{-1} heating rate;	20.175 mg g^{-1}, 80.70%	Zhou et al. (2019)

3.5 Cadmium Desorption and Recovery

Biomass regeneration potential and cadmium recovery are necessary determinants for the applicability of WH biosorbents at industrial scales. The practical efficiency of a biosorbent is determined not only by its adsorptive capacity but also by its accessibility and potential for reuse.

Shen et al. (2018) reported the use of nitric acid as an eluent at lower molar concentrations, wherein the Cd (II) removal efficiency of E. crassipes biochar pellets remained at 91.1% after three adsorption-desorption cycles. Meanwhile, Zheng et al. (2016) utilized Cu (II) ions, that have high affinity to sorption sites, to desorb over 90% of Cd (II) from dried biomass. Liu et al. (2020) demonstrated the sustainability of WH biochar-alginate capsules, which retained up to 70% of its initial adsorption capacity following 10 reuses.

As shown in Table 4, a number of studies accounted for the usefulness of the high Cd desorption capacity of WH for biomass regeneration and Cd recovery (Mahmood et al., 2010; Ding et al., 2016; Shen et al., 2018). However, at present circumstances, a survey of literature shows that WH-biosorption studies expounding on Cd recovery are limited.

Table 4. Cadmium desorption by WH biosorbents.

Biosorbent Type	Eluent	Maximum Desorption Capacity	Reference
WH-derived ash	HNO_3	27.54 µg g^{-1}, 96.9%	Mahmood et al. (2010)
WH biochar (450°C)	HCl	≈60%	Ding et al. (2016)
Dried WH roots	Cu	>90%	Zheng et al. (2016)
WH leaf biochar pellets	HNO_3		Shen et al. (2018)

4. CONCLUSIONS

Water hyacinth biosorption is an effective means for cadmium remediation. Through biosorption applications, the environmental concerns associated with the toxicity of cadmium and the invasive property of E. crassipes are minimized. Several solution and sorbent parameters significantly impact its adsorption capacity. Cadmium sorption is favored at near-neutral pH levels to reduce competition with interfering ions, while lower initial sorbent and sorbate concentrations allow maximized adsorption without risk of precipitation. Unlike dried biomass, live biosorbents are hindered by metal toxicity. Pretreatment of biomass is advantageous as dried biosorbents have consistent efficient removal rates. However, biochar studies have become more prominent in recent years. The inclusion of pyrolysis at high temperatures allows more sorbent modifications such as the increased presence of functional groups, porosity, and surface area that aid in adsorption. Despite the accessibility, inexpensive cost, and excellent removal capacity of WH biomass, its usage in industrial scales requires further investigation, specifically on the themes of cadmium desorption, metal recovery, multi-metal, and continuous sorption systems.

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6. REFERENCES

Ding, Y., Yunguo, L., Liu, S., Li, Z., Tan, X., Huang, X., Zeng, G., Zhou, Y., Zheng, B., & Cai, X. (2016, January). Competitive removal of Cd(II) and Pb(II) by biochars produced from water hyacinths: performance and mechanism. Royal Society of Chemistry Advances 2016, 6, 5223-5232. https://doi.org/10.1039/c5ra26248h

Fett, J.P., Cambraia, J., Oliva, M.A, & Jordão, C.P. (1994a, June). Cadmium uptake and growth inhibition in Water Hyacinth: effect of nutrient solution factors. Journal of Plant Nutrition, 17(7), 1205-1217. https://doi.org/10.1080/ 01904169409364799

Fett, J.P., Cambraia, J., Oliva, M.A, & Jordão, C.P. (1994b, June). Absorption and distribution of cadmium in Water Hyacinth plants. Journal of Plant Nutrition, 17(7), 1219-1230. https://doi.org/10.1080/ 01904169409364800

Grenni, P., Caracciolo, A.B., Mariani, L., Cardoni, M., Riccucci, C., Elhaes, H., & Ibrahin, M. (2019, June). Effectiveness of a new green technology for metal removal from contaminated water. Microchemical Journal, 147, 1010-1020. https://doi.org/10.1016/j.microc.2019.04.026

Hasan. S.H., Talat, M., & Rai, S. (2007, March). Sorption of cadmium and zinc from aqueous solutions by water hyacinth (Eichhornia crassipes). Bioresource Technology, 98(4), 918-928. https://doi.org/10.1016/j.biortech.2006.02.042

Hassoon, H.A. & Najem, A.M. (2017, September 23). Removal of Some Traces Heavy Metals from Aqueous Solutions by Water Hyacinth Leaves Powder. Iraqi Journal of Science, 58(2A), 611-618.

Ibrahim, H.S., Ammar, N.S., Soylak, M., & Ibrahim, M. (2012, October). Removal of Cd(II) and Pb(II) from aqueous solution using dried water hyacinth as a biosorbent. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 96, 413-420. https://doi.org/10.1016/j.saa.2012.05.039

International Water Association. (2018). Wastewater Report 2018. https://reliefweb.int/sites/reliefweb.int/files/resources/OFID%20Wastewater%20report%202018%20screen.pdf

Lee, C., et al. (2015, March 24). Lead and copper removal from aqueous solutions using carbon foam delivered from phenol resin. Chemosphere, 130, 59-65. https://doi.org/10.1016/j.chemosphere.2015.02.055

Li, F., Shen, K., Long, X., Wen., J., Xie, X., Zeng, X., Liang, Y., Wei, Y., Lin, Z., Huang, W., & Zhong, R. (2016, February 16). Preparation and Characterization of Biochars from Eichornia crassipes for Cadmium Removal in Aqueous Solutions. PLoS One, 11(2), e0148132. https://doi.org/10.1371/journal.pone.0148132

Li, M., Xiao, X., Wang, S., Zhang, X., Li, J., Pavlostathis, S.G., Luo, X., Luo, S., & Zeng, G. (2020, June). Synergistic removal of cadmium and organic matter by a microalgae-endophyte symbiotic system (MESS): An approach to improve the application potential of plant-derived biosorbents. Environmental Pollution, 261, 114117. https://doi.org/10.1016/j.envpol.2020.114177

Li, Q., Tang, L., Hu, J., Jiang, M., Shi, X., Zhang, T., Li, Y., & Pan, X. (2018, October 5). Removal of toxic metals from aqueous solution by biochars derived from long-root Eichhornia crassipes. Royal Society open science, 5(10), 180966. https://doi.org/10.1098/rsos.180966

Liu, C., Ye, J., Lin, Y., Wu, J., Price, G.W., Burton, D., & Wang, Y. (2020, September). Removal of Cadmium (II) using water hyacinth (Eichhornia crassipes) biochar alginate beads in aqueous solutions. Environmental Pollution, 264(2020), 114785. https://doi.org/10.1016/j.envpol.2020.114785

Mahamadi, C. & Nharingo, N. (2006, June). Modelling the kinetics and equilibrium properties of cadmium biosorption by river green alga and water hyacinth weed. Toxicological and Environmental Chemistry 89(2), 297-305. https://doi.org/10.1080/02772240601010063

Mahamadi, C. & Nharingo, T. (2010, February). Competitive adsorption of Pb2+, Cd2+ and Zn2+ ions onto Eichhornia crassipes in binary and ternary systems. Bioresource Technology, 101(3), 859-864. https://doi.org/10.1016/j.biortech.2009.08.097

Mahamadi, C. & Zaranyika, M. (2007). Adsorption of cadmium from aqueous solution by acid-treated water hyacinth weed Eichhornia Crassipes, in the presence of K, Ca and Mg: Role of non-spectroscopic interferences during ICP-AES determination. Electronic Journal of Environmental, Agricultural and Food Chemistry, 6(5), 2034-2044.

Mahmood, T., Malik, S.A. & Hussain, S. (2010, May). Biosorption and recovery of heavy metals from aqueous solutions by eichhornia crassipes (water hyacinth) ASH. Bioresources, 5(2):1244-1256.

Manju, Kumari, S., Sharma, J., Gupta, S., Kumar, M., Kumar, S.S., Kumar, A., Verma, A., Shalu, Sharma, P., Bajawa, K., Lal, S., & Bishnoi, N.R. (2016, September 29). An Assessment of Cadmium Removal from Simulated Waste Water Using Leftover Biomass of Water Hyacinth Immobilized via Emericella nidulans. Journal of Applied Life Sciences International, 8(3), 1-10. https://doi.org/10.9734/JALSI/2016/27845

Mishra, V.K. & Tripathi, B.D. (2008, October). Concurrent removal and accumulation of heavy metals by the three aquatic macrophytes. Bioresource Technology, 99(15), 7091-7097. https://doi.org/10.1016/j.biortech.2008.01.002

Módenes, A.N., Espinoza-Quiñones, F. R., Borba, C.E., Trigueros, D. E. G., Lavarda, F. L., Abugderah, M. M. & Kroumov A. D. (2011, October). Adsorption of Zn(II) and Cd(II) ions in batch system by using the Eichhornia crassipes. Water Science & Technology, 64(9), 1857-1863. https://doi.org/10.2166/wst.2011.764

Murithi, G., Onindo, C.O., Wambu, E.W., & Muthakia, G.K (2014, May). Removal of Cadmium(II) Ions from Water by Adsorption using Water Hyacinth (Eichhornia crassipes) Biomass. BioResources, 9(2), 3613-3631. https://doi.org/10.15376/biores.9.2.3613-3631

Patel, K.P., Patel, P.M., & Patel, K.M. (2014, March). Removal of Zinc and Cadmium by two aquatic plant water lettuce (Pistia stratiotes) and water hyacinth (Eichhornia crassipes). Environmental Science & Technology (2014), 2.

Priya, S., & Selvan, S. (2017). Water Hyacinth (Eichhornia Crassipes) – An Efficient and Economic Adsorbent for Textile Effluent Treatment – A Review. Arabian Journal of Chemistry, 10(2), S3548-3558. https://doi.org/10.1016/j.arabjc.2014.03.002

Rahimzadeh, M. R., Rahimzadeh, M. R., Kazemi, S., & Moghadamnia, A.-akbar. (2017). Cadmium Toxicity and Treatment: An Update. Caspian J Intern Med, 8(3), 135-145. https://doi.org/ 10.22088/cjim.8.3.135

Romanova, T.E. & Shuvaeva, O. (2015, July). Identification of the binding forms of cadmium during accumulation by water hyacinth. Chemical Speciation and Bioavailability, 27(3), 139-145. https://doi.org/10.1080/09542299.2015.1113388

Schneider, I.A.H., Rubio, J., & Smith, R.W. (1995, September). Eichhornia crassipes as biosorbent for heavy metal ions. Minerals Engineering, 8(9), 979-988. https://doi.org/10.1016/0892-6875(95)00061-T

Shen, Y., Zhu, W., Huan, L., Ho, S., Chen, J., Xie, Y., & Shi, X. (2018 June). Enhancing cadmium bioremediation by a complex of water-hyacinth derived pellets immobilized with Chlorella sp. Bioresource Technology, 257, 157-163. https://doi.org/10.1016/j.biortech.2018.02.060

Solidum, J. & Solidum, G. (2012). Assessment and Remediation of Heavy Metals in Community Tap Water from Manila, Philippines. 2012 International Conference on Environmental Science and Engineering IPCBEE, 32.

Soriano, A.N., Orfiana, O.N., Pangon, M.B., Nieva, A.D., & Adornado, A.P. (2016). Simulated Biosorption of Cd(II) and Cu(II) in Single and Binary Metal Systems by Water Hyacinth (Eichhornia crassipes) using Aspen Adsorption. ASEAN Journal of Chemical Engineering, 16(2), 21-43. https://doi.org/10.22146/AJCHE.49892

Swain, G., Adhikari, S., & Mohanty, P. (2014, February) Phytoremediation of Copper and Cadmium from Water Using Water Hyacinth, Eichhornia Crassipes. International Journal of Agricultural Science and Technology, 2(1), 1. https://doi.org/10.14355/ijast.2014.0301.01

Verma, V.K., Tewari, S., & Rai, J.P.N. (2008, April). Ion exchange during heavy metal bio-sorption from aqueous solution by dried biomass of macrophytes. Bioresource Technology, 99(6), 1932-1938. https://doi.org/10.1016/j.biortech.2007.03.042

Wolowiec, M., Komorowska-Kaufman, M., Pruss, A., Rzepa, G., & Bajda, T. (2019, August 14). Removal of Heavy Metals and Metalloids from Water Using Drinking Water Treatment Residuals as Adsorbents: A Review. Minerals 2019, 9(8), 487. https://doi.org/10.3390/min9080487

World Health Organization. (2010). EXPOSURE TO CADMIUM: A MAJOR PUBLIC HEALTH CONCERN. https://www.who.int/ipcs/features/cadmium.pdf

Zhang, F., Wang, X., Yin, D., Peng, B., Tan, C., Liu, Y., Tan, X., & Wu, S. (2015, April 15). Efficiency and mechanisms of Cd removal from aqueous solution by biochar derived from water hyacinth (Eichornia crassipes). Journal of Environmental Management, 153, 68-73

Zheng, J., Liu, H., Feng, H., Li, W., Lam, M.H., Lam, P.K., & Yu, H. (2016, December). Competitive sorption of heavy metals by water hyacinth roots. Environmental Pollution, 219, 837-845. https://doi.org/10.1016/j.envpol.2016.08.001

Zhou, R., Ming, Z., Zhou, J. & Wang, J. (2019, November). Optimization of biochar preparation from the stem of Eichhornia crassipes using response surface methodology on adsorption of Cd2+. Scientific Reports, 9(1), 17538. https://doi.org/10.1038/s41598-019-54105-1

An Experimental Study on Sugarcane (*Saccharum officinarum*) Bagasse and Corn (Zea mays L.) cob as a Potential Bio-adsorbent for Used Engine Oil

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Abstract: Oil pollution is one of the leading causes of detriment to water ecosystems. Bio-adsorbents have been studied for oil cleanup potential, but mixed bio-adsorbents have not been thoroughly studied yet. Thus, this study investigated Sugarcane (*Saccharum officinarum*) bagasse and Corn (*Zea mays*) cobs, two of the most underutilized agricultural wastes, as bio-adsorbents in their natural form. Five formulations were used, and used motor oil was utilized as the adsorbate. One gram of bio-adsorbent was used in a mixture of 3 grams of oil and 200 milliliters of water per trial. The oil sorption capacity (OSC) and water sorption amounts were collected to determine the efficiency in selectively adsorbing motor oil. Results showed that all formulations had similar oil sorption capacities, ranging from 288% to 298%, with pure bagasse (F1) having the highest and the formulation with a bagasse-cob mass ratio of 3:1 (F2) having the lowest. Statistical analysis posited that all group means for OSC are equal. Additionally, findings suggested that water sorption amount increases as the percentage by mass of bagasse in the formulation increases. F1 sorbed the most water with 5.80 grams, whereas the formulation with pure cobs (F5) sorbed the lowest with 2.09 grams, followed by the formulation with a bagasse-cob mass ratio of 1:3 (F4) with 3.22 grams. These results signified that not all mean water sorption amounts measured were equal, suggesting that formulations F4 and F5 are the most efficient in selectively absorbing oil.

Key Words: *Saccharum officinarum; Zea mays;* oil sorption capacity; bio-adsorbents

1. INTRODUCTION

Oil spills are one of the leading causes of water pollution worldwide, posing dangers to aquatic habitats, poisoning fishes, and affecting people's livelihoods in coastal communities (National Oceanic and Atmospheric Administration, 2019). The majority of these spills are caused by human activity, particularly the runoff from cars that leak motor oil. Though there are multiple ways of dealing with oil spills, the use of adsorbents is primarily seen as being most effective due to its flexibility and simplicity (Crini et al., 2018). Synthetic materials form the most significant proportion of all adsorbents, but while they are effective and yield a high oil sorption capacity, their non-biodegradability, cost, and disposal method may sometimes outweigh their benefits (Al-Jammal & Juzsakova, 2017). An alternative route may be the use of bio-adsorbents—adsorbents derived from biological material like agricultural wastes (agro-wastes) (Crini et al., 2018). While this method has been thoroughly researched, most procedures focus on chemically treating agro-waste via silanization, acetylation, and other treatments to make it less hydrophilic (Gorgulho et al., 2018). The hydrophilic nature of agro-waste due to its cellulose content is one of the major limiting factors in the mainstream use of adsorbents. Suitable adsorbents must repel water to prevent sinking, requiring a minimum water sorption amount (Guilharduci et al., 2017). However, recent papers have demonstrated the potential of certain agro-wastes to attain promising results without chemical treatments. In particular, Choi (2018) showed the potential of powdered corn cobs in adsorbing large amounts of oil due to their low hydroxyl action, making them naturally hydrophobic. Behnood et al. (2016) and Gorgulho et al. (2018), on the other hand, demonstrated the potential of sugarcane bagasse as a decent bio-adsorbent due to its floatability and high surface area.

Though these studies have laid the groundwork on the feasibility of bagasse and corn cob bio-adsorbents, no research to date has described the potential of the two agro-wastes when used together. Sugarcane bagasse and corn cob have different properties that play to their advantages separately, but it is unknown whether these properties would

Table 1
Adsorbent Formulation Details

Adsorbent Name	Experiment Labels	Adsorbent Formulation	Corn Cob (g)	Sugarcane Bagasse (g)	Total (g)
F1	SB	100% S. Bagasse	0	1	1
F2	3B – 1C	75% S. Bagasse, 25% C. Cob	0.25	0.75	1
F3	1B – 1C	50% S. Bagasse, 50% C. Cob	0.5	0.5	1
F4	1B – 3C	25% S. Bagasse, 75% C. Cob	0.75	0.25	1
F5	CC	100% C. Cob	1	0	1

Table 1 summarizes the specific details about the adsorbents placed in each

interact constructively—leading to an increase in their capability to adsorb oil—or not. Additionally, both materials are the main underutilized agro-wastes of the Philippines and can be accessed easily due to the Philippines' large market for sugar and corn (Cajes, 2013; Baconguis and Pasagdan, 2013). Hence, this study aimed to identify whether a combination of bagasse and corn cob may increase Oil Sorption Capacity. It also aimed to determine what kind of formulation can serve as the most efficient adsorbent, which is the adsorbent with the highest oil sorption capacity and lowest water sorption capacity.

2. METHODOLOGY

2.1. Materials

For the adsorbents, corn cobs were collected from fresh yellow corn bought from Biñan City Market. These collected corn cobs were used in natura or "in their natural state," only dried to eliminate moisture. The researchers collected sugarcane bagasse from "Tubo ko," a sugarcane juice stall in SM Sta. Rosa, also in natura.

Used motor oil, the adsorbate, was sourced from a mechanic shop from Santa Rosa, Laguna. Only one source vehicle for the used motor oil was used for consistency. The study used a synthetic blend motor oil with an oil grade of SAE 20W-40, which is one of the primary motor oil grades sold in the Philippines, and the oil grade available to the researchers.

2.2. Procedure

All sugarcane bagasse and corn cobs were thoroughly rinsed and washed with distilled water (Gorgulho et al., 2018) to get rid of impurities. They were cut with a thickness between 0.5 to 1.0 cm (Choi, 2018) and sun-dried for 24 hours. Afterwards, the adsorbents were weighed on a weighing scale and dried in an oven at 110°C for 2 hours. The measuring and drying processes were repeated until the adsorbents' mass plateaued and were brittle enough to be powdered (Ascutia et al., 2015). The dried sugarcane bagasse and corn cobs were reduced separately using a ceramic mortar and pestle, as adapted from Ascutia et al. (2015). A blender was used to process the dried materials further, and they were sieved separately using 24-mesh and 28-mesh sieves. Particles within the -24 +28 mesh range were used for the experiment.

Table 1
Adsorbent Formulation Details

Adsorbent Name	Experiment Labels	Adsorbent Formulation	Corn Cob (g)	Sugarcane Bagasse (g)	Total (g)
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F2	3B – 1C	75% S. Bagasse, 25% C. Cob	0.25	0.75	1
F3	1B – 1C	50% S. Bagasse, 50% C. Cob	0.5	0.5	1
F4	1B – 3C	25% S. Bagasse, 75% C. Cob	0.75	0.25	1
F5	CC	100% C. Cob	1	0	1

Table 1 summarizes the specific details about the adsorbents placed in each container. Labels were used in conducting the experiment, where SB labels referred to F1, 3B-1C labels referred to F2, 1B-1C labels referred to F3, 1B-3C pertained to F4, and CC pertained to F5. This correspondence is shown in Table 1.

Figure 1. *Initial mixture set-up*

The experiment had three trials. The researchers poured 200 milliliters (mL) of distilled water and 3 grams (g) of used motor oil in each of the five glass containers for each trial, then were left for 30 minutes to allow the oil to spread more evenly on the water. This set-up is shown in Figure 1.

Formulations with mixed materials were mixed thoroughly after weighing the necessary components. After weighing all adsorbents accurately, they were placed onto the oil in the mixture evenly and were left in contact for four hours.

The adsorbents were recovered from the containers using a surgical scalpel and were placed

directly onto the filter paper by wiping then weighed. The containers were placed beside a bag of desiccants and covered for drying. Once the mass did not change for at least 24 hours, the adsorbents were weighed to get the final mass.

2.3. Research Design

The study used an experimental research design with the five manipulated bio-adsorbent formulations as the independent variable and the Oil Sorption Capacity (OSC) as the dependent variable. The controlled variables were the amount and type of motor oil and water used in each container and the bio-adsorbents' initial mass.

2.4 Data Analysis Strategy

In determining the amount of oil adsorbed (A_{oil}) and water absorbed (A_{water}), calculations using the following formulas were used:

$$A_{oil} = M_f - M_i = (R_f - (C_{cont} + C_{paper}) - M_i)$$

$$A_{water} = M_w - M_f = (R_w - (C_{cont} + C_{paper}) - M_i)$$

where M_i is the initial mass of the adsorbents before placing in the mixture, the mass of the recovered adsorbents before drying is M_w, and M_f is their mass after drying. M_f and M_w are derived from raw data (which are C_{cont}, C_{paper}, R_w, and R_f). C_{cont} is the mass of the clean, empty recovery container. C_{paper} is the mass of the clean filter paper. The mass of the recovery container, filter paper, and recovered adsorbent before drying is denoted as R_w, and their mass after drying is R_f. The average amount of oil adsorbed and water absorbed of all adsorbent formulations were compared.

The oil sorption capacity (OSC), denoted by Q, was computed using the following formula adapted from Choi (2018)

$$Q = \frac{M_f - M_i}{M_i}$$

M_f is the final mass of the recovered adsorbent after drying, and M_i is the adsorbent's initial mass before it was immersed in the oil-water mixture. However, OSC was expressed as a rate in % for this study by multiplying Q by 100. This formula measured how much oil the adsorbent can adsorb with respect to the adsorbent's initial mass. OSC values greater than 100% mean that the mass of oil adsorbed exceeded the initial mass of the bio-adsorbent before usage.

One-way analysis of variance (ANOVA) was employed to identify any differences in the mean OSCs and water sorption amounts. Tukey's HSD post hoc test was used to determine which adsorbent formulations differed if the one-way ANOVA test indicated an existing difference.

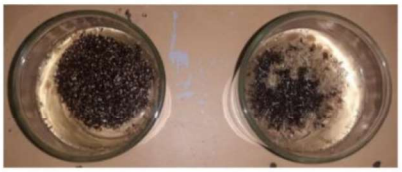


Figure 2. *Set-ups after placement of bio-adsorbents F5 (left) and F1 (right)*

Figure 3. *Set-ups after placement of bio-adsorbents F2 (left), F3 (middle), and F4 (right)*

3. RESULTS AND DISCUSSION

3.1 Documentation

Figure 4. *F1 bio-adsorbent, after 4 hours contact time*

Figure 5. *F2 bio-adsorbent, after 4 hours contact time*

Figure 6. *F3 bio-adsorbent, after 4 hours contact time*

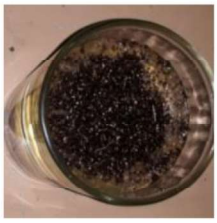


Figure 7. *F4 bio-adsorbent, after 4 hours contact time*

Figure 8. *F5 bio-adsorbent, after 4 hours contact time*

3.2. Oil Sorption Capacity

Figure 9. *Average oil sorption capacity by all bio-adsorbent formulations*

The mean OSC in % of the bio-adsorbents ranged from 288% to 298%. F1 showed the highest, and F2 had the lowest OSC, as illustrated in Figure 9. F3, F4, and F5 showed OSCs of 290%, 291% and 293%, respectively. The slight drop of F2's mean OSC from F1 and the upward trend of mean OSC starting from F2 until F5 may hint that the adsorption mechanism of corn cob and bagasse particles may be opposing each other. However, their values were relatively too close to each other for such a conclusion to be drawn.

One-way analysis of variance was conducted to identify any significant differences among the mean oil sorption capacity values. However, at $\alpha = 0.05$, results showed no statistically significant differences [$F(4,10) = 1.78$, $p = 0.210$]. This result signifies that all five bio-adsorbent formulations had similar mean OSCs. No further post hoc analyses were conducted since all group mean OSCs were found to be statistically equal.

3.3. Water Sorption and Total Sorption

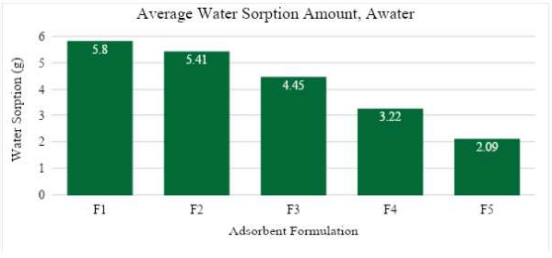
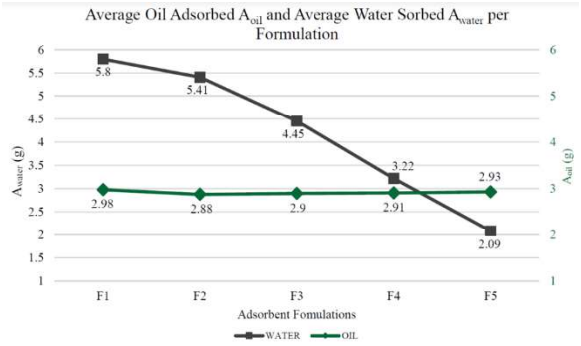


Figure 10. *Average water sorption amount by all bio-adsorbent formulations*

The mean water sorption amounts exhibited by all bio-adsorbent formulations ranged from 2.09 grams to 5.80 grams, as the graph of water amount sorbed in Figure 10 illustrates. The values followed a downward linear trend from F1 to F5. F1 sorbed an average of 5.80 grams of water, F2 sorbed 5.41 grams, F3 sorbed 4.45 grams, F4 sorbed 3.22 grams, and F5 sorbed only 2.09 grams of water.



As shown in Figures 10 and 11, this declining trend in water sorption indicates that an increasing proportion of bagasse in the bio-adsorbent formulation leads to higher water sorption. This trend showed the higher hydrophilicity of sugarcane bagasse, as discussed by Gorgulho et al. (2018) and Guilharduci et al. (2017). Consequently, formulations that contained more corn cob particles by mass sorbed less water. This observation was also reported by Choi (2018) in her paper, stating that corn cobs are less attracted to water than other agricultural wastes due to their lower hydroxyl action.

Upon employing one-way analysis of variance to see any significant differences among the mean water sorption amounts, at $\alpha = 0.05$, it was shown that there were indeed significant differences in the five group means [$F(4,10) = 23.40$, $p = 0.000046$]. Upon conducting Tukey's HSD as the post hoc test, results showed that the water sorption of F4 was significantly lower than those of F1 and F2. The mean water sorption of F5 was also shown to be lower than those of F1, F2, and F3. These results signify that, in general, formulations F4 and F5 had significantly lower water sorption amounts, one of the characteristics of an ideal oil bio-adsorbent. Considering that all bio-adsorbents had similar oil sorption capacities, these two formulations can then have more efficiency in adsorbing oil, especially in larger scales of oil spill cleanup.

4. CONCLUSIONS

4.1 Summary of Findings

The average OSCs of all bio-adsorbent formulations ranged from 288% to 298%, where F1 achieved the highest and F2 had the lowest with 288%. Upon conducting one-way analysis of variance on the five bio-adsorbent formulations (at $\alpha = 0.05$), it was found that there were no statistically significant differences in the mean OSCs among all formulations. For the water sorption amount, there was a downward trend from F1 with the highest water sorbed of 5.80 grams, where it decreased from then on with F5 as the lowest (2.09 grams). These findings point to the higher

hydrophobicity of corn cob particles and higher hydrophilicity of bagasse. Upon conducting a one-way analysis of variance (at $\alpha = 0.05$), it was shown that at least one pair of formulations had significant differences between their mean water sorption amounts. Therefore, using Tukey's HSD as the post hoc test, it was shown that, in general, F4 and F5 formulations had significantly lesser water sorption amounts compared to the F1, F2, and F3 formulations.

4.2 Conclusions and Recommendations

This study explored the novel idea of combining sugarcane bagasse and corn cob to create an effective bio-adsorbent and hypothesized that at least one bio-adsorbent formulation would have a differing mean oil sorption capacity, as well as for water sorption amount.

Results indicated that the mean OSCs of all bio-adsorbent formulations are relatively similar in effectiveness when adsorbing oil. Additionally, upon statistical analysis, it was also proven that there are no significant differences between the mean OSCs.

Statistical analysis proved that there are indeed significant differences between the water sorption of F4 and F5 formulations with a lower amount than F1, F2, and F3 formulations. Thus, F4 and F5 have different mean water sorption amounts than the rest.

Because of their similar OSCs, all formulations have great potential in adsorbing oil and can be used for oil spill cleanup. However, since lower water sorption indicates more efficiency for exhibiting greater selective attraction to oil, F4 and F5 can be more efficient than the rest.

The ideal interaction from all mixed bio-adsorbents was exhibited by the F4 formulation, which had the highest mean OSC among all mixed bio-adsorbents while having one of the lowest water amount sorbed. These characteristics shown by bio-adsorbent formulation F4, as well as F5, are the ideal attributes of an oil bio-adsorbent. In general, for a larger scale oil-adsorption, formulations F4 and F5 may be a better choice than the rest due to less attraction to water and a better exhibition of selective attraction to oil. Regardless, corn cob and sugarcane bagasse can be used as effective bio-adsorbents without chemical treatment and may be used interchangeably or in conjunction with each other for any oil spill cleanup applications, without compromise in their oil sorption capacity.

It is recommended for future researchers to delve into other formulations to analyze the interactions between sugarcane bagasse and corn cobs. Additionally, further studies can emphasize different oil concentrations in the oil-water mixture. This recommendation also brings the possible need to standardize the oil-sorbent ratios in sorbent testing. Lastly, future research may also focus on exploring the influence of contact times on a sorbent's OSC and its tendency to sink.

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6. REFERENCES

Al-Jammal, N. & Juzsakova, T. (2017). *Review on the effectiveness of adsorbent materials in oil spills clean up*, 7th International Conference of ICEEE, Hungary, 2016. https://www.researchgate.net/publication/319254182_Review_on_the_Effectiveness_of_Adsorbent_Materials_in_Oil_Spills_Clean_Up/link/5a8020c80f7e9be137c7bd72/download

Ascutia, M., Gamboa, R., Mariano, L., Narvas, N., Perez, F., Solis, M., & Lampitoc, R. (2015). Effectiveness of sugarcane bagasse in the biosorption of lead (Pb^ 2+) in wastewater: A preliminary study. *ANTORCHA*, *2* (1 and 2), 1.

Baconguis, S. & Pasagdan, A. (2013). Waste biomass statistics in the Philippines. *Canopy International, 39*(2013): 8–10.

Behnood, R., Anvaripour, B., Jaafarzadeh, N., & Farasati, M. (2016). Oil spill sorption using raw and acetylated sugarcane bagasse. *J. Cent. South Univ., 23*, 1618–1625. https://doi.org/10.1007/s11771-016-3216-8

Cajes, A. (2013). *Philippine waste agricultural biomass: Prospects and opportunities*, Workshop on Waste Agricultural Biomass to Energy in South East Asia. UNEP-International Environmental Technology Centre, Cambodia

Choi, H. J. (2018). Agricultural bio-waste for adsorptive removal of crude oil in aqueous solution. *Journal of Material Cycles and Waste Management*, *21*(2), 356-364.

Crini, G., Lichtfouse, E., Wilson, L., & Morin-Crini, N. (2018). Adsorption-oriented processes using conventional and non-conventional adsorbents for wastewater treatment. In G. Crini & E. Lichtfouse (Eds.), *Green Adsorbents for Pollutant*

Removal, Environmental Chemistry for a Sustainable World 18. Springer (pp. 23-71). doi.org/10.1007/978-3-319-92111-2_2

Gorgulho, H. de F., Guilharduci, V. V. da S., & Martelli, P. B. (2018). Sugarcane bagasse as potentially low-cost biosorbent. *Sugarcane - Technology and Research*. doi:10.5772/intechopen.72153

Guilharduci, V. V. D. S., Martelli, P. B., & Gorgulho, H. D. F. (2017). Efficiency of sugarcane bagasse-based sorbents for oil removal from engine washing wastewater. *Water Science and Technology, 75*(1), 173-181.

National Oceanic and Atmospheric Administration. (2019). *How does oil impact marine life?*. https://oceanservice.noaa.gov/facts/oilimpacts.html

Systematic Mapping on Adsorption Studies Using Spent Coffee Grounds

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Abstract: The increase in demand of coffee in the Philippines, led to the increase of production of spent coffee grounds (SCG) waste; utilization of this material is crucial as SCG pose environmental hazards. To evaluate the adsorbent capability of SCG, this study utilized systematic mapping. Research questions that were defined are as follows: 1) What is the research trend on adsorption studies using SCG? 2) What are the processes utilized to produce adsorbent from SCG? 3) What are the different contaminants adsorbed using SCG? 4) What are the important characterizations and performance of SCG adsorbents? It was determined that SCG undergoes various processes such as drying, carbonization, and physical and chemical activation to convert its structure to porous material with a high surface area of up to 2785 m^2/g. Furthermore, it was used to adsorb various contaminants such as heavy metals, dyes, and pharmaceuticals with adsorption capacity and removal efficiency of up to 1222.5 mg/g and 100%, respectively. It was also determined that various factors affect adsorption capacity and removal efficiency, namely pH level, adsorbent dosage, initial concentration, and contact time depending on the contaminant. With these, the potentials of SCG as raw material for adsorbent production were found beneficial to reduce its disposal to landfills.

Key Words: spent coffee grounds; adsorption; systematic mapping; valorization

1. INTRODUCTION

Aside from the beverage industry, pharmaceuticals and cosmetics industry also utilize coffee products, making it the third most consumed product next to water and tea, and the second most traded commodity next to petroleum (Szenthe, 2020). Consequently, global coffee production reached 163.7 million 60-kilogram bags in the year 2019-2020 (Shahbandeh, 2021). The Philippines alone produced 210 thousand 60-kg coffee bags in 2019 (International Coffee Organization, 2020). As a consequence of this big market, approximately 6 million tons of SCG are generated yearly all around the world (Ballesteros et al., 2014; Getachew & Chun, 2017). SCG left off in dumpsites gradually produces methane gas which contributes to the depletion of the ozone layer that protects the planet from excessive ultraviolet rays (Crumbley, 2009). Thus, there is a need to valorize such waste and devise sustainable ways to protect the environment.

Several researchers have investigated the various utilizations of SCG. With the use of direct transesterification, H. C. Nguyen et al. (2019) were able to produce biodiesel from SCG. In another study conducted by (Coelho et al., 2020), polysaccharides extracted from SCG were utilized to produce biopolymeric films. Adsorbents were also derived from SCG to adsorb different known contaminants such as tetracycline and strontium (V.-T. Nguyen et al., 2021; Shin et al., 2021).

In a study conducted by (Shin et al., 2021), magnetic and non-magnetic biochar were derived from SCG to adsorb strontium ions (Sr^{2+}). Magnetic biochar was obtained by mixing pre-treated SCG into $FeCl_3 \bullet_6H_2O$ which allows it to become an easily recoverable adsorbent via magnets once the adsorption process is finished. Characterization of both materials exhibited different surface morphological structures and elemental analysis. Magnetic biochar contained traces of Fe, implying that it was successfully impregnated in the SCG, making it magnetic. However, both materials showed no significant difference in their adsorption capacities of Sr^{2+}.

Alkaline-modified SCG were utilized in a study conducted by (V.-T. Nguyen et al., 2021) to adsorb tetracycline from aqueous solutions. SCG was impregnated with NaOH then carbonized with N^2 gas. The adsorbent obtained was able to adsorb 113.64

mg/g of tetracycline which is almost three times of the tetracycline adsorbed by untreated SCG (39.22 mg/g).

Several studies in different fields such as medicine, social sciences, and environmental sciences have used systematic mapping to review the research trend about a certain topic or evaluate the performance of a specific material in a certain application. In a study conducted by Tigue et al. (2020), systematic mapping was utilized to review the existing trend on acid mine drainage treatment using geopolymer and permeable reactive barrier. Their systematic mapping approach consisted of five steps namely: Definition of Research Questions, Conduct Search, Screening of Papers, Keywording using Abstracts, and Data Extraction and Mapping. In this study, the aforementioned steps will be adapted and modified to provide a review on the utilization of SCG as an adsorbent using a systematic mapping approach framework. In order to achieve this objective, the following specific objectives are to be addressed:

SO1: To determine the different studies on adsorption utilization of SCG.

SO2: To determine the various processes utilized to produce adsorbent from SCG.

SO3: To identify the different contaminants SCG adsorbent is able to adsorb.

SO4: To identify the different characterization used for the SCG adsorbent.

SO5: To evaluate the performance of SCG as an adsorbent.

This study only focused on adsorbents derived from SCG and data extracted can be utilized to maximize its potential in future research studies. Furthermore, all research articles reviewed were obtained from Scopus only. Also, instead of SCG going into landfills and harming the environment, it can be further utilized and processed as an adsorbent to remove different known contaminants in wastewaters.

2. METHODOLOGY

In order to provide an organized review of the current findings on adsorption studies using SCG as a precursor for adsorbents, systematic mapping was utilized. Figure 2.1 illustrates the steps that were adapted and modified from the study of Tigue et al. (2020). All steps were followed asides from keywording, which was incorporated in the data extraction and mapping step.

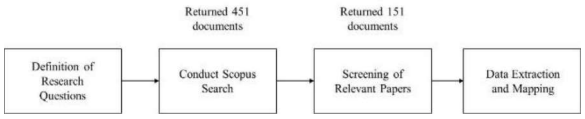

Figure 2.1. *Systematic Mapping Process*

2.1. Definition of Research Questions

The first step in this systematic process is the definition of research questions. Four research questions were synthesized to guide the whole systematic process as presented below.

These will aid in providing an overview of the studies through the relevant information and details present in every study.

RQ1: What is the research trend on adsorption studies using SCG?

RQ2: What are the processes utilized to produce adsorbent from SCG?

RQ3: What are the different contaminants adsorbed using SCG?

RQ4: What are the important characterizations and performance of SCG adsorbents?

2.2. Conduct Scopus Search

Scopus was used to gather the articles relevant to this study. A search string (TITLE-ABS-KEY (coffee AND grounds)) AND (adsorption) was defined to limit the results for the search process. Adsorption studies that utilized SCG were considered in the relevant searches.

2.3. Screening of Relevant Papers

Important information from the studies obtained were examined in screening of relevant papers. These information are mainly observed in the title, abstract, and keywords present in the study. The papers obtained were tabulated in spreadsheet format to present the extracted information in an organized manner. As can be seen in Figure 2.2, details such as title of publication, date of publication, authors, journal name, general utilization, and specific utilization were initially obtained and placed in a spreadsheet.

Authors	Title	Year	Source title	General Utilization	Specific Utilization	DOI
Shin J., Lee Y.-G., Kwak J., Kim S., Lee S.-H., Park Y., Lee S.-D., Chon K.	Adsorption of radioactive strontium by pristine and magnetic biochars derived from spent coffee grounds	2021	Journal of Environmental Chemical Engineering	Adsorption	strontium	10.1016/j.jece.2021.105119
Nguyen V.-T., Nguyen T.-B., Huang C.P., Chen C.-W., Bui X.-T., Dong C.-D.	Alkaline modified biochar derived from spent coffee ground for removal of tetracycline from aqueous solutions	2021	Journal of Water Process Engineering	Adsorption	tetracycline	10.1016/j.jwpe.2020.101908
San Martin D., Orive M., Iñarra B., Garcia A., Goiri I., Atxaerandio R., Urkiza J., Zufia J.	Spent coffee ground as second-generation feedstuff for dairy cattle	2021	Biomass Conversion and Biorefinery	Food	feedstuff	10.1007/s13399-020-00610-7
Rangel A.V., Becerra M.G., Guerrero-Amaya H., Ballesteros L. M., Mercado D.F.	Sulfate radical anion activated agro-industrial residues for Cr(VI) adsorption: is this activation process technically and economically feasible?	2021	Journal of Cleaner Production	Adsorption	chromium	10.1016/j.jclepro.2021.125793
Saberian M., Li J., Donnoli A., Bonderenko E., Oliva P., Gill B., Lockrey S., Siddique R.	Recycling of spent coffee grounds in construction materials: A review	2021	Journal of Cleaner Production	Filler	construction materials	10.1016/j.jclepro.2021.125837
Oliveira G., Passos C.P., Ferreira P., Coimbra M.A., Gonçalves I.	Coffee by-products and their suitability for developing active food packaging materials	2021	Foods	Food	food packaging	10.3390/foods10030683
Ma Y., Jiang T., Zhang A., Cao J.	Spent coffee ground-based interfacial solar steam generation	2021	Journal of Material Cycles and Waste Management	Energy	solar steam	10.1007/s10163-020-01148-6
Mendoza Martinez C.L., Saari J., Melo Y., Cardoso M., de Almeida G.M., Vakkilainen E.	Evaluation of thermochemical routes for the valorization of solid coffee residues to produce biofuels: A Brazilian case	2021	Renewable and Sustainable Energy Reviews	Energy	biofuel	10.1016/j.rser.2020.110585
Padma Ishwarya S., Nisha P.	Foaming agents from spent coffee grounds: A mechanistic understanding of the modes of foaming and the role of coffee oil as antifoam	2021	Food Hydrocolloids	Food	foaming agent	10.1016/j.foodhyd.2020.106354
Azam K., Akhtar S., Gong Y.Y., Routledge M.N., Ismail A., Oliveira C.A.F., Iqbal S.Z., Ali H.	Evaluation of the impact of activated carbon-based filtration system on the concentration of aflatoxins and selected heavy metals in roasted coffee	2021	Food Control	Filtration	aflatoxins and heavy metals	10.1016/j.foodcont.2020.107583
Thant Zin M.M., Kim D.-J.	Simultaneous recovery of phosphorus and nitrogen from sewage sludge ash and food wastewater as struvite by Mg-biochar	2021	Journal of Hazardous Materials	Recovery	phosphorus and nitrogen	10.1016/j.jhazmat.2020.123704
Loffredo E., Parlavecchia M.	Use of plant-based sorbents and mycodegradation for the elimination of endocrine disrupting chemicals from soil: A novel facile and low-cost method	2021	Environmental Technology and Innovation	Sorbent	endocrine disrupting chemicals	10.1016/j.eti.2021.101358
Adan-Mas A., Alcaraz L., Arévalo-Cid P., López-Gómez F.A., Montemor F.	Coffee-derived activated carbon from second biowaste for supercapacitor applications	2021	Waste Management	Activated Carbon	supercapacitor	10.1016/j.wasman.2020.11.043
Rocha T.D.A.F., Ferreira M.D.C., Freire J.T.	Processing spent coffee ground powders for renewable energy generation: Mechanical dewatering and thermal drying	2021	Process Safety and Environmental Protection	Energy	renewable energy	10.1016/j.psep.2020.09.003

Figure 2.2. *Spreadsheet*

2.4. Data Extraction and Mapping

To address the defined research questions, relevant information was extracted. The information obtained were based on the studies acquired from the conduct search which were then screened and categorized. Relevant information such as adsorbate, processing and characterization of SCG, and adsorption capacity and removal efficiency reported in the study were analyzed to aid in gathering data which were used to answer the research questions.

3. RESULTS AND DISCUSSION

3.1. Research Trend on SCG Adsorbent Studies

The search string defined for studies on adsorption returned 451 papers, wherein 151 papers were considered relevant. As can be seen in Figure 3.1 the number of published papers per year was no more than 10 from 2002 to 2018 except for 2016, which eventually decreased in the following two years. In the year 2019, a sudden increase in the number of published papers was observed. This implies that studies on adsorption using SCG have just recently gained more attention. Hence, there is more to explore on the mentioned topic and systematic mapping would aid in providing an overview on the topic to know how to fully maximize the potential of SCG as an adsorbent.

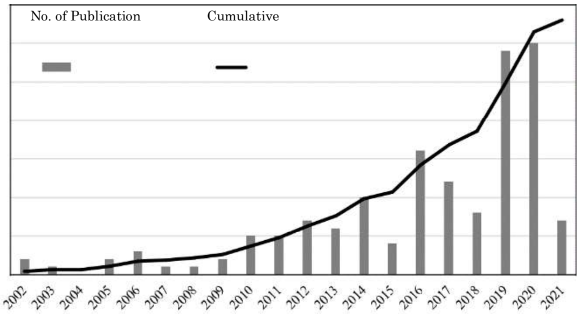

Figure 3.1. *Trend on SCG Adsorbent Studies*

3.2. Processing of Adsorbents Derived from SCG

SCG naturally contains 58.5% carbon content on a dry weight basis (Pujol et al., 2013). To fully maximize such property, they undergo processes such as drying, carbonization, activation, etc. These allow SCG to develop porous structures and high surface areas, wherein adsorbates can adhere during the process of adsorption. Moreover, processes involving production of adsorbent from SCG were categorized into two: Dried SCG and Processed SCG. Shown in Figure 3.2 is the flow of general processes performed on SCG to produce an adsorbent.

To produce Dried SCG, SCG are initially washed to remove impurities. Followed by drying or sieving, both of which could be interchanged. Processed SCG also undergo these, however additional steps are taken such as physical or chemical activation, and carbonization. These processes allow SCG to form a microporous or macroporous structure and high surface area to produce a more effective adsorbent (Yuliusman et al., 2017).

Aside from these common processes, some studies also added unique steps to obtain Dried SCG. Torres-Caban et al. (2019) pretreated SCG with 0.1M NaOH to further remove soluble materials. To reduce drying time and temperature, Loffredo and Taskin (2017) steam sterilized SCG in an autoclave at 121 ˚C for 15 minutes.

Studies that produced processed SCG also included innovative steps, such as ultrasonic treatment that increases the extraction of the components (Benyekkou et al., 2020), hydroalcoholic extraction process that was utilized to replace commonly used processes before activation (Alcaraz et al., 2019), and CO^2 plasma jet that produces activated carbon with unique surface morphology and pore size (Kang et al., 2020).

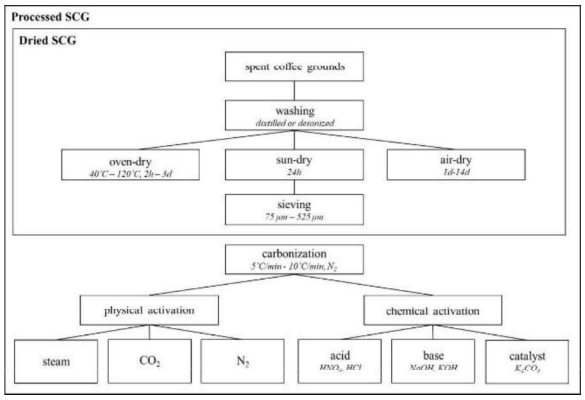

Figure 3.2. *Flow Diagram for Preparation of Adsorbents from SCG*

3.3. Contaminants Adsorbed by SCG Adsorbents

Figure 3.3 illustrates the corresponding percentage of papers published based on the contaminant SCG was able to adsorb. Some of the contaminants under the "Others" category are ozone, BTEX, crude oil, and livestock wastewater pollutants (Acosta et al., 2021; Hsieh & Wen, 2020; Huong et al., 2021; Sangpongchai & Prueksasit, 2017).

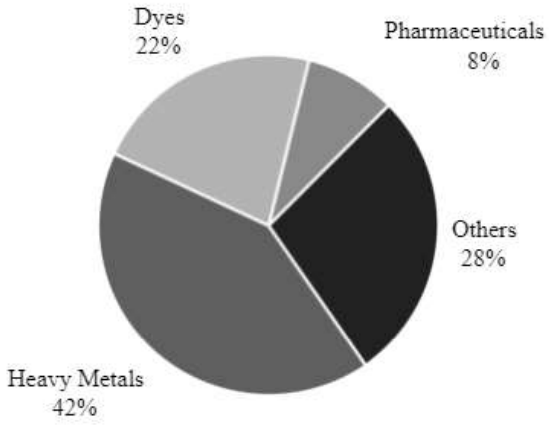

Figure 3.3. *Contaminants Adsorbed by SCG*

3.4. Important Characterizations of SCG Adsorbents

As SCG undergo various processes to derive adsorbent from it, characterization tests such as BET, Elemental Analysis, SEM, and FT-IR are conducted to verify if the processes were successful in producing an adsorbent. Seen in Table 3.1 are the range of values obtained for the different characterization tests conducted on adsorbents derived from SCG.

Table 3.1. *Important Characteristics of SCG Adsorbents*

Characterization	Range of Values
Surface Area (m^2/g)	0.047 – 2785
Pore Volume (cm^3/g)	0.00935 – 14.2
Pore Size (nm)	0.6– 520
Composition	
%C	30.59 – 99.64
%H	0.8– 18.56
%O	0.23 – 64.11
%N	0.8– 21.69
%Ash	1.8 – 37.7
SEM magnification (x)	40 – 50000
FT-IR (cm^{-1})	
C-H	630 – 3472
C-O	900 – 1741
O-H	613 – 3890

3.5. Performance of SCG as an Adsorbent

Heavy Metals

Figure 3.4 illustrates the adsorption capacity of SCG of heavy metals ranging from 0.657 mg/g up to 251.71 mg/g (Seniūnaite et al., 2018; Song et al., 2019). The removal efficiency, on the other hand, ranges from 60% to 100% as can be seen in Figure 3.5. Copper and zinc presented low removal efficiency of 18% and 9% respectively (Jutakridsada et al., 2016; Sertoli et al., 2019).

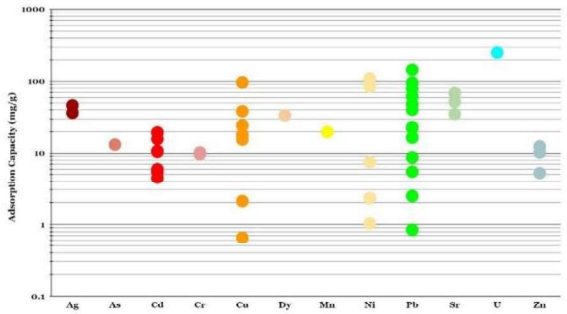

Figure 3.4. *Heavy Metals Adsorption Capacity of SCG*

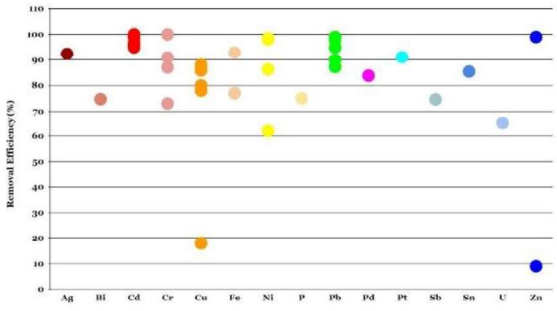

Figure 3.5. *Heavy Metals Removal Efficiency of SCG*

Dyes

As can be seen in Figure 3.6, the highest adsorption capacity exhibited by SCG is on an Anionic Azo Dye at 1222.5 mg/g (Jung et al., 2017) followed by methylene blue and acid orange 7 at 986.8 mg/g and 665.9 mg/g respectively (Jung et al., 2016). Moreover, Figure 3.7 illustrates that removal efficiency for dyes are all at least 80%.

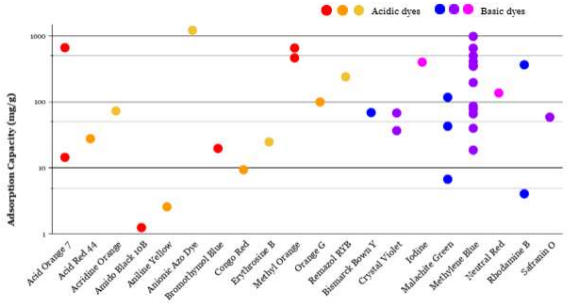

Figure 3.6. *Dyes Adsorption Capacity of SCG*

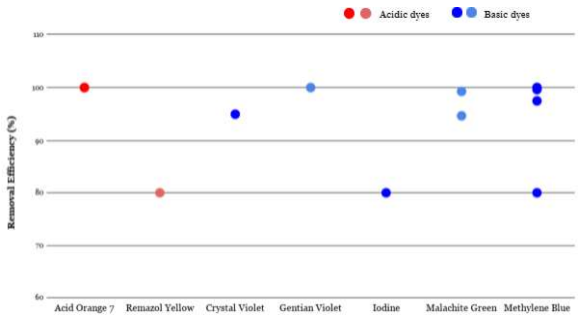

Figure 3.7. *Dyes Removal Efficiency of SCG*

Figure 3.7. *Dyes Removal Efficiency of SCG*

Pharmaceuticals

Based on the extracted data, pharmaceutical contaminants are the least explored in terms of using SCG as an adsorbent. Hence, as shown in Figure 3.8, the not very high adsorption capacity ranging from 5.5774 mg/g up to 370.37 mg/g as compared to heavy metals and dyes (V.-T. Nguyen, Nguyen, Chen, Hung, Huang, et al., 2019; Pavlović et al., 2015). It also exhibited a removal efficiency of 90%, 55%, and 96% for diclofenac, sulfamethoxazole, and tetracycline respectively (Lazarotto et al., 2020; Lykoudi et al., 2020; V.-T. Nguyen, Nguyen, Chen, Hung, Vo, et al., 2019). This also implies that there is more to explore in using SCG as an adsorbent for pharmaceutical contaminants.

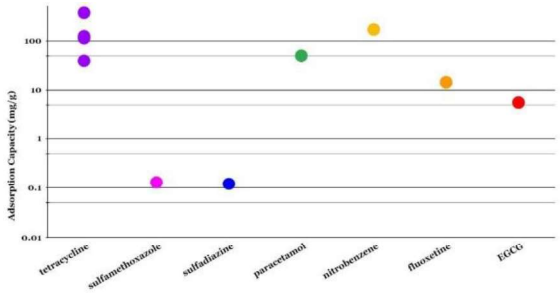

Figure 3.8. *Pharmaceuticals Adsorption Capacity of SCG*

4. CONCLUSION

This study has reviewed the potential of SCG as an adsorbent to many known contaminants of the environment. The results show that adsorption studies using SCG as a precursor for adsorbent have slowly been building up through the years and have recently gained more attention. It was found that as SCG contains high carbon content (58.5%), hence it undergoes processes such as drying, carbonization, and chemical and physical activation that will allow it to develop porous structures and high surface areas of up to 2785 m^2/g which are essential for adsorption. In addition, adsorbents derived from SCG are able to adsorb contaminants with adsorption capacity and removal efficiency of 1222.5 mg/g and 100%, respectively. These include heavy metals, dyes, and pharmaceuticals, all of which pose a hazard to the environment. Moreover, the data extracted and summarized from different studies can be utilized to maximize the potential of SCG as an adsorbent in future research studies. As this study was limited to 151 papers, more databases aside from Scopus can be explored to obtain more research papers that will undergo systematic review. This will give a wider overview of the current findings on SCG as an adsorbent to different known contaminants.

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6. REFERENCES

Acosta, L., Galeano-Caro, D., Medina, O. E., Cortés, F. B., & Franco, C. A. (2021). Nano-intermediate of magnetite nanoparticles supported on activated carbon from spent coffee grounds for treatment of wastewater from oil industry and energy production. Processes, 9(1), 1–21. https://doi.org/10.3390/pr9010063

Alcaraz, L., Escudero, M. E., Alguacil, F. J., Llorente, I., Urbieta, A., Fernández, P., & López, F. A. (2019). Dysprosium removal from water using active carbons obtained from spent coffee ground. Nanomaterials, 9(10). https://doi.org/10.3390/nano9101372

Ballesteros, L. F., Teixeira, J. A., & Mussatto, S. I. (2014). Chemical, Functional, and Structural Properties of Spent Coffee Grounds and Coffee Silverskin. Food and Bioprocess Technology, 7(12), 3493–3503. https://doi.org/10.1007/s11947-014-1349-z

Benyekkou, N., Ghezzar, M. R., Abdelmalek, F., & Addou, A. (2020). Elimination of paracetamol from water by a spent coffee grounds biomaterial. Environmental Nanotechnology, Monitoring and Management, 14. https://doi.org/10.1016/j.enmm.2020.100396

Coelho, G. O., Batista, M. J. A., Ávila, A. F., Franca, A. S., & Oliveira, L. S. (2020). Development and characterization of biopolymeric films of galactomannans recovered from spent coffee grounds. Journal of Food Engineering, 289, 110083. https://doi.org/10.1016/j.jfoodeng.2020.110083

Crumbley, L. (2009). Climate for Action: New Uses for Used Coffee Grounds. The EPA Blog. https://blog.epa.gov/2009/02/24/climate-for-action/

Getachew, A. T., & Chun, B. S. (2017). Influence of pretreatment and modifiers on subcritical water liquefaction of spent coffee grounds: A green waste valorization approach. Journal of Cleaner Production, 142, 3719–3727. https://doi.org/10.1016/j.jclepro.2016.10.096

Hsieh, P.-F., & Wen, T.-Y. (2020). Evaluation of Ozone Removal by Spent Coffee Grounds. Scientific Reports, 10(1). https://doi.org/10.1038/s41598-019-56668-5

Huong, T. T. T., Van Hoang, N., Ngoc Toan, V., Tong, N. X., Quan, T. A., & Thu, V. K. (2021). Initial Results of Using Biochar Derived from Spent Coffee Grounds to Remove Pollutants from Livestock Wastewater in Vietnam. In Lecture Notes in Civil Engineering (Vol. 108). https://doi.org/10.1007/978-3-030-60269-7_16

International Coffee Organization. (2020). Total production by all exporting countries. http://www.ico.org/prices/po-production.pdf

Jung, K.-W., Choi, B. H., Hwang, M.-J., Choi, J.-W., Lee, S.-H., Chang, J.-S., & Ahn, K.-H. (2017). Adsorptive removal of anionic azo dye from aqueous solution using activated carbon derived from extracted coffee residues. Journal of Cleaner Production, 166, 360– 368. https://doi.org/10.1016/j.jclepro.2017.08.045

Jung, K.-W., Choi, B. H., Hwang, M.-J., Jeong, T.-U., & Ahn, K.-H. (2016). Fabrication of granular activated carbons derived from spent coffee grounds by entrapment in calcium alginate beads for adsorption of acid orange 7 and methylene blue. Bioresource Technology, 219, 185–195. https://doi.org/10.1016/j.biortech.2016.07.098

Jutakridsada, P., Prajaksud, C., Kuboonya-Aruk, L., Theerakulpisut, S., & Kamwilaisak, K. (2016). Adsorption characteristics of activated carbon prepared from spent ground coffee. Clean Technologies and Environmental Policy, 18(3), 639–645. https://doi.org/10.1007/s10098-015-1083-x

Kang, H., Choi, S., Lee, J. H., Kim, K.-T., Song, Y.-H., & Lee, D. H. (2020). Plasma jet assisted carbonization and activation of coffee ground waste. Environment International, 145. https://doi.org/10.1016/j.envint.2020.106113

Lazarotto, J. S., de Lima Brombilla, V., Silvestri, S., & Foletto, E. L. (2020). Conversion of spent coffee grounds to biochar as promising TiO2 support for effective degradation of diclofenac in water. Applied Organometallic Chemistry, 34(12). https://doi.org/10.1002/aoc.6001

Loffredo, E., & Taskin, E. (2017). Adsorptive removal of ascertained and suspected endocrine disruptors from aqueous solution using plant-derived materials. Environmental Science and Pollution Research, 24(23), 19159–19166. https://doi.org/10.1007/s11356-017-9595-z

Lykoudi, A., Frontistis, Z., Vakros, J., Manariotis, I. D., & Mantzavinos, D. (2020). Degradationof sulfamethoxazole with persulfate using spent coffee grounds biochar as activator. Journal of Environmental Management, 271. https://doi.org/10.1016/j.jenvman.2020.111022

Nguyen, H. C., Nguyen, M. L., Wang, F. M., Liang, S. H., Bui, T. L., Ha, H. H., & Su, C. H. (2019). Using switchable solvent as a solvent and catalyst for in situ transesterification of spent coffee grounds for biodiesel synthesis. Bioresource Technology, 289, 121770. https://doi.org/10.1016/j.biortech.2019.121770

Nguyen, V.-T., Nguyen, T.-B., Chen, C.-W., Hung, C.-M., Huang, C. P., & Dong, C.-D. (2019). Cobalt-impregnated biochar (Co-SCG) for heterogeneous activation of peroxymonosulfate for removal of tetracycline in water. Bioresource Technology, 292. https://doi.org/10.1016/j.biortech.2019.121954

Nguyen, V.-T., Nguyen, T.-B., Chen, C.-W., Hung, C.-M., Vo, T.-D.-H., Chang, J.-H., & Dong,

C.-D. (2019). Influence of pyrolysis temperature on polycyclic aromatic hydrocarbons production and tetracycline adsorption behavior of biochar derived from spent coffee ground. Bioresource Technology, 284, 197–203. https://doi.org/10.1016/j.biortech.2019.03.096

Nguyen, V.-T., Nguyen, T.-B., Huang, C. P., Chen, C.-W., Bui, X.-T., & Dong, C.-D. (2021). Alkaline modified biochar derived from spent coffee ground for removal of tetracycline from aqueous solutions. Journal of Water Process Engineering, 40. https://doi.org/10.1016/j.jwpe.2020.101908

Pavlović, M. D., Buntić, A. V., Šiler-Marinković, S. S., Antonović, D. G., & Dimitrijević-Branković, S. I. (2015). Recovery of (−)-epigallocatechingallate (EGCG) from aqueous solution by selective adsorption onto spent coffee grounds. European Food Research and Technology, 241(3), 399–412. https://doi.org/10.1007/s00217-015-2472-4

Pujol, D., Liu, C., Gominho, J., Olivella, M. À., Fiol, N., Villaescusa, I., & Pereira, H. (2013). The chemical composition of exhausted coffee waste. Industrial Crops and Products, 50, 423–429. https://doi.org/10.1016/j.indcrop.2013.07.056

Sangpongchai, S., & Prueksasit, T. (2017). Adsorption efficiency of the activated charcoal produced from spent coffee ground for removal of the BTEX released from indoor paint. EnvironmentAsia, 10(1), 99–108. https://doi.org/10.14456/ea.2017.12

Seniūnaite, J., Vaiškūnaite, R., & Paliulis, D. (2018). Coffee grounds as low-cost adsorbent for the removal of copper (II) and lead (II) from aqueous solutions. Bulgarian Chemical Communications, 50(1), 74–81.

Sertoli, L., Carnier, R., de Abreu, C. A., Coscione, A. R., & Melo, L. C. A. (2019). Coffee waste biochars: Characterization and zinc adsorption from aqueous solution. Coffee Science, 14(4), 518–529. https://doi.org/10.25186/cs.v14i4.1634

Shahbandeh, M. (2021). Coffee market: worldwide production 2003/04-2019/20. Statista. https://www.statista.com/statistics/263311/worldwide-production-of-coffee/#statisticContainer

Shin, J., Lee, Y.-G., Kwak, J., Kim, S., Lee, S.-H., Park, Y., Lee, S.-D., & Chon, K. (2021). Adsorption of radioactive strontium by pristine and magnetic biochars derived from spent coffee grounds. Journal of Environmental Chemical Engineering, 9(2). https://doi.org/10.1016/j.jece.2021.105119

Song, S., Gu, P., Chen, Z., Wang, X., Zhang, R., & Wen, T. (2019). Removal of U(VI) by acid-oxidized biochar: Batch experiments and spectroscopy study. Scientia Sinica Chimica, 49(1), 155–164. https://doi.org/10.1360/N032018-00143

Szenthe, A. (2020). Top Coffee Producing Countries. World Atlas. https://www.worldatlas.com/articles/top-coffee-producing-countries.html

Tigue, A. A. S., Malenab, R. A. J., & Promentilla, M. A. B. (2020). A Systematic Mapping and Scoping Review on Geopolymer and Permeable Reactive Barrier for Acid Mine Drainage Treatment Research. Process Integration and Optimization for Sustainability, 4(1), 15–35. https://doi.org/10.1007/s41660-020-00105-y

Torres-Caban, R., Vega-Olivencia, C. A., & Mina-Camilde, N. (2019). Adsorption of Ni2+ and Cd2+ from water by calcium Alginate/Spent coffee grounds composite beads. Applied Sciences (Switzerland), 9(21). https://doi.org/10.3390/app9214531

Yuliusman, Nasruddin, Afdhol, M. K., Haris, F., Amiliana, R. A., Hanafi, A., & Ramadhan, I. T. (2017). Production of activated carbon from coffee grounds using chemical and physical activation method. Advanced Science Letters, 23(6), 5751–5755. https://doi.org/10.1166/asl.2017.8822

Assessing the Technological Maturity of Vegetable Protein-Based Biodegradable Packaging Material Production

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Abstract: The insurgence of plastic waste has posed a detrimental challenge to the environment. Despite actions taken, the plastic problem persists, giving rise to several other issues affecting life on Earth. One of the identified solutions to avert this is to create a biodegradable alternative that would limit plastic dependency and limit the pressure on the environment. In this paper, the current vegetable protein-based packaging industry was explored. This includes the emergence of biodegradable films, innovations applied in their development, and market adoption barriers. This also considers synthesizing the developed films' pertinent properties as a vital component to knowing whether it satisfies its purpose as intended. From a set of established criteria, a narrative review was conducted on 40 selected published journal articles from the Elsevier-Science Direct database on vegetable protein-based biodegradable packaging (PBBP) material. The findings of the study present a wide range of credible alternatives exhibiting competitive properties. While PBBP is still not at par with conventional plastics, the defined gaps in this sector could be a stepping stone for future studies to focus on developing low-cost methods and materials while giving equal importance to durability and biodegradability, hence, a broader scale for PBBP adoption.

Key Words: plastic alternatives; bioplastic; mechanical properties; plastic pollution

1. INTRODUCTION

Throughout the years, plastics were widely used by society. According to Thompson et al. (2009), plastics are lightweight, durable, corrosion-resistant materials with high thermal and electrical insulation properties, and were given importance due to its versatility and convenience. However, plastics have negatively impacted the environment. Plastic pollution became one of the pressing environmental issues, as its rapid increase in production overwhelms the world's capability to deal with it. The world's plastic production totaled around 359 million metric tons in 2018, where non-biodegradable single-use plastics account for 40 percent (Tiseo, 2021).

In the Philippines, plastic pollution is also rampant. An article by the World Wide Fund for Nature (2018) pointed out the factors causing the enormous amount of plastics: people continuously purchasing in small amounts that resulted in more waste; and improper waste disposal, making the country one of the world's leading plastic polluters. While environmental preservation is a significant task for the government and other environmentally-allied professionals, it is incumbent among all people to be vigilant and concerned about this issue.

To address this problem, biodegradable plastics derived from natural sources that do not contain harmful chemical fillers and quickly break down were created (Connecticut Plastics, 2020). However, biodegradable plastic production is deemed costly, given the pertinent processes and needed components.

That made the researchers interested in assessing the technological readiness of a plastic alternative, namely vegetable protein-based biodegradable packaging materials, if ready for mass production and utilization, that will take a step further in lessening conventional plastic use. With that, they would highlight and synthesize the recent innovations in PBBP material development and define the impediments that prevent its wider adoption in various industries.

2. METHODOLOGY

The study's design is a narrative review, a type of qualitative research synthesis that analyzes a body of literature with diverse methodologies and theoretical conceptualizations (Baumeister, 2013). It focused on a specific type of plastic alternative, biodegradable protein films.

To narrow down the research scope, a set of criteria was established for the article selection: (1) the film must have a vegetable protein matrix; (2) it must highlight any innovation in components, process, or properties; (3) it must present quantitative data on the mechanical properties; and (4) it must be a journal

article published within the last five years. Although quantitative data is pertinent, the review did not employ the statistical significance of the individual findings.

Data collection was primarily done using the internet. The Elsevier-Science Direct database was mainly utilized as it provides a wide range of bibliographic data regarding biodegradable films. A comprehensive bibliographic search was carried out using the following search string keywords: Biodegradable Packaging Material; Biodegradable Films; Vegetable Proteins; Innovation; and Mechanical Properties, and with publication year ranging from 2015 to 2020. The search results were refined to published journal articles. No books and review articles were included because these do not provide a thorough discussion regarding the studies. A total of forty (40) studies on innovations in PBBP materials were pooled.

An analysis of the collated studies was also conducted. First, the studies were assessed based on the type of innovation and publication year to display the recent trends and characteristics of PBBP research by presenting illustrative representations. Second, the journal articles were sorted per innovation, and salient, emerging themes were identified. A qualitative discussion was imparted to synthesize the studies' findings. Lastly, an analysis of the Strengths, Weaknesses, Opportunities, and Threats (SWOT) of PBBP production was undertaken to display extensive understanding of the industry's internal and external attributes.

3. RESULTS AND DISCUSSION

Fig. 1. Recent innovations on PBBP materials.

The most ventured innovation among the gathered studies, as shown in Figure 1, is the incorporation of bio composite materials as reinforcement and experimentation on film development process. Following those were studies that focused on strengthening mechanical properties and the causation of inhibitory properties as researchers also took note of bacterial infections and food spoilages.

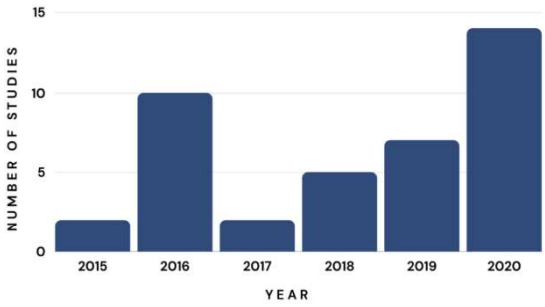

Fig. 2. Pooled studies based on publication year.

Figure 2 shows the collated studies based on publication year from 2015 to 2020, to ensure a synthesis that is relevant in today's context. Out of all 40 gathered studies, 14 were published in 2020, whereas 10 of the studies were published in 2016, as slightly old but still pertinent innovations were considered. Lastly, 5 and 7 studies were from 2018 and 2019, respectively, while 2 studies were published in 2015 and 2017 each.

3.1 Innovations Incorporating Composite Materials

Table 1. Remarkable innovations incorporating composite materials on PBBP.

Vegetable Protein	Incorporated Composite Material	Notable Findings	Reference
Soy	Cellulose nanocrystals (CNCs); pine needle extract (PNE)	The addition of CNCs: • lowered moisture content; • enhanced TS and EAB. The addition of PNE decreased WVP.	Yu et al. (2018)
	Cellulose nanofibers (CNFs)	The addition of 1.0 mL CNFs led to: • highest TS; • higher heat capacity.	Borela & Apolinar (2020)
Whey	Oat husk nanocellulose (ONC)	The addition of 5 wt% ONC: • decreased moisture content; • decreased WVP by 34%; • increased TS by 93%; • increased Young's modulus by 47%;.	Qazanfarzadeh & Kadivar (2016)
	Cellulose nanofibers with polymethyl methacrylate (CNF-g-PMMA)	The addition of CNF: • decreased water permeation by 51-64%; • enhanced TS.	Samadani et al. (2019)
Zein	Pomegranate peel extract (PE) in chitosan nanoparticles (CSNPs)	The addition of CSNPs/PE increased: • TS; • EAB; • heat flow.	Cui et al. (2020)

Note: TS - tensile strength; WVP - water vapor permeability; EAB - elongation at break

Various studies in creating protein-based biodegradable films sought into adding composite materials into the film matrix for reinforcement. The incorporated biocomposites commonly include cellulose fibers, chitosan particles, and plant extracts. The findings of these studies, as shown in Table 1, highlighted improved barrier and mechanical properties, especially moisture content, water vapor permeability, and tensile strength that are usually assessed in biodegradable packaging materials. Hence, the incorporation of composite materials led to enhanced properties of vegetable PBBP films that could springboard future studies that will venture into creating improved biodegradable packaging materials for wider adoption.

3.2 Innovations on Film Development Process

Components	Process	Notable Findings	References
PPI, glycerol	Injection molding	A 70:30, PPI:glycerol ratio, exhibits: • enhanced elastic bending, TS; • ability to absorb mechanical energy before rupturing; • fast water uptake capacity.	Perez et al. (2016)
SPI, cassava starch, stearic & citric acid	Extrusion, thermocompression	A 40:60, cassava starch: SPI ratio, exhibits: • high maximum TS, water solubility; • good WVP and oil permeability.	Ferreira et al. (2020)
WPI, glycerol	Ultraviolet radiation treatment, heat treatment	The highest dose of UV treatment, 12 J cm^{-1}, increased: • TS; • puncture strength; • deformation; • elastic modulus. Heat treatment improved the film's functionality.	Diaz et al. (2016)
Zein, chitosan	Cold plasma treatment	Films treated with cold plasma: • increased barrier properties; • enhanced zein and chitosan molecules compatibility.	Chen et al. (2019)
WPI, carboxymethylated chitosan (CMC)	Transglutaminase (TGase) treatment	WPI-CMC (75:25) film treated with TGase improved: • WVP; • mechanical properties.	Jiang et al. (2016)

Note: SPI - Soy Protein Isolate; WPI - Whey Protein Isolate; PPI - Pea Protein Isolate; TS - Tensile Strength; WVP - Water Vapor Permeability

Based on the studies, an inhibiting factor for PBBP utilization is the costly and complex processing methods of transforming proteins into biodegradable films. Different processes have been explored, including integrating conventional techniques like injection molding, and extrusion. However, this still requires reinforcement techniques that emanate additional costs. Some of these techniques are shown in Table 2. As indicated, the incorporation of such processes improved the films' properties, enabling them to achieve their packaging function.

3.3 Innovations Strengthening Mechanical Properties

Table 3. Recent innovations strengthening mechanical properties of the films.

Components	Mechanical Properties	Notable Findings	References
SPI, GPTMS, POSS	TS: SPI: 33.3 SPI:GPTMS:POSS: 62.1 EAB: SPI: 213.5 SPI:GPTMS:POSS: 101.2	Adding GPTMS and POSS increased TS and offset yield strength.	Xia et al. (2016)
SPI, CNC, glycerol	TS: 3.13 to 4.79 EAB: 98.2 to 86.5	Modified film using CNC increased TS by 23%.	Zhang et al. (2016)
Nanocellulose, whey protein isolate, bergamot oil	WPI: EM:135.8 ± 32.0b TS: 19.8 ± 2.5ab E:14.7 ± 2.7bc WPI-10NC: EM:180.7 ± 20.7b TS:29.4 ± 1.4a E:26.3 ± 8.9ab	Mixing nanocellulose and bergamot oil with WPI enhanced the mechanical resistance and WVP.	Sogut (2020)
SPI, rapeseed oil concentration (ROC)	TS: ROC1: 1.21(0.42) ROC3: 0.91(0.19) YM: ROC1: 0.91(0.29) ROC3: 0.68(0.12) EAB: ROC1: 4.12(0.14) ROC3: 4.19(0.16)	ROC improved WVP. Increasing dosage from 1% to 3% induced favorable mechanical properties.	Galus (2018)
SPI, ZPI	1/1TS: 1.320±0.288 2/1TS: 1.628±0.861 1/2TS: 3.387±0.564	Higher amounts of zein in composite films strengthened its structure.	Tsai & Weng (2020)

Note: SPI - Soy Protein Isolate; TS - Tensile Strength in MPa; EAB - Elongation at Break in %; YM - Young Modulus in MPa;

3.4 Innovations Triggering Inhibitory Properties

Table 4. Notable studies venturing into PBBPs' causation of inhibitory properties.

Components	Method Used	Microbes Tested		Inhibition Zone	References
WPI, water soluble chitosan	Agar Disk Diffusion Method	Fungi	*Aspergillus niger*	WPI[c]: ND WSCh1.5%(w/w): 54.17[a] WSCh3%(w/w): 87.50[a]	Vanden Braber et al. (2020)
			Fusarium sp.	WPI[c]: ND WSCh1.5%(w/w): 52.50[a] WSCh3%(w/w): 52.50[a]	
			Penicillium roqueforti	WPI[c]: ND WSCh1.5%(w/w): 82.50[a] WSCh3%(w/w): 97.50[a]	
			Rhizopus sp.	WPI[c]: ND WSCh1.5%(w/w): 52.50[a] WSCh3%(w/w): 97.50[a]	
WPI, TiO_2 nanoparticles, cellulose nanofibers (CNFs), rosemary essential oil (REO)		Gram-positive	*S. aureus*	WPI:CNFs[c]: ND WPI/TiO_2/REO had the most effect Besides the control, WPI/REO had the least effect	Alizadeh-Sani et al. (2018)
			L. monocytogenes		
		Gram-negative	*E. coli O157:H7*		
			P. fluorescens		
			S. enteritidis		
ZPI, cinnamon essential oil (CEO), chitosan nanoparticles (CNP)		Gram-positive *S. aureus*		zein[c]: ND zein & CNPs: ND zein & CEO: 21.66±0.57[b] zein, CNPs & CEO: 27.33±1.93[b]	Vahedikia et al. (2019)
		Gram-negative *E. coli*		zein[c]: ND zein & CNPs: ND zein & CEO: 11.00±1.00[b] zein, CNPs, & CEO: 11.33±1.61[b]	
Chinese chive extract root, chitosan		Gram-positive	*S. aureus*	CS[c]: 7.13±0.14[a] CS-CRE1: 10.64±0.21[a] CS-CRE3: 14.73±0.29[a] CS-CRE5: 18.12±0.36[a]	Riaz et al. (2020)
			B. cereus	CS[c]: 6.21±0.12[a] CS-CRE1: 11.83±0.23[a] CS-CRE3: 15.39±0.30[a] CS-CRE5: 18.79±0.37[a]	
		Gram-negative	*E. coli*	CS[c]: 4.43±0.08[a] CS-CRE1: 7.18±0.14[a] CS-CRE3: 12.87±0.25[a] CS-CRE5: 16.21±0.32[a]	
			S. typhimurium	CS[c]: 4.11a0.08[a] CS-CRE1: 6.87±0.13[a] CS-CRE3: 11.54±0.23[a] CS-CRE5: 14.91±0.29[a]	
SPI, cortex phellodendron extract		Gram-positive *S. aureus*		The inhibition zones for *S. aureus* were larger than for *E. coli*.	Liang & Wang (2018)
		Gram-negative *E. coli*			

Note: WPI - whey protein isolate; SPI - soy protein isolate; ZPI - zein protein isolate; ND - not detected; [a] diameter in mm; [b] diameter in mm^2; [c] control group;

Some conducted studies gave attention to the provocation of inhibitory properties, aside from strengthening the mechanical properties in a produced PBBP material. These researchers sought to obtain active packaging films that can help prevent food spoilages or bacterial infection. In doing that, the credibility of the film improved, and as seen in Table 4, said researchers were successful in doing so.

Note: The complete list of innovations is available upon request.

3.5 SWOT Analysis

Table 5. SWOT analysis on the collated studies regarding PBBP films.

Factor	Highlights			
Strengths	Lessened environmental burden	Reduced petroleum consumption	Expanding interest in the field of PBBP	Competitive properties
Weaknesses	Availability of pertinent equipment for production	Innovations further aligned into strengthening mechanical properties	Fastidious environmental conditions	
Opportunities	Environmental consciousness	Unintended benefits	Variety of applications	Business opportunity
Threats	Consumer acceptance	Unpreparedness for mass-market production	Expensiveness of the production process and raw materials	Risk of an environmental crisis due to waste build-up

3.5.1 Strengths

The PBBPs showed biodegradability varying from weeks to months, depending on raw materials added into the formulation, and they were composed of vegetable proteins and other bio-based materials, instead of non-renewable petroleum, which is harmful to the environment. An increase in the number of PBBP-related studies was also observed, mirroring that, people become more engaged and aware of climate change while addressing the sustainability problem. Lastly, promising properties of PBBPs that are not present with conventional plastics are being initiated, like inhibitory properties.

3.5.2 Weaknesses

Some steps in creating PBBP materials require proper treatment of raw materials using certain pieces of equipment that are not usually available for most countries that could be interested in producing PBBPs for market use. Meanwhile, studies usually lean into achieving sufficient mechanical properties and not on the improvement of film biodegradation. That is crucial, for the driving force behind the PBBP creation is producing packaging materials that help address plastic pollution. Regarding biodegradability, some films degrade only in a certain environment, where others require composting facilities that cater to biodegradable packaging waste, while some employ chemical and other degrading techniques.

3.5.3 Opportunities

People start to realize the possible consequences of harmful activities to the environment. Amongst studies exploring PBBP, plastic pollution is the common dilemma motivating researchers to contribute to the existing body of knowledge and create a step towards limiting single-use plastic consumption. Concerning the development of biodegradable films, utilizing by-products like pomegranate and banana peels to reinforce their properties was seen to have an unintended benefit of solving poor waste disposal. Although some films and coatings show appreciable potential in biodegradable packaging production, conducting physical and chemical modifications may pave the way for market adoption, since people are more inclined to invest in environmentally-sound products nowadays. Producing viable plastic alternatives could become a sustainable market opportunity that both individuals and the environment can benefit from.

3.5.4 Threats

At present, few consumers have knowledge on the existence of PBBP films and its production, which can stem uncertainty, making it difficult to kickstart market consumption of such films. Additionally, due to the assurance that PBBP films can degrade, importance of preferable biodegradation conditions was downplayed, focusing instead on enhancing mechanical properties. As composite manufacturing is a highly specialized field and raw materials are costly, spending high amounts of money is inevitable in the production of composite PBBP films, leading to the question if the product is worth the trouble or not. Lastly, despite the created sustainable solution, the accumulation of PBBP film wastes is still inevitable as biodegradation requires certain conditions. Therefore, if said conditions are not met, that could potentially worsen the condition of the environment.

4. CONCLUSIONS

Over the past five years, innovative research on PBBPs has risen, predominantly on infusing composite materials and performing strengthening processes for the improvement of its properties. With that, its possibility of market production is high. However, the availability of pertinent equipment and uneconomical production cost makes its adoption still implausible. To accelerate development, future studies should consider developing ways in creating durable yet cost-friendly PBBPs. In addition to that, biodegradability should also be considered. Shortening the biodegradation time and establishing a wide range of environmental conditions for degradation are some aspects to improve on. While PBBPs can reduce plastic consumption, it is not the silver bullet to ending plastic pollution.

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6. REFERENCES

Alizadeh-Sani, M., Khezerlou, A., & Ehsani, A. (2018). Fabrication and characterization of the bionanocomposite film based on whey protein biopolymer loaded with TiO2 nanoparticles, cellulose nanofibers and rosemary essential oil. Industrial Crops and Products, 124, 300–315. https://doi.org/10.1016/j.indcrop.2018.08.001

Baumeister, R. F. (2013). Writing a literature review. In M. J. Prinstein & M. D. Patterson (Eds.), The portable mentor: Expert guide to a successful career in psychology (pp. 119-132; 2nd ed.). New York: Springer Science+ Business Media.

Borela, V. T., & Apolinar, D. A. (2020). Banana Peel Cellulose Nanofibers (CNFs) as Retrofitting Material to Soy-Protein in Manufacturing Biodegradable Food Packaging. Journal of Scientific Research in Medical and Biological Sciences, 1(1), 10–29. https://doi.org/10.47631/jsrmbs.v1i1.22

Chen, G., Dong, S., Zhao, S., Li, S., & Chen, Y. (2019). Improving functional properties of zein film via compositing with chitosan and cold plasma treatment. Industrial Crops and Products, 129, 318–326. https://doi.org/10.1016/j.indcrop.2018.11.072

Connecticut Plastics. (2020). Biodegradable Plastics. http://www.pepctplastics.com/resources/connecticut-plastics-learning-center/biodegradable-plastics/

Cui, H., Surendhiran, D., Li, C., & Lin, L. (2020). Biodegradable zein active film containing chitosan nanoparticle encapsulated with pomegranate peel extract for food packaging. Food Packaging and Shelf Life, 24, 100511. https://doi.org/10.1016/j.fpsl.2020.100511

Díaz, O., Candia, D., & Cobos, Á. (2016). Effects of ultraviolet radiation on properties of films from whey protein concentrate treated before or after film formation. Food Hydrocolloids, 55, 189–199. https://doi.org/10.1016/j.foodhyd.2015.11.019

Ferreira, L. F., de Oliveira, A. C. S., Begali, D. D. O., Neto, A. R. D. S., Martins, M. A., de
Oliveira, J. E., Borges, S. V., Yoshida, M. I., Tonoli, G. H. D., & Dias, M. V. (2021). Characterization of cassava starch/soy protein isolate blends obtained by extrusion and thermocompression. Industrial Crops and Products, 160, 113092. https://doi.org/10.1016/j.indcrop.2020.113092
Galus, S. (2018). Functional properties of soy protein isolate edible films as affected by rapeseed oil concentration. Food Hydrocolloids, 85, 233–241. https://doi.org/10.1016/j.foodhyd.2018.07.026

Jiang, S.-juan, Zhang, X., Ma, Y., Tuo, Y., Qian, F., Fu, W., & Mu, G. (2016). Characterization of whey protein-carboxymethylated chitosan composite films with and without transglutaminase treatment. Carbohydrate Polymers, 153, 153–159. https://doi.org/10.1016/j.carbpol.2016.07.094

Liang, S., & Wang, L. (2018). A Natural Antibacterial-Antioxidant Film from Soy Protein Isolate Incorporated with Cortex Phellodendron Extract. Polymers, 10(1), 71. https://doi.org/10.3390/polym10010071

Perez, V., Felix. M., Romero, A., and Guerrero, A. (2016). Characterization of pea protein-based
bioplastics processed by injection moulding. Food and Bioproducts Processing, 97(2016), 100-108. https://doi.org/10.1016/j.fbp.2015.12.004

Qazanfarzadeh, Z., & Kadivar, M. (2016). Properties of whey protein isolate nanocomposite films reinforced with nanocellulose isolated from oat husk. International Journal of Biological Macromolecules, 91, 1134–1140. https://doi.org/10.1016/j.ijbiomac.2016.06.077

Riaz, A., Lagnika, C., Luo, H., Dai, Z., Nie, M., Hashim, M. M., … Li, D. (2020). Chitosan-based biodegradable active food packaging film containing Chinese chive (Allium tuberosum) root extract for food application. International Journal of Biological Macromolecules, 150, 595–604. https://doi.org/10.1016/j.ijbiomac.2020.02.078

Samadani, F., Behzad, T., & Enayati, M. S. (2019). Facile strategy for improvement properties of whey protein isolate/walnut oil bio-packaging films: Using modified cellulose nanofibers. International Journal of Biological Macromolecules, 139, 858–866. https://doi.org/10.1016/j.ijbiomac.2019.08.042

Sogut, E. (2020). Active whey protein isolate films including bergamot oil emulsion stabilized by nanocellulose. Food Packaging and Shelf Life, 23, 100430. https://doi.org/10.1016/j.fpsl.2019.100430
Thompson, R. C., Moore, C. J., vom Saal, F. S., & Swan, S. H. (2009). Plastics, the environment and human health: current consensus and future trends. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526), 2153–2166. https://doi.org/10.1098/rstb.2009.0053

Tiseo, I. (2021). Global plastic production 1950-2019. https://www.statista.com/statistics/282732/global-production-of-plastics-since-1950/.

Tsai, M.-J., & Weng, Y.-M. (2019). Novel edible composite films fabricated with whey protein isolate and zein: Preparation and physicochemical property evaluation. LWT, 101, 567–574. https://doi.org/10.1016/j.lwt.2018.11.068

Vahedikia, N., Garavand, F., Tajeddin, B., Cacciotti, I., Jafari, S. M., Omidi, T., & Zahedi, Z. (2019). Biodegradable zein film composites reinforced with chitosan nanoparticles and cinnamon essential oil: Physical, mechanical, structural and antimicrobial attributes. Colloids and Surfaces B: Biointerfaces, 177, 25–32. https://doi.org/10.1016/j.colsurfb.2019.01.045

Vanden Braber, N. L., Di Giorgio, L., Aminahuel, C. A., Díaz Vergara, L. I., Martín Costa, A. O., Montenegro, M. A., & Mauri, A. N. (2021). Antifungal whey protein films activated with low quantities of water soluble chitosan. Food Hydrocolloids, 110, 106156. https://doi.org/10.1016/j.foodhyd.2020.106156

World Wide Fund for Nature. (2018). The scourge of single-use plastic in the Philippines. https://wwf.panda.org/knowledge_hub/where_we_work/coraltriangle/?329831/The-scourge-of-single-use-plastic-in-the-Philippines

Xia, C., Zhang, S., Shi, S. Q., Cai, L., Garcia, A. C., Rizvi, H. R., & D'Souza, N. A. (2016). Property enhancement of soy protein isolate-based films by introducing POSS. International Journal of Biological Macromolecules, 82, 168–173. https://doi.org/10.1016/j.ijbiomac.2015.11.024

Yu, Z., Sun, L., Wang, W., Zeng, W., Mustapha, A., & Lin, M. (2018). Soy protein-based films incorporated with cellulose nanocrystals and pine needle extract for active packaging. Industrial Crops and Products, 112, 412–419. https://doi.org/10.1016/j.indcrop.2017.12.031

Zhang, S., Xia, C., Dong, Y., Yan, Y., Li, J., Shi, S. Q., & Cai, L. (2016). Soy protein isolate-based films reinforced by surface modified cellulose nanocrystal. Industrial Crops and Products, 80, 207–213. https://doi.org/10.1016/j.indcrop.2015.11.070

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Oil Adsorption Capacity of Mahogany (*Swietenia macrophylla*) Fruit Shells in Varying Particle Sizes

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Abstract: The growing demands for petroleum products increase the risk of oil spills, and these accidents cause long-term devastation to biodiversity and communities. Researchers are now searching for adsorbents from biowastes due to current oil cleanup methods' costs and potential dangers. Hence, the lack of relevant studies and underutilization of mahogany *(Swietenia macrophylla)* fruit shells (MFS) have prompted an investigation into oil adsorption capacity and particle size effects. Sorption capacity was measured using untreated MFS in chosen particle sizes of B-8 (0.6mm<x<2mm) and B-25 (0.1mm<x<0.6mm) in pure oil and water systems and oil-water mixture. Contact time was optimized by comparing 1-hour and 24-hour exposure in the pure systems. Surface characterization showed heterogeneity with fiber aggregations and no porosity, limiting adsorption. One-Way Analysis of Variance determined contact time insignificance, greater water affinity of particles, and B-25 superiority, which achieved maximum adsorption of $1.886_{go/gmfs}$ in a pure oil system and $1.684_{go/gmfs}$ in an oil-water mixture due to the increased surface area in smaller particles. These results, combined with the limited usage of mahogany fruit shells, justify their use as a potential oil bioadsorbent.

Key Words: mahogany; particle size; oil spill; biosorbent; surface characterization

1. INTRODUCTION

The Exxon Valdez and Deepwater Horizon disasters in 1989 and 2010, respectively, are notable international oil spills; in the Philippines, the 2006 Guimaras oil spill headlines such occurrences. Although caused by varying factors in different places, the commonality between these disasters is a combination of destruction and long-term devastation. The adverse effects on marine life, seabird deaths, mangrove destruction, and community displacement recorded from these oil spills are proof of detrimental impacts to ecosystems, biodiversity, and humans (Barron et al., 2020; Beyer et al., 2016; Sacramento & Geges, 2019; Xia et al., 2017)

With 116,000 tons of oil released into water bodies in 2018 alone, these spills continue to pose significant risks to the environment (International Tanker Owners Pollution Federation Ltd., 2019). Researchers are developing cleanup techniques, with chemicals as the conventional means (Tewari & Sirvaiya, 2015). However, this approach is expensive and possibly dangerous to the environment if misused (El-Din et al., 2018; Shah et al., 2019). Thus, the need for inexpensive and sustainable alternative oil cleanup methods is highlighted in cases wherein the affected area lacks funds and resources. This challenge was apparent in the Guimaras oil spill, where the local government was forced to utilize an improvised approach in cleaning the oil using human hair and chicken feathers from the locals (Patil et al., 2020; Romero, 2006).

The mentioned materials employ the biosorption method, which offers an eco-friendly treatment for reducing and recovering contaminants such as oil from aqueous mediums by using biodegradables or biomasses (Doshi et al., 2018). Since biosorption is geared towards providing a more straightforward and inexpensive alternative to chemical methods, the renewability and availability of industrial and agricultural waste products make these suitable biosorbents (Mohammed et al., 2014; Wolok et al., 2020).

Mahogany (*Swietenia macrophylla*) is a tree species naturalized to the Philippines; its fruits are known for a bursting mechanism that disperses seeds. Although its bark chunks are used in treating wounds and infections, and its logs utilized for furniture, the commercially established purposes and uses of mahogany products do not employ the fruit shell, making these widely underutilized waste products (Sartape et al., 2015). Currently, there have only been two biosorption studies conducted using mahogany fruit shells (MFS), with Sartape et al. (2015) reporting up to 99.05% removal of methylene blue dye at pH 9 and Magoling & Macalalad (2017) achieving 92.3% Chromium (VI) removal efficiency.

Finding other uses of MFS may reduce waste in areas with dense mahogany tree populations, and the potential for a successful bioadsorbent may benefit coastal communities at the most significant risk of oil spills. Hence, the researchers tested and statistically determined the effect of varying the MFS particle size and contact time on water sorption and oil adsorption capacity. To further understand the biosorbent, scanning electron microscope (SEM) analysis was done for surface characterization. It is worth noting that the study is limited to a home-based setup; therefore, synthetic motor oil was used as a substitute for crude oil, and no saltwater simulation was done. The inability to perform a more complex laboratory study does not invalidate the findings of this study; given the lack of research focusing on MFS, insights and baseline data on oil adsorption in this study will expand the scientific community's knowledge body.

2. METHODOLOGY

2.1. Biosorbent Preparation and Characterization

A kilogram of dried mahogany fruit shells was procured from a seller in Tambulig, Zamboanga del Sur, Philippines. The MFS preparation of Sartape et al. (2015) was adapted. The shells were brushed to remove foreign particles and sun-dried for 72 hours. After crushing, the MFS underwent batch screening using BSS 8 and BSS 25 test sieves and a 100µm mesh (Figure 1). Particle sizes of B-8 and B-25 were produced with ranges of 0.6mm<x<2mm and 0.1mm<x<0.6mm (Figure 2). These were stored in airtight containers with desiccants until usage.

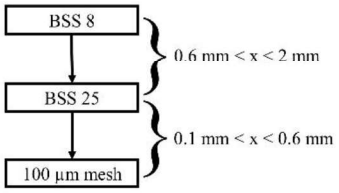

Figure 1. MFS Batch Screening Process

Figure 2. MFS Particle Sizes: (A) B-8 [0.6mm<x<2mm] (B) B-25 [0.1mm<x<0.6mm]

An MFS sample was sent via courier to the De La Salle University Central Instrumentation Facility (DLSU-CIF) for Scanning Electron Microscopy (SEM) using a JEOL JSM-IT500HR to perform surface characterization without Energy Dispersive X-ray Spectroscopy (EDS). Platinum sputtering was ordered, and magnifications of 50X, 200X, 1000X, and 5000X were selected for the prepared biosorbent.

2.2. Biosorption Experiments

The methodology of Ben Jmaa & Kallel (2019) was adapted for the preparation of the pure systems and oil-water mixture. In identical glass containers of 900g capacity, the pure oil and pure water systems were filled with 30g of Raimol Flash 4T Motor Oil 20W-40 SG/CD and water, respectively. The original oil-water mixture ratio of 30g of motor oil to 970g of water was downscaled to 6g:194g to fit the same containers.

The pure systems were used to determine the maximum oil adsorption and water sorption capacity of the MFS and optimize the contact time for the oil-water mixture. One experiment run of the pure systems comprises pure oil and pure water setups for each particle size. These systems were agitated for 10 minutes using a magnetic stirrer set to 1000rpm before introducing 0.45g of MFS, the standard loading for both chosen particle sizes in all experiments. Subsequently, the systems with biosorbent were mixed for a further 15 minutes before letting these settle until the assigned contact time. A comparison between 1-hour and 24-hour contact time and biosorption capacity was drawn by performing five experiment runs of the pure systems in both particle sizes for each chosen duration.

The oil-water mixture aimed to simulate the performance of the MFS biosorbent in oil spill applications. An experiment run consists of three setups containing motor oil and water in a 6g:194g ratio: B-8 (0.6mm<x<2mm), B-25 (0.1mm<x<0.6mm), and C (No biosorbent). These mixtures were agitated for 10 minutes using a magnetic stirrer set to 1000rpm before MFS loading. The stirrer continued mixing for an additional 15 minutes, after which the setups were left to settle until the investigated contact time. Due to the presence of water in the mixture, the spent MFS biosorbents were dried in an oven at 90°C until weight became constant.

A 100µm mesh was used to recover spent MFS in both pure systems and oil-water mixtures, while a jewelry scale with accuracy up to 0.001g and a capacity of 50g was used in weighing samples. Ethical disposal of generated waste products was observed throughout experimentation.

2.3. Data Analysis Strategy

As adopted from de Fátima Gorgulho et al. (2018), Equation (1) was used to compute oil and water sorption capacity (q) by subtracting the weight of the MFS before sorption (Wi) from the weight after sorption (Wf); the difference was then divided by Wi (Figure 3). The mean sorption capacity values were

interpreted using One-Way Analysis of Variance (ANOVA) to statistically determine the significance of contact time to sorption, after which the same tool was used to investigate the relationship of particle size to sorption. In addition, the significance of the difference between MFS oil adsorption and water sorption was statistically tested by using ANOVA to compare the means of each particle size of the same contact time (Figure 4).

$$q = \frac{W_f - W_i}{W_i} \quad (1)$$

Where:

q = sorption capacity

W_i = initial mass of the MFS (before sorption)

W_f = final mass of the MFS (after sorption)

Figure 3. Sorption Capacity Formula

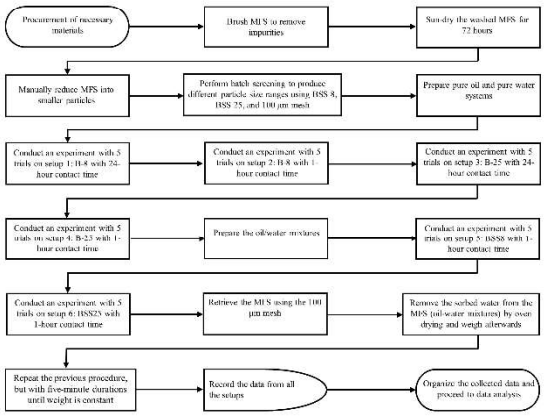

Figure 4. Flowchart of the Procedure

3. RESULTS AND DISCUSSION

3.1. Scanning Electron Microscope (SEM) Analysis

The analysis by the DLSU-CIF determined that at 50X magnification, the B-25 MFS sample consisted of long round-like fibers with varying sizes and inconsistent shape patterns (Figure 5). At 1000X, there were no signs of porosity; instead, a surface formed by aggregations of fiber layers and sheets was identified at 5000X (Figure 6). Fiber bundling in lignocellulosic biomasses such as MFS provides morphological structure (Lee et al., 2015; Magoling & Macalalad, 2017). Particle heterogeneity may increase adsorption as rough surface morphologies increase the surface area available (Meili et al., 2017; Shamim, 2018; Zanini et al., 2017).

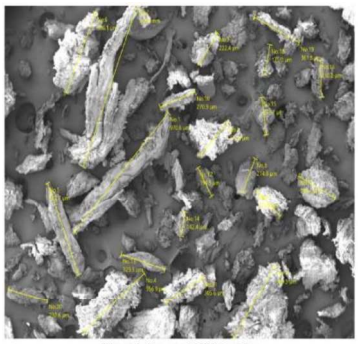

Figure 5. Measured MFS Particles

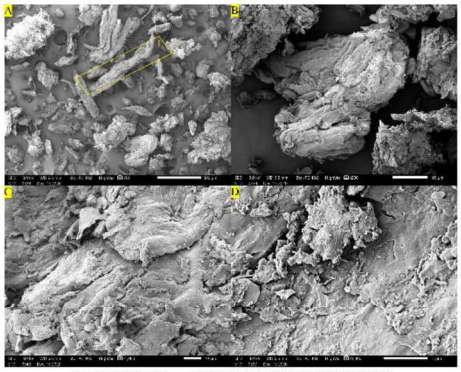

Figure 6. MFS SEM Images: (A) 50X (B) 200X (C) 1000X (D) 5000X

The SEM analysis findings are also aligned with the data from Sartape et al. (2015), who have reported beforehand that the MFS exhibit a rough surface morphology due to the incorporation of multiple particles that smoothened after adsorption.

3.2. Average Sorption Capacities in Pure Systems

Table 1. B-8 Mean Sorption Capacities

	Mean Sorption	
	1-hour	24-hour
Pure water *(g water / g MFS)*	2.173	1.995
Pure oil *(g oil / g MFS)*	1.558	1.649

Average water sorption for B-8 after five trials was $2.173_{gw/gmfs}$ and $1.995_{gw/gmfs}$ in 1-hour and 24-hour setups, respectively (Table 1). The results show that the shorter contact time produced better results when compared to the 24-hour exposure; therefore, informally validating the hypothesis that there are no significant drawbacks to choosing a 1-hour contact time. Mean oil adsorption shows $1.558_{go/gmfs}$ and $1.649_{go/gmfs}$ uptake in 1-hour and 24-hour setups, respectively (Table 1). Unlike the pure water system, the longer contact time is associated with greater adsorption capacity, prompting statistical analysis for the significance of the difference. The mean values for sorption in both assigned contact times suggest particles' greater affinity for water, as evidenced by the higher water sorption values.

Table 2. B-25 Mean Sorption Capacities

	Mean Sorption	
	1-hour	24-hour
Pure water *(g water / g MFS)*	2.827	2.822
Pure oil *(g oil / g MFS)*	1.769	1.886

Average water sorption for B-25 after five trials was $2.827_{gw/gmfs}$ and $2.822_{gw/gmfs}$ in 1-hour and 24-hour setups, respectively (Table 2). The results are consistent with the findings from the B-8 tests, showing that the shorter contact time produced better results. This trend suggests that there may be no significant adverse impacts if a 1-hour contact time is chosen. It is worth noting that the difference between the two is slim; hence, further statistical analysis is needed. Mean oil adsorption shows $1.769_{go/gmfs}$ and $1.886_{go/gmfs}$ uptake in 1-hour and 24-hour setups, respectively (Table 2). These values are aligned with the B-8 results, which presented greater oil adsorption capacity in 24 hours, prompting statistical analysis for the significance of the difference. Greater water sorption is also evident in the B-25 particle size.

3.3. Effects of Contact Time on Sorption Capacity

Table 3. Comparison of Sorption in 1-hour and 24-hour Contact Times

Dataset (1 hour vs. 24 hours)	P-value ($\alpha = 0.05$)	Remarks
B-8 (Pure Water)	0.546	Insignificant
B-8 (Pure Oil)	0.261	Insignificant
B-25 (Pure Water)	0.961	Insignificant
B-25 (Pure Oil)	0.288	Insignificant

The B-8 pure water and oil systems had a p-value of 0.546 and 0.261, respectively, when the two contact time groups were subjected to One-Way ANOVA. The B-25 pure water and oil systems garnered p-values of 0.961 and 0.288 when using the same statistical method (Table 3). The analysis proved that in all pure systems, regardless of particle size, the sorption capacities of 1-hour and 24-hour contact times were not significantly different ($p > 0.05$). This result determined that no significant drawbacks are attributed to a shorter exposure time. Therefore, the choice to employ a 1-hour contact time in the oil-water mixture experiments is justified.

3.4. Statistical Difference of Water Sorption and Oil Adsorption

Table 4. Comparison of Water and Oil Sorption Capacities

Dataset (Water Sorption vs. Oil Adsorption)	P-value ($\alpha = 0.05$)	Remarks
B-8 (1 hour)	0.035	Significant
B-8 (24 hours)	0.065	Insignificant
B-25 (1 hour)	6.6×10^{-5}	Significant
B-25 (24 hours)	6.6×10^{-5}	Significant

When comparing water sorption and oil adsorption in the pure systems, the One-Way ANOVA resulted in p-values of 0.035, 0.065, 6.6×10^{-5}, and 6.6×10^{-5} for B-8 1-hour, B-8 24-hour, B-25 1-hour, and B-25 24-hour setups, respectively (Table 4). These values indicate that there is no significant difference in water and oil sorption in B-8 with 24 hours of contact time ($p>0.05$). However, contrary to this finding, B-8 and B-25 with 1-hour contact time and B-25 with 24 hours of contact have a significantly greater affinity for water intake ($p < 0.05$). The data and statistical analysis suggest that MFS, similar to most untreated lignocellulosic biomasses, does not exhibit hydrophobicity (Sbiai et al., 2011).

3.5. Oil Adsorption in Oil-water Mixture

Table 5. Oil Adsorption Capacity in Oil-water Mixture

	Mean Sorption
B-8 *(g oil / g MFS)*	1.478
B-25 *(g oil / g MFS)*	1.684

The mean adsorption capacities in the oil-water mixture after five trials were $1.478g_o/g_{mfs}$ and $1.684g_o/g_{mfs}$ for B-8 and B-25, respectively (Table 5). The data showed greater oil adsorption for B-25. Statistical analysis is needed to characterize the difference between the two particle sizes.

3.6. Effect of Particle Size on Sorption

Table 6. Particle Size Comparison in Pure Systems

Dataset (B-8 vs. B-25)	P-value ($\alpha = 0.05$)	Remarks
Pure Water (1 hour)	0.024	Significant
Pure Water (24 hours)	0.002	Significant
Pure Oil (1 hour)	0.043	Significant
Pure Oil (24 hours)	0.032	Significant

When comparing the two chosen particle sizes in pure water systems, p-values were determined to be 0.024 and 0.002 for 1-hour and 24-hour contact times, respectively. Regarding pure oil systems, the p-values for 1 hour and 24 hours were 0.043 and 0.032 (Table 6). The statistical analysis determined that the B-25 particle size has significantly higher oil adsorption and water sorption capacity than B-8 across all contact times ($p < 0.05$). This result implies that the smaller particle size performs better in systems containing pure substances; however, the performance of the MFS biosorbent in a mixture cannot be generalized from this finding.

Table 7. Particle Size Comparison in Oil-Water Mixture

Dataset (B-8 vs. B-25)	P-value ($\alpha = 0.05$)	Remarks
Oil-Water Mixture	0.003	Significant

One-Way ANOVA results showed a p-value of 0.003 when the B-8 and B-25 particle sizes were compared (Table 7). The B-25 MFS bioadsorbent was determined to have a significantly greater oil adsorption capacity in oil-water mixtures based on

this value. This finding was consistent with the results of particle size comparison in the pure water and oil systems.

The consistency of B-25 in outperforming B-8 in terms of sorption capacity can be observed across all the experimental setups (Figure 7). The sorption superiority of the finer particles may be explained by the increased surface area associated with smaller sorbent sizes, which gives rise to a more significant number of binding sites and contact surfaces on the MFS, ultimately enhancing the sorption capacity in the process (Behnood et al., 2013; El Gheriany et al., 2020; Ibrahim et al., 2009; Kelly-Vargas et al., 2012).

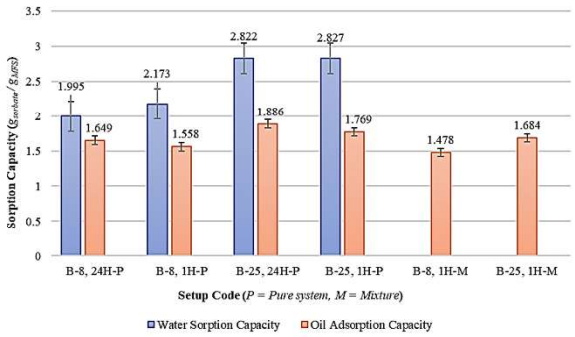

Figure 7. Mean Sorption Values in the Biosorption Experiments

4. CONCLUSIONS

Statistical analysis determined an insignificant difference in the 1-hour and 24-hour contact times. It was noted that the B-25 particle size (0.1mm<x<0.6mm) was more effective than B-8 at sorption in both pure systems and oil-water mixtures due to the increased surface area in smaller particles. However, One-Way ANOVA presented the biosorbents' significantly higher affinity for water. MFS water sorption is attributed to it being untreated lignocellulosic biomass; whereas, the low oil adsorption capacity is due to the lack of porosity. The investigation on the oil adsorption of MFS and particle size effects suggests that the bioadsorbent can be used as a potential oil cleanup method. Considering that mahogany (*Swietenia macrophylla*) fruit shells are underutilized wastes, an added purpose expands the body of knowledge and benefits places with dense mahogany tree populations.

Home-based experimentation limited the capacity to use crude oil and saltwater; hence synthetic motor oil and tap water were used as substitutes. An investigation into the performance of MFS in adsorbing different oil types in saltwater is recommended. Noting the hydrophilic nature of lignocellulosic biomasses, further studies may focus on the physicochemical modification of MFS to optimize adsorption. Lastly, the determined water affinity opens up pathways for future research concerned with MFS use in water or moisture sorption.

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6. REFERENCES

Barron, M. G., Vivian, D. N., Heintz, R. A., & Yim, U. H. (2020). Long-term ecological impacts from oil spills: comparison of exxon valdez, hebei spirit, and deepwater horizon. Environmental science & technology, 54(11), 6456-6467.

Behnood, R., Anvaripour, B., Jaafarzade Haghighi Fard, N., & Farasati, M. (2013). Application of natural sorbents in crude oil adsorption. Iranian Journal of Oil and Gas Science and Technology, 2(4), 1-11.

Ben Jmaa, S., & Kallel, A. (2019). Assessment of performance of Posidona oceanica (L.) as biosorbent for crude oil-spill cleanup in seawater. BioMed research international, 2019.

Beyer, J., Trannum, H. C., Bakke, T., Hodson, P. V., & Collier, T. K. (2016). Environmental effects of the Deepwater Horizon oil spill: a review. Marine pollution bulletin, 110(1), 28-51.

de Fátima Gorgulho, H., da Silva Guilharduci, V. V., & Martelli, P. B. (2018). Sugarcane Bagasse as Potentially Low-Cost Biosorbent. Sugarcane: Technology and Research, 265.

Doshi, B., Sillanpää, M., & Kalliola, S. (2018). A review of bio-based materials for oil spill treatment. Water research, 135, 262-277.

El-Din, G. A., Amer, A. A., Malsh, G., & Hussein, M. (2018). Study on the use of banana peels for oil spill removal. Alexandria engineering journal, 57(3), 2061-2068.

El Gheriany, I. A., El Saqa, F. A., Amer, A. A. E. R., & Hussein, M. (2020). Oil spill sorption capacity of

raw and thermally modified orange peel waste. Alexandria Engineering Journal, 59(2), 925-932.

Ibrahim, S., Ang, H. M., & Wang, S. (2009). Removal of emulsified food and mineral oils from wastewater using surfactant modified barley straw. Bioresource technology, 100(23), 5744-5749.

International Tanker Owners Pollution Federation Ltd. (2019). 2018 Tanker Oil Spill Statistics: Number of spills remains low. https://www.itopf.org/news-events/news/article/2018-tanker-oil-spill-statistics-number-of-spills

Kelly-Vargas, K., Cerro-Lopez, M., Reyna-Tellez, S., Bandala, E. R., & Sanchez-Salas, J. L. (2012). Biosorption of heavy metals in polluted water, using different waste fruit cortex. Physics and Chemistry of the Earth, Parts A/B/C, 37, 26-29.

Lee, C. M., Kubicki, J. D., Fan, B., Zhong, L., Jarvis, M. C., & Kim, S. H. (2015). Hydrogen-bonding network and OH stretch vibration of cellulose: comparison of computational modeling with polarized IR and SFG spectra. The Journal of Physical Chemistry B, 119(49), 15138-15149.

Magoling, B. J. A., & Macalalad, A. A. (2017). Optimization and response surface modelling of activated carbon production from Mahogany fruit husk for removal of chromium (VI) from aqueous solution. BioResources, 12(2), 3001-3016.

Meili, L., da Silva, T. S., Henrique, D. C., Soletti, J. I., de Carvalho, S. H. V., Fonseca, E. J. D. S., ... & Dotto, G. L. (2017). Ouricuri (Syagrus coronata) fiber: a novel biosorbent to remove methylene blue from aqueous solutions. Water Science and Technology, 75(1), 106-114.

Mohammed, M. A., Shitu, A., & Ibrahim, A. (2014). Removal of methylene blue using low cost adsorbent: a review. Research Journal of Chemical Sciences, 4(1), 91- 102.

Patil, S. B., Shreya, K., & Kruti, S. (2020). Extraction of Amino acids from Human Hair" Waste" and Used as a Natural Fertilizer. Journal of Pharmaceutical Sciences and Research, 12(2), 271-278.

Romero, P. (2006, August 28). GMA to unveil Guimaras rehab plan. The Philippine Star. https://www.philstar.com/headlines/2006/08/28/355012/gma-unveil-guimaras-rehab-plan

Sacramento, N. J. J., & Geges, D. (2019). Community Livelihood Recovery: Experiences from

2006 Guimaras Oil Spill in the Philippines. Journal of Human Ecology, 8(1).

Sartape, A. S., Patil, S. A., Patil, S. K., Salunkhe, S. T., & Kolekar, S. S. (2015). Mahogany fruit shell: a new low-cost adsorbent for removal of methylene blue dye from aqueous solutions. Desalination and Water Treatment, 53(1), 99-108.

Sbiai, A., Kaddami, H., Sautereau, H., Maazouz, A., & Fleury, E. (2011). TEMPO-mediated oxidation of lignocellulosic fibers from date palm leaves. Carbohydrate Polymers, 86(4), 1445-1450.

Shah, M. U. H., Moniruzzaman, M., Sivapragasam, M., Talukder, M. M. R., Yusup, S. B., & Goto, M. (2019). A binary mixture of a biosurfactant and an ionic liquid surfactant as a green dispersant for oil spill remediation. Journal of Molecular Liquids, 280, 111-119.

Shamim, S. (2018). Biosorption of heavy metals. Biosorption, 2, 21-49.

Tewari, S., & Sirvaiya, A. (2015). Oil spill remediation and its regulation. International Journal of Engineering Research and General Science, 1(6), 1-7.

Wolok, E., Barafi, J., Joshi, N., Girimonte, R., & Chakraborty, S. (2020). Study of bio-materials for removal of the oil spill. Arabian Journal of Geosciences, 13(23), 1-11.

Xia, W., Zhou, C., & Peng, Y. (2017). Enhancing flotation cleaning of intruded coal dry-ground with heavy oil. Journal of Cleaner Production, 161, 591-597.

Yang, J., Ching, Y. C., & Chuah, C. H. (2019). Applications of lignocellulosic fibers and lignin in bioplastics: A review. Polymers, 11(5), 751.

Zanini, M., Marschelke, C., Anachkov, S. E., Marini, E., Synytska, A., & Isa, L. (2017). Universal emulsion stabilization from the arrested adsorption of rough particles at liquid-liquid interfaces. Nature communications, 8(1), 1-9.

Comparative Analysis of Colorfastness of Extracted Pigment from Kangkong (*Ipomoea aquatica*) with Varied Alcohol Solutions

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Abstract: Inorganic pigments are the most preferred pigments to be produced due to their greater resistance to fade, efficiency in the application, and how it is overall easier and faster to produce. However, natural water is polluted, and close vegetation is damaged because of the affected water channels that have been damaged due to improper disposal by the manufacturing industry. This paper reviews a comparative analysis of the colorfastness of extracted pigment from kangkong with varied alcohol solutions. A total of 7 varying ethyl alcohol solutions with concentrations ranging from 10% to 70% were obtained using the dilution equation. Kangkong leaves were then utilized for the extraction of chlorophyll due to its high leaf yield rate. The Brightness levels and Saturation levels had an inverse and direct correlation to the alcohol concentration, respectively. This suggests that a greater alcohol concentration is more effective and efficient in the extraction of chlorophyll because the samples had a better expression of colors. After observing the color value before and after administering the colorfastness test, the alcohol concentration in the extraction of chlorophyll has an inverse relationship with the colorfastness of the pigment on textile material.

Key Words: kangkong; ethyl alcohol; colorfastness; chlorophyll; pigment

1. INTRODUCTION

Pigment has been used since 2600 BC and has grown in relevance to society over time (Whittle, S., 2016). However, it is relatively unappreciated by the masses. It has both a functional and aesthetic significance in its application to textile materials. In the coming years, its market size is expected to grow in value, with it having reached 33.2 billion US dollars back in 2019 (Grand View Research, 2020). With the rapid increase in value for pigment, the methods employed to achieve this feat are questioned.

There are two types of pigments that are used for application on textile materials: organic and inorganic pigments. The latter being the most preferred to be produced. This is due to the inorganic pigment's greater resistance to fade, efficiency in the application, and how it is overall easier and faster to produce. However, the production method that is used for inorganic pigments is destructive to the environment. Inorganic pigments are produced by using inorganic metallic compounds, that if used in high amounts, will cause a negative effect on the environment it is exposed to.

Due to a majority of the manufacturing industry using inorganic pigments as colorants for their products, natural water is polluted and close vegetation is damaged because of the affected water channels (Impact of dyes, 2016). The reason behind this damage is due to inorganic pigments being composed of chemicals, that if disposed of improperly, may cause a negative impact on the aforementioned water channels (Koel Colours Private Limited, 2018). Despite this, the cost-effectiveness of inorganic pigments has allowed the pigments to be continually produced, thus increasing water pollution in the environment. As such, it is necessary to provide grounds for manufacturers to transition to utilizing organic pigments, as well as using an alternative environment-friendly production method.

For this study, the researchers have opted to see if the variation of alcohol concentrations in the use of ethyl alcohol in the extraction of chlorophyll from Kangkong leaves will result in the change of color fastness when applied to cotton textile material.

2. METHODOLOGY

The methodology of this study has a total of 5 phases wherein phase 1 is the preparation of alcohol concentrations by dilution, phase 2 is the extraction of chlorophyll using the diluted alcohol concentrations, phase 3 is where the pigment is applied to the textile, phase 4 is the colorfastness test, and finally, in phase 5, the color value is then digitally identified.

2.1 Materials and Equipment

The following materials were used by the researchers for this study: cotton textile materials, kangkong leaves, and 70% ethyl alcohol. As for the equipment, a medium-sized pot was used for the extraction process of the chlorophyll.

2.2 Preparation of Alcohol Concentrations

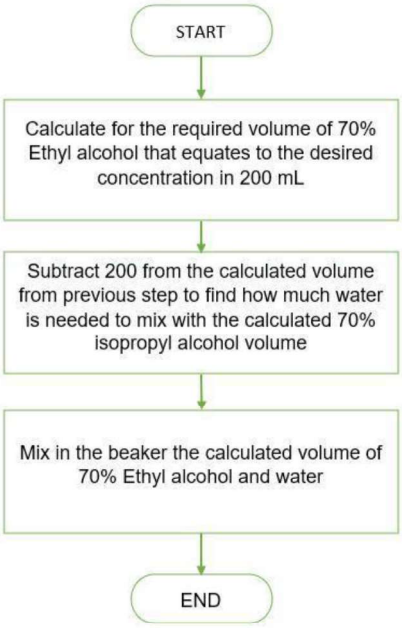

Fig. 1. Preparation of alcohol concentration by dilution

Due to ethyl alcohol being solely commercially sold in 70% alcohol concentrations, a method for diluting the alcohol from 70% is necessary to obtain varying concentrations for the study. Using the dilution equation, which is (C1)(V1) = (C2)(V2), we calculate the volume of the starting solution, which is represented by V1. Initial concentration is represented by C1, while C2 represents the desired concentration and V2 for the total final volume. After dilution, a total of 7 solutions of varying ethyl alcohol concentrations should be obtained.

2.3 Extraction of Chlorophyll

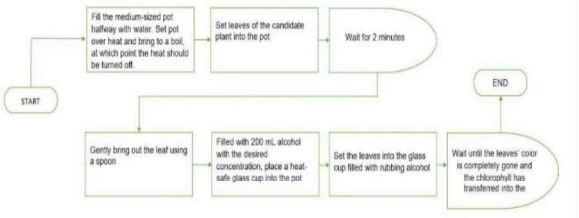

Fig. 2. Extraction of chlorophyll with varying alcohol concentrations

The process of extracting the chlorophyll from the kangkong leaves is straightforward. It simply involves submerging the leaf into boiling water to weaken it and allow the chlorophyll to more easily transfer into the solvent, ethyl alcohol. For 6 min, the leaf sits within the boiling water, which is the time found after performing preliminary tests to determine the steps that needed to be adjusted to properly extract the chlorophyll. The weakened leaf is allowed to rest, submerged in the bowl of 200 milliliters (mL) ethyl alcohol for 1 h. Once extracted, the chlorophyll-alcohol solution is immediately used in the next phase.

2.4 Application of Chlorophyll to Textile

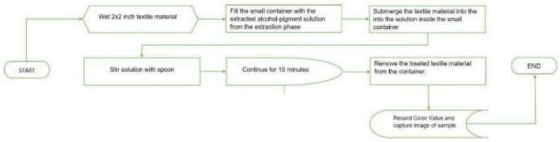

Fig. 3. Application of chlorophyll onto textile material

The extracted chlorophyll is used to dye a 2 in x 2 in textile material made of cotton. The bucket method or sink method was used to apply the chlorophyll. The method is simply submerging the textile into the chlorophyll-alcohol solution for 10 min while it is stirred to ensure an equal distribution of color across the sample. The samples were then dried while concealed from sun exposure to prevent them from being affected by lightfastness, which is different from colorfastness. Once dried, the images of the samples were captured with the homemade photo studio. More details on the studio will be provided in a later section.

2.5 Colorfastness Test

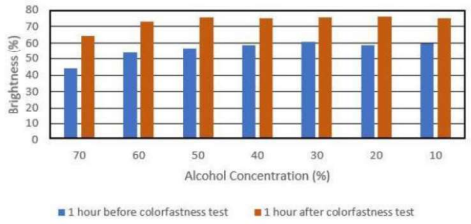

Fig. 5. Comparison of average brightness levels of the samples before and after the colorfastness test.

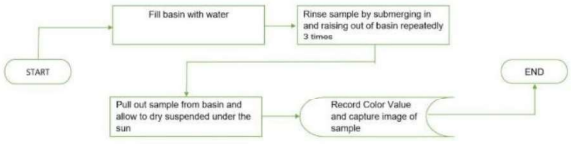

Fig. 4. Colorfastness test method

Once the samples have been collected, it is then subjected to the colorfastness test. The test involves replicating the stress typical clothing undergoes while laundering to observe if the color will fade after experiencing the stress. The test is based on the colorfastness test procedures published by the Southeast University (Shishir, M. M. H., 2014). After preliminary testing, it was necessary to decrease the stress since the color fade is too extreme to make a comparative analysis between the samples. The samples were submerged into room temperature water repeatedly for 3 times and then dried in the same drying conditions mentioned in the previous phase.

2.6 Digital Identification of Color Value

A digital application was used to digitally identify them using the images captured using the home studio to identify the color value of the samples. The application used is adobe photoshop was able to provide a detailed analysis of the coloration of the sample using the captured images such as the hue, saturation, and brightness. These are necessary components to assess the change in coloration of the sample before and after the colorfastness test since the loss of color due to color fade is attributed to the loss of saturation in a color (What is Color Fading and Can It Be Prevented, 2017).

3. RESULTS AND DISCUSSION

A total of 7 varying ethyl alcohol solutions with concentrations ranging from 10% to 70% were obtained. It was observed that a noticeable change in color had occurred in the solutions. Due to how in each solution, the percentage of the ethyl alcohol used was decreased, resulting in the dilution of color in the decreasing concentrations. As for the cotton textile materials, each piece had been submerged in a corresponding ethyl alcohol solution for over 12 hours to best see the coloration of the chlorophyll. As for the drying process, it was opted that the cotton textile was to be dried under a period of 10 minutes with no exposure to sunlight

The brightness levels, which correspond to the color value of a sample, were found for each sample before and after the colorfastness test seen. The average levels across the three trials were found and graphed in figure 5. The Saturation levels were also taken into account because this also represents an important component in the expression of color. Like the brightness levels, the average saturation levels across all three trails for each alcohol concentration was found. This can be viewed in figure 6. The Brightness levels had an inverse correlation with the alcohol concentration, while the Saturation levels had a direct correlation with the alcohol concentration based on the graphs of the average levels of brightness and saturation. These relationships imply that a greater alcohol concentration is more effective and efficient in extraction chlorophyll because the samples had a better expression of colors. This is consistent with the fact that alcohol is capable of weakening the cell walls of plant cells to allow for the contents of the cell to be released (Center, B. S, 2015). It is because of this function of alcohol that chlorophyll can easily be extracted with solutions of greater alcohol concentrations.

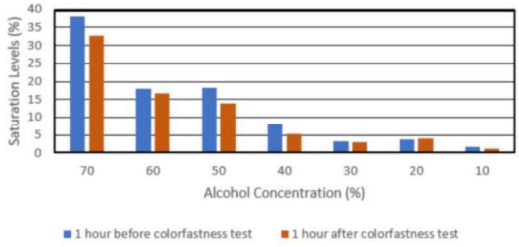

Fig. 6. Comparison of average saturation levels of the samples before and after the colorfastness test.

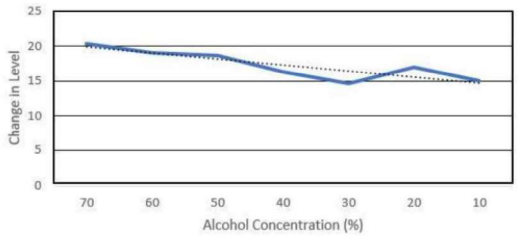

Fig. 7. Difference of Average Brightness levels before and after the colorfastness test.

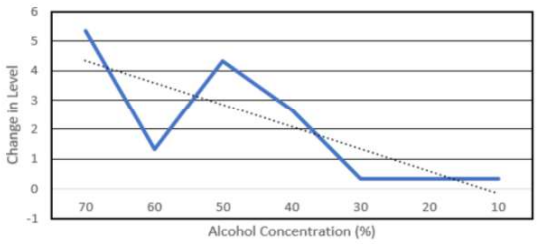

Fig. 8. Difference of Average Saturation levels before and after the colorfastness test.

There is a clear effect from the colorfastness test; however, what is important is how drastic the change is in each level after administering the test after comparing the levels of the samples before and after the colorfastness test. It can be observed from figures 7 and 8 that as the concentration of the alcohol decreased, there is a noticeable loss of change in levels. The difference implies that there is an inverse relationship between alcohol concentration and

colorfastness because there is a decrease in the difference between the average brightness and saturation levels before and after the test, albeit minimal.

4. CONCLUSIONS

After observing the color value before and after administering the colorfastness test, alcohol concentration in the extraction of chlorophyll has an inverse relationship with the colorfastness of the pigment on textile material. Additionally, it also has an inverse relationship with brightness levels and a direct relationship with saturation levels. If the priority is to provide a higher quality color application on textile material, then the use of a high alcohol concentration when extracting chlorophyll is preferred; however, if colorfastness is prioritized, finding an alcohol level that balances the color expression while maintaining a minimal loss of color is necessary.

5. ACKNOWLEDGMENTS

The researchers would like to thank Dr. Kerry P. Cabral for his continuous efforts in supporting and advising the researchers throughout the research paper.

6. REFERENCES

Center, B. S. (2015, June 30). Alcohols. BODE SCIENCE CENTER. https://www.bode-science-center.com/center/glossary/alcohols.html

Grand View Research (2020). Dyes and Pigments Market Size, Share & Trends Analysis Report by Product (Dyes (Reactive, Vat, Acid, Direct, Disperse), Pigment (Organic, Inorganic)), By Application, By Region, And Segment Forecasts, 2020 - 2027. Market Analysis Report, N/A(N/A), 1-130. https://www.grandviewresearch.com/indystry-analysis/dyes-and-pigments-market

Impact of dyes. (2016, June 29). Trusted Clothes. https://www.trustedclothes.com/blog/2016/06/23/impact-of-dyes/

Koel Colours Private Limited. (2018). Difference between Organic Pigments and Inorganic

Pigments.Retrievedfromhttps://www.koelcolours.com/blog/pigments/difference-organic-pigments-inorganic pigments/#:~:text=Organic%20pigments%20are%20made%20up,chemical%20composition%20to%20create%20colours.

Shishir, M. M. H. (2014, March 24). Color fastness of dyed goods . Slideshare. https://www.slideshare.net/sheshir/color-fastness-to-dyed-goods-gp-3

What is Color Fading and Can It Be Prevented? (2017, December 26). Embassy Cleaners - Dry Cleaner Specializing in Carpet Cleaning and Restoration in Westchester, NY. https://embassycleaners.com/color-fading/

Whittle, S. (2016). The History of Fabric Dye. Retrieved from https://www.acecleanuk.co.uk/blog/the-history-of-fabricdye/#:~:text=The%20first%recorded%20mention%20of,of%20clothing%20is%20dyed%20synthetically.

Advantages and Disadvantages of Traditional Abaca, Genetically Modified Abaca, and Cross Hybrid Abaca

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De La Salle University Integrated School, Manila

Abstract: Abaca (Musa Textilis Née), also known as Manila hemp, is a plant native to the Philippines, which expanded through different parts of Asia. It is a biodegradable and sustainable source of fiber known for its high quality. Due to viruses, poor government support, and lack of fundings, the abaca fiber industry is encountering obstacles in keeping up with the global demands. Over time, researchers developed new abaca types such as crossbred abaca and genetically modified abaca to solve these problems, but these have their own deficiencies as well. The purpose of the study was to identify, assess, and elaborate on the advantages and disadvantages of each of the abaca types. This was accomplished through the evaluation of literature and the collection of data in interviews. The study was a systematic review focusing on meta-synthesis, with information derived from previously published research or related literature and information from experts in the field. It was determined that traditional abaca is vastly preferred over genetically modified abaca and cross hybrid abaca, due to a number of reasons, including lack of research and economic viability. Traditional abaca was found to be more sustainable overall. It was recommended that traditional abaca should be promoted more to spread awareness, and that farmers should be educated regarding the proper process of caring for abaca plants. Stigma regarding cross hybrid and genetically modified abaca should be addressed as well.

Key Words: traditional abaca; cross hybrid abaca; genetically modified abaca; Philippine abaca industry; abaca virus

1. INTRODUCTION

1.1 Background of the study

Abaca, also known as Musa textilis Née, is a plant that originated in the Philippines. It is known as Manila hemp internationally. The Philippines was first to cultivate (Lalusin, 2010) and has remained the world's top abaca supplier for several years. It is among thecountry's top exports, boosting the Philippines' economy, and has an average of 4.7 billion pesos in export value (PhilFIDA, n.d.). Traditional varieties are still used due to the lack of new and improved varieties of abaca (Lalusin, 2010). These traditional abaca varieties are more likely to contract diseases such as the abaca bunchy top virus (ABTV) or the abaca bract mosaic virus. These viruses kill or give low-quality abaca yields, potentially affecting the industry as it reduces the income of many 21st century farmers. Furthermore, the Philippines is currently facing competition in the abaca industry with Indonesia and Costa Rica.

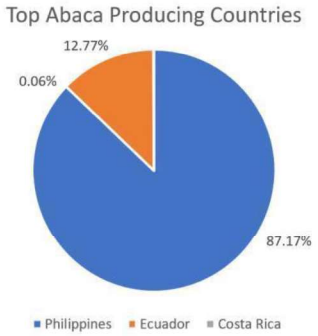

Figure 1. Top abaca producing countries.

Waller et al. (2019) stated that farmers lack knowledge in utilizing modern farming practices affecting farming productivity and efficiency. Moreover, the PhilFIDA roadmap of 2018-2020 discussed issues about lack of funding for the abaca industry requiring 5.633P billion and that more abaca seedling nurseries are lacking per region to hike outputs in production. Furthermore, the industry has

been encountering losses due to the impacts led by the abaca viruses and poor management of the government. The researchers were led to conduct the study because of the lack of consolidating research regarding which among cross hybrid abaca, genetically modified abaca, and traditional abaca is considered the best. The advantages and disadvantages of each abaca type will be determined, assessed, and compared. Furthermore, the study would help 21st-century farmers apply new farming methods and help the industry gain new and efficient farming methods and techniques.

1.2 Research Questions

Due to the lack of consolidating research, there is no concrete and validated document that can be distributed regarding which type of abaca is best to cultivate, given the properties and characteristics of the different abaca types. With that, the researchers aim to answer the following questions:

1. Which among traditional abaca, genetically modified abaca, and cross hybrid abaca is best suited for the Philippines' abaca industry in terms of economic viability, growth, and production?
2. What are their properties, uses, and applications?
3. What are the advantages and disadvantages of each?
4. How will their advantages or benefits, disadvantages or issues, and properties affect the Philippine abaca industry?

1.3 Objectives

The researchers assessed the advantages and disadvantages of traditional abaca, genetically modified abaca, and cross hybrid abaca. The specific objectives are as follows:

a) To identify the properties and uses of traditional abaca, genetically modified abaca, and cross hybrid abaca
b) To determine and assess their benefits and issues and their possible impacts and influences in the abaca industry
c) To compare and evaluate the differences between each type of abaca

1.4 Scope and Limitations

This study reviewed, compared, and assessed the advantages and disadvantages between traditional abaca, genetically modified abaca, and cross hybrid abaca, which was done through a systematic review focusing on meta-synthesis. The data was derived from interviews of experts or people involved with the Philippine abaca industry, as well as previous studies to find which abaca type would be more beneficial economically and agriculturally. Interviews were conducted for clarification and support for the gathered data. The different properties and uses of the abaca types were discussed and distinguished from each other. Each abaca type was examined, identifying its benefits and disadvantages.

1.5 Significance of the Study

The comparisons between traditional, crossbred, and genetically modified variants of abaca can help 21st-century farmers gain information in applying modern methods and techniques in farming. It can guide in identifying the type of abaca, its properties, its productivity, efficiency, and effectiveness in farming. This study can also aid experts and organizations in the abaca industry in identifying needed information for strategies to improve the abaca economy, aid industrial growth, compete internationally, and utilize advanced agricultural methods. The paper may also help future researchers and organizations in conducting similar studies about the abaca industry.

2. METHODOLOGY

The researchers performed a systematic review focusing on meta-synthesis regarding the characteristics and properties of each type of abaca from related studies. A meta-synthesis is used to combine qualitative data by combining information from related literature to find common themes and concepts (Siddaway et al., 2019). A systematic review was utilized for this paper because it summarizes the large quantities of research that have been published about the different types of abaca.

The researchers first identified the research questions, then searched for related literature, composed of articles selected through inclusion criteria. The content from the articles was analyzed and various themes were noted. Following that, respondents for the study were identified and contacted, and online interviews or surveys were conducted to further expound and validate the previously collected data. The data from the interviews was cross-checked with the previous data to find similar ideas and themes. The data were synthesized and evaluated to find the answers to the questions presented. The results were then interpreted and the conclusion for the topic was formed.

The data was presented through a narrative on which abaca cultivar is the most preferable to produce and utilize. The reasons and explanations as to why would be presented as well to elaborate the previously found data and research.

Inclusion Criteria (Respondents)	Inclusion Criteria (Related Literature)
• Experts that are in the abaca field or have connections to the abaca industry	• Local and international studies published after 2010 that is related to abaca
• Experts that have conducted abaca-related research	• Qualitative, quantitative, and mixed methodology
• Relevant government officials	• Academic journals, conference papers, and reports related to abaca
	• News articles regarding discoveries in the abaca industry
	• Non-academic articles from reputable sources
	• Older studies documenting the history of abaca in the Philippines
	• Situations of 21st-century farmers in the Philippines

3. RESULTS AND DISCUSSION

3.1 Characteristics of Abaca

Abaca is among the strongest natural fibers. It can be used as a raw material in textile manufacturing. It has high fiber yield and quality, high tensile strength, and resistance to virus diseases. Abaca is considered to be sustainable, as its waste can be reused as fertilizer. It is also the type of abaca preferred by buyers and farmers due to familiarity and that other abaca types may have unwanted side effects.

Cross hybrid abaca possesses high yield, good fiber quality, and disease resistance. The Bandala hybrid, specifically, is resistant to the bunchy top virus. Another abaca hybrid, a hybrid of Pacol and traditional abaca, is also resistant to ABTV and can be used as a raw material. However, its fiber quality is lacking (Lalusin et al., 2015). It is stated that cross hybrid abaca has similar qualities to traditional abaca, such as folding endurance, burst strength, tensile strength, and environmental adaptability. Furthermore, the application of cross hybrid abaca may help reduce losses caused by the viruses. However, cross hybrid abaca requires more tests, trials, and studies to verify and further identify its potentials in the industry and the market. In addition, it was noted that some abaca hybrids such as the Daratex have low fiber recovery due to their low tensile strength.

Genetically modified abaca is more resistant to ABTV. However, the fiber quality is still inconclusive (PhilFIDA, n.d.). Both hybrid and genetically modified are neither strong enough nor have enough reliable studies. Additional issues for genetically modified abaca would also include sustainability and production cost. More studies are needed to properly identify characteristics and the results of existing studies are inconclusive. With this, genetically modified abaca is currently not a viable option. A lot of the current information and research regarding its characteristics, among others, are theoretical and therefore may be faulty.

3.2 Other Issues Related to Abaca

The abaca virus can cause damage to the plant, reducing its production quality and economic viability. Using resistant varieties would be the best way to control the effects of diseases, yet it should be the same standard as the current abaca types. Currently, traditional varieties are still recommended, as with the results of the survey. However, traditional varieties are more susceptible to ABTV, due to the environment than conventional farming practices create, i.e., a breeding ground for insects. These can still be managed with recommended practices, like regular cleaning and fertilization. Otherwise, depletion of the topsoil and its fertility may occur.

Some reasons as to why abaca diseases occur would be that: an infected cutting knife for all the plants, following "pohada" system, the attitude of farmers, and lack of knowledge and funding. These are all important issues, but temporary solutions are used instead, as abaca is an industrial crop.

Studies regarding genetically modified abaca have inconclusive results (PhilFIDA, n.d.), and nothing has been developed for commercial use. At present, there are still negative connotations with farmers regarding genetically modified and hybrid abaca due to a previous issue with these. Additional issues include fiber quality, resistance traits stability, etc. Cross hybrid abaca types cannot also be mass-produced, for similar reasons. According to a respondent, one hybrid type was introduced in the 1990s called Daratex, which incurred many issues, such as cooking fiber batches. The industry suffered due to losses encountered.

3.3 Economic Benefits and Sustainability

Currently, it is believed that traditional abaca would provide more benefits in the long run. More studies may be needed to answer the question more objectively, as there is more information

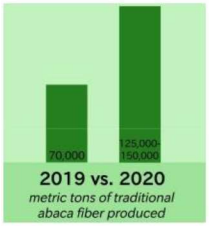

Figure 2. A comparison of the production of abaca fiber in 2019 and 2020.

regarding traditional abaca than either cross hybrid or genetically modified abaca. Foreign buyers, who constitute a significant amount of the market, are against hybrid or genetically modified types. Furthermore, traditional abaca has been used since the 1900s, and it has been helping the country's economy consistently.

In 2019, over 70,000 metric tons of traditional abaca were produced. The demand in 2020 was around 125,000 to 150,000 metric tons. Exports of abaca fiber and manufacture also generated an average of US$97.1 million per year in the last decade (Department of Agriculture, 2019). Additionally, abaca is sought after as a raw material as it is sustainable: it can replace synthetic, plastic, and petroleum-based products; it is more sustainable than wood pulp. Abaca causes relatively fewer environmental problems than typically used materials as it does not disturb weather patterns.

Neither cross hybrid types nor genetically modified types have been properly propagated in the market. A respondent stated that the Bandala hybrid can be used for its virus resistance, have a high production level if propagated, and can be used to produce textile products, similar to traditional abaca. According to another respondent, it is too early to introduce abaca hybrids, not while it is inferior to traditional abaca.

3.4 Production and Growth

Traditional abaca may be best suited to the environment, as new hybrids have not yet gone through multilocational trials. It was also stated that the Bandala hybrid might also thrive in the Philippine environment, though there have been no proper conclusions regarding this. Abaca is location-specific; different varieties are recommended for different areas. In general, it can survive and thrive in the country's environment. Abaca also requires partial shade. However, they thrive on well-drained fertile soil, mountains and interlands, with type II, III, and IV climates, as well as areas rich in volcanic soil (PhilFIDA, n.d.).

Additionally, the mindset of farmers regarding the plants must be changed. Many farmers lack information regarding modern techniques (Waller et al., 2019). They should adapt to modern and proper farming practices such as fertility maintenance as traditional abaca is self-sustainable to reproduce.

Currently, there is insufficient information and data to determine the abaca type with more efficient and cost-effective production. One reason would be that both hybrids and genetically modified types have restricted market access. Traditional abaca can produce more as hybrid abaca is easily broken, with a low chance of recovery. According to another respondent, the abaca with the more efficient and cost-effective production type would be varieties with low-quality fibers, especially wild and hybrid species, as the production cost would be lower.

Fibers are the ultimate product of abaca. Several factors affect fiber quality, such as the method of stripping, blade used, etc. Hybrid abaca has a lower fiber recovery since the tensile strength is lower compared to traditional abaca. Much fiber is broken while stripping, and more effort is required to produce the same amount of hybrid fiber with traditional abaca fiber. Genetically modified abaca elseways**,** shows inconclusive results on its data on fiber quality and abaca yield (PhilFIDA, n.d.). More studies or trials are needed to assess the properties of the genetically modified abaca and its fiber.

4. CONCLUSIONS

It was determined that traditional abaca is a more viable option in the market due to it being of higher quality compared to the other abaca types despite issues in its vulnerability against diseases. This vulnerability can be remedied with proper sanitation, cleaning practices, detection of the abaca viruses, and application of modern agricultural practices. The usage of crossbred abaca and genetically-modified abaca could help prevent significant financial losses led by the viruses and improve the fiber quality and yield; however, further tests and trials are needed to determine the capabilities of the crossbred and genetically modified abaca varieties.

The survey only had a limited number of respondents and it is recommended to conduct similar studies in the future. To solve issues in the abaca industry, political leaders, abaca farmers, researchers, and the general public should be educated on the importance and potential of abaca through seminars, online campaigns, training programs, and conferences. A respondent had also addressed the importance of modern applications in agriculture for abaca farming. Abaca farmers should also be educated regarding the issues of the traditional abaca and the abaca industry. This would include identification of infected plants, implementation of proper farming practices, among other information. Raising awareness on the issues should also be promoted to the general public, the government, and people in positions of power through seminars, online campaigns, training programs, and conferences. The spreading of the virus could be prevented this way.

For the industry to improve, it would be recommended that experts set and evaluate reasonable goals for the industry. If previously used methods do not work, then new methods and strategies should be used. People involved in the

industry should be actively engaged in it as well for the industry to thrive. More studies regarding cross hybrid and genetically modified abaca should be conducted. Additionally, political leaders, researchers, and farmers should be educated about the abaca hybrids' agronomic and economic potential. This could be a way to reduce the stigma and misconceptions that surround hybrid and genetically modified abaca in the market.

5. ACKNOWLEDGMENTS

We would like to extend our deepest gratitude to our research adviser, Ms. Chona Abeledo, for her continuous guidance and support throughout the year. We offer our sincere appreciation for the learning opportunities and lessons given and imparted to us. The completion of this research could have not been completed without the support of our family and friends. Your encouragements have provided comfort when times get rough and it was a great relief to know that you were by our side.

6. REFERENCES

Arcalas, J. (2018). Market demand, competition test strength of PHL's abaca. Business Mirror. https://businessmirror.com.ph/2018/02/27/market-demand-competition-test-strength-of-phls-abaca-3/

Armecin, R., Sinon, F. G. & Moreno, L. O. (2015). Abaca fiber: a renewable bio-resource for industrial uses and other applications. In Biomass and Bioenergy Applications. (107-118). https://doi.org/10.1007/978-3-319-07578-5

Boguero, A. P. B., Parducho, M. A. L., Mendoza, M. R. D. R., Abustan, M. A. M., & Lalusin, A. G. (2016). Molecular Screening of Abaca (Musa textilis L. Nee) Accessions Using Microsatellite Markers Associated With Resistance to Bunchy Top Virus. Philippine Journal of Crop Science, 41(2), 13–19. https://www.cabi.org/gara/FullTextPDF/2016/20163306766.pdf

Bureau of Agriculture and Fisheries Standards. (2016). Abaca fiber-Grading and Classification-Hand-stripped and Spindle/ Machine-stripped. http://www.philfida.da.gov.ph/images/Publications/PNS/PNSBAFS1802016AbacaFiberHandstrippedandMachineStripped.pdf

Bureau of Agriculture and Fisheries Standards. (2019). Non-food crops – Abaca – Code ofGood Agricultural Practices (GAP). http://www.philfida.da.gov.ph/images/Publications/PNS/PNS-Non-food-Abaca-GAP. pdf

Dancel, R. R. (2018). Abaca Fiber as a Retrofitting Material. Proceedings of Researchfora International Conference, August. https://www.researchgate.net/publication/328900481_Abaca_Fiber_as_a_Retrofittin g_Material

Dapar, L. (2014). Socio-ecological Analysis of Abaca Production in Biliran Island, Philippines. https://www.academia.edu/38147362/Socio_ecologicalAnalysisOfAbacaProduction ABSTRACT_pdf

De Castro, N. L., Sardido, M. L., Alino, J. B. J., & Deomampo, N. R. (1988). Abaca [industry in the Philippines]. PCARRD Commodity Industry Analysis Series (Philippines). https://agris.fao.org/agris-search/search.do?recordID=PH8910458

Department of Agriculture. (2019). Philippine Abaca Industry Roadmap 2018-2022. https://www.da.gov.ph/wp-content/uploads/2019/06/Philippine-Abaca-Industry-Road map-2018-2022.pdf

Department of Science and Technology. (2015). Improved abaca varieties to nail PH as top exporting country abaca: weaving more opportunities into farmers' lives. http://www.dost.gov.ph/index.php/knowledge-resources/news/44-2015-news/746-improved-abaca-varieties-to-nail-ph-as-top-exporting-country-abaca-weaving-more-op portunities-into-farmers-lives

Department of Science and Technology. (2020). DOST-FPRDI: ABACA HYBRID YIELDS QUALITY FIBER. http://www.dost.gov.ph/knowledge-resources/news/67-2020-news/1832-dost-fprdi-a baca-hybrid-yields-quality-fiber.html

Eroy, M.N. (2012). Productivity and Profitability of Abaca Varieties/Hybrids (Musa textilis Nee) Under Mature Tall Coconuts in Davao City, Southern Mindanao, Philippines. CORD, 28(2), 9. https://doi.org/10.37833/cord.v28i2.101

Felix, R. (2006). Genetic engineering eyed to solve problems of ailing abaca industry. The Philippine Star. https://www.philstar.com/business/agriculture/2006/04/02/329400/genetic-engineeri ng-eyed-solve-problems-ailing-abaca-industry

Fernandez, A., Torre, R., Fabon, M., & Lalusin, A. (2016). Growth and Fiber Yield of Abaca Hybrids Under Compostella Valley Province, Philippines Condition. CreateSpace Independent Publishing Platform. https://www.researchgate.net/publication/337559760_GROWTH_AND_FIBER_YIELD_OF_ABACA_HYBRIDS_UNDER_COMPOSTELA_VALLEY_PROVINCE_PHILIPPINES_CONDITION

Fernandez, R. (2018). DOST finds abaca, other fibers viable for banknotes. The Philippine Star. https://www.philstar.com/headlines/2018/08/13/1842083/dost-finds-abaca-other-fibers-viable-banknotes

Food and Agriculture Organization of the United Nations. (2013). Abaca. Future Fibers. http://www.fao.org/economic/futurefibres/fibres/abaca

Hayase, S. (2018). Manila Hemp in World, Regional, National, and Local History. Journal of Asia-Pacific Studies, 171–188.

Lalusin, A. (2010). Abaca Breeding for a More Reliable Philippine Abaca Industry. Annual BSP-UP Professorial Chair Lectures. Manila: Malate. http://www.bsp.gov.ph/events/2010/pls/downloads/BSP_5a_lalusin.pdf

Lalusin, A. G., & Villavicencio, M. L. H. (2015). Abaca (Musa textilis nee) breeding in the philippines. In Industrial Crops: Breeding for Bioenergy and Bioproducts (pp. 265–289). Springer New York. https://doi.org/10.1007/978-1-4939-1447-0_12

Lee, G. (1920). Abaca (Manila hemp): The Fiber Monopoly of the Philippine Islands. The Scientific Monthly, 11(2), 159-170. https://www.jstor.org/stable/6637

Miraflor, M. B. (2017). Abaca fiber for the country's paper bills? https://business.mb.com.ph/2017/06/18/abaca-fiber-for-the-countrys-paper-bills/

Mousavi, S. R., & Eskandari, H. (2011). A General Overview on Intercropping and Its Advantages in Sustainable Agriculture. Journal of Applied Environmental and Biological Sciences, 1(11), 482–286. https://www.researchgate.net/publication/220000362_A_General_Overview_on_Intercropping_and_Its_Advantages_in_Sustainable_Agriculture

Noriega, R. (2020). DOST-FPRDI researchers discover 'Bandala' abaca hybrid yields high quality fiber. Manila Bulletin. https://mb.com.ph/2020/06/08/dost-fprdi-researchers-discover-bandala-abaca-hybrid -yields-high-quality-fiber/

Ocfemia, G. O. (1930). Bunchy-Top of Abaca or Manila Hemp I. A Study of the Cause of the Disease and Its Method of Transmission. American Journal of Botany, 17(1), 1-18. https://doi.org/10.2307/2446376

Panela, S. (2013). PHL researchers looking into developing abaca for nanotechnology. GMA News. https://www.gmanetwork.com/news/scitech/science/341825/phl-researchers-looking-into-developing-abaca-for-nanotechnology/story/

Parac, E. P., Lalusin, A. G., Pangga, I. B., & Filomena, F. C. (2020). Characteristics of selected hybrids of abaca (Musa textilis nee) with resistance to bunchy top.

Philippine Agricultural Scientist, 103(1), 1–12. https://www.researchgate.net/publication/349345665_Characteristics_of_Selected_Hybrids_of_Abaca_Musa_textilis_Nee_with_Resistance_to_Bunchy_Top

Pelzer, K. J. (1948). The Philippine Abaca Industry. Far Eastern Survey, 17(6), 71–74. https://doi.org/10.2307/3022719

Philippine Fiber Industry Development Authority. (2014). Abaca Sustainability Manual. http://www.philfida.da.gov.ph/images/Publications/abacasustainabilitymanual/ASM. pdf

Philippine Fiber Industry Development Authority (n.d.). Philippine abaca help in global conservation. Department of Agriculture. http://www.philfida.da.gov.ph/index.php/archived-articles/19-philippine-abaca-helps -in-global-environment-conservation

Philippine Fiber Industry Development Authority. (2013). The Philippine Abaca Industry Roadmap 2018-2022 . THE PHILIPPINE ABACA INDUSTRY ROADMAP 2018-2022 (pp. 1–129). Cebu: Philippine Fiber Industry Development Authority.

Saragih, S. W., Lubis, R., Wirjosentono, B., & Eddyanto. (2018). Characteristic of abaca (Musa textilis) fiber from Aceh Timur as bioplastic. AIP Conference Proceedings, 2049. https://doi.org/10.1063/1.5082463

Shahri W., Tahir I., Ahad B. (2014) Abaca fiber: a renewable bio-resource for industrial uses and other applications. Biomass and Bioenergy. Springer, https://doi.org/10.1007/978-3-319-07641-6_3

Siddaway, A. P., Wood, A. M., & Hedges, L. V. (2019). How to Do a Systematic Review: A Best Practice Guide for Conducting and Reporting Narrative Reviews, Meta-Analyses, and Meta-Syntheses. In Annual Review of Psychology (Vol. 70, Issue 1, pp. 747–770). Annual Reviews Inc. https://doi.org/10.1146/annurev-psych-010418-102803

Simbaña, E. A., Ordóñez, P. E., Ordóñez, Y. F., Guerrero, V. H., Mera, M. C., & Carvajal, E. A. (2020). Abaca. In Handbook of Natural Fibres (pp. 197–218). Elsevier. https://doi.org/10.1016/b978-0-12-818398-4.00008-6

Sinha, A.K., Bhattacharya, S. & Narang, H.K. (2021). Abaca fibre reinforced polymer composites: a review. J Mater Sci 56, 4569–4587. https://doi.org/10.1007/s10853-020-05572-9

Teramoto, N., Urata, K., Ozawa, K. & Shibata, M. (2004). Biodegradation of aliphatic polyester composites reinforced by abaca fiber. Polymer Degradation and Stability. 86(3), 401-409 https://doi.org/10.1016/j.polymdegradstab.2004.04.026

Valdebella, M. M. (2016). Upgrading Abaca Industry through New Hybrid Varieties. https://www.bar.gov.ph/index.php/digest-home/digest-archives/771-2016-2nd-quarte r/5833-upgrading-abaca-industry-through-new-hybrid-varieties

Viesca, H. M. (2020). UPLB symposium on PH abaca fiber raises aid for abaca farmers in typhoon-hit Catanduanes. OVCRE. https://ovcre.uplb.edu.ph/press/news/item/558-uplb-symposium-on-ph-abaca-fiber-ra ises-aid-for-abaca-farmers-in-typhoon-hit-catanduanes

Vilaseca, F., Valadez- Gonzalez, A., Herrera-Franco, P., Pélach, M., López, J.& Mutjé, P. (2009). Biocomposites from abaca strands and polypropylene. part I: evaluation of the tensile properties. Bioresource Technology. 101(1), 387-395 https://doi.org/10.1016/j.biortech.2009.07.066

Waller, V., & Wilsby, A. (2019). Abaca in the Philippines, an overview of a potential important resource for the country: Relating the tensile strength of the single fiber to the microfibrilar angle. http://www.diva-portal.org/smash/get/diva2:1352495/FULLTEXT01.pdf

Zoologists on the Move: Mga Karanasan, Hamon, at Motibasyon ng mga Zoologists edad 25-50 sa Metro Manila

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Abstrak: Ang pananaliksik na ito ay tungkol sa danas ng mga *zoologists* sa Metro Manila. Binigyang pansin dito ang pangkalahatang danas, hamon, at motibasyon ng mga kalahok. Ang pananaliksik ay isinagawa gamit ang penomenolohikal na disenyo ng pag-aaral. Pinili ang labing-isang (11) kalahok gamit ang *Purposive Sampling* teknik. Bumuo rin ng Patnubay na Talatanungan na naglalaman ng dalawampung (20) tanong na ginamit sa isinagawang pakikipanayam. Batay sa pagsusuri ng mga mananaliksik, nakita na ang mga karaniwang karanasan ng mga *zoologists* ay ang pagsasagawa ng mga eksperimento sa *field site* o laboratoryo, ang paggawa at pagbabahagi ng mga pananaliksik nila, at pagtuturo sa mga nais maging isang *zoologist*. Ang mga hamon naman na kinaharap nila ay ang mga panganib na nakakasalubong nila tuwing nagsasagawa sila ng *fieldwork* at ang kakulangan ng suporta at kamalayan ng gobyerno at ng mga lokal na tao. Samantala, ang nagsisilbing motibasyon nila ay ang mga oportunidad at gantimpala na natatanggap nila sa trabaho, mga panlabas na impluwensya kagaya ng mga *advisers* at magulang nila, ang kanilang mga adbokasiya, iba't ibang batayan ng pagpili nila ng trabaho, at ang kanilang relihiyon. Sa kabuuan, hindi naging madali ang mga karanasan ng mga *zoologist*, gayunpaman patuloy nila itong ginagawa dahil sa mga taong nakapaligid sa kanila at mga benepisyong kanilang natatanggap.

Susing Salita: hamon; hayop; karanasan; motibasyon; *zoologist*

1. INTRODUKSIYON

Ayon sa *Commission on Higher Education* (CHED) ng Pilipinas, ang *Natural Sciences* na kurso, kabilang na ang *Zoology* ay nakatanggap ng 31,188 na mag-aaral sa buong Pilipinas, subalit, 8,693 lamang ang nakapagtapos sa kursong ito noong 2018 hanggang 2019. Kapansin-pansin na wala masyadong mga pananaliksik tungkol sa buhay ng isang *zoologist* sa Pilipinas. Lahat ng mga pananaliksik na mayroong relasyon sa buhay ng mga *zoologists* ay tungkol lamang sa kanilang mga hamon. Ayon kina Stanhope, Carver, at Weinstein (2015), mahirap maging isang *entomologist*, dahil mas nanganganib ang kanilang buhay pagdating sa kanilang kalusugan. Bukod dito, hindi kaya ng mga *zoologists* ipahayag ang mga bago nilang kaalaman dahil hindi sila marunong makipag-usap sa ibang taong hindi bahagi ng kanilang larangan, at puro *jargon* lamang ang kanilang ginagamit (Johnson, 2009).

Ayon pa rin sa *Commission on Higher Education* (CHED) ng Pilipinas, ang *Medical at Allied* na kurso ay nakatanggap ng 215,234 na mag-aaral sa Pilipinas, at 42,425 ang nakatapos sa kursong ito. Kung ikukumpara ang mga mag-aaral na kumuha ng *Natural Sciences* at ang mga kumuha ng *Medical at Allied*, makikita ang malaking diperensya sa dalawang ito.

Kaugnay nito dahil sa kakulangan ng impormasyon at kamalayan tungkol sa kanila, nais ng mga mananaliksik na malaman ang mga karanasan, hamon, at kanilang motibasyon. Makatutulong ang pag-aaral na ito upang magkaroon ng mas malalim na kaalaman sa mga natatanging karanasan ng mga *zoologists*.

1.1 Mga Layunin ng Pag-aaral

Nakatuon ang pananaliksik na ito sa pag-aanalisa sa mga karanasan, hamon, at motibasyon ng ilang mga *zoologists* edad 25-50 sa Pilipinas.

Nais ng mga mananaliksik na masagot ang mga sumusunod na katanungan:

1. Ano ang karaniwang ginagawa ng isang *zoologist* sa trabaho, at mga halimbawa nito?
2. Ano ang mga hamon na nararanasan ng mga *zoologists* patungo sa kanilang trabaho?
3. Ano ang mga naging motibasyon ng mga respondente upang maging isang *zoologist*?

1.2 Saklaw at Limitasyon

Sakop ng pananaliksik na ito ang pagsusuri sa mga karanasan, hamon, at motibasyon ng *zoologists* sa Metro Manila. Nakatuon ang pag-aanalisa sa iba't ibang aspeto sa buhay-trabaho ng mga *zoologists*.

Nilimitahan ng mga mananaliksik ang pag-aaral na ito sa mga *zoologists* edad dalawampu't lima (25)

hanggang limampung (50) sapagkat mayroon na silang sapat na kaalaman at karanasan sa kanilang larangan. Ang mga *zoologists* ay manggagaling sa tatlong (3) na institusyon na ito: Unibersidad ng Pilipinas, Unibersidad ng Santo Tomas, at ang Pambansang Museo ng Pilipinas. Ang mga nasabing paaralan at museo ay ilan sa mga institusyon sa Metro Manila na mayroong departamento ng *Zoology* o kaya mayroong mga *zoologists* na sanay na sa kanilang trabaho.

2. METODOLOHIYA

2.1. Disenyo ng Pananaliksik

Ang pag-aaral na ito ay tungkol sa mga karanasan, hamon, at motibasyon ng mga *zoologists* sa Metro Manila. Ito ay isinagawa gamit ang penomenolohikal na disenyo. Tinangka nitong ilarawan ang danas ng mga *zoologists* sa Metro Manila.

2.2. Mga Kalahok at Sampling Teknik

Ang mga kalahok ay binubuo ng labing-isang (11) piniling *zoologists* (guro at *curator*) mula sa Unibersidad ng Pilipinas, Unibersidad ng Santo Tomas, at ang Pambansang Museo ng Pilipinas. Pinili ang mga kalahok gamit ang Purposive Sampling teknik.

2.3. Instrumento ng Pag-aaral

Ang instrumento ng pananaliksik na ginamit sa pangangalap ng mga datos ay ang Patnubay na Talatanungan. Naglalaman ito ng dalawampung (20) tanong na nagsilbing gabay sa isinagawang interbyu.

2.4 Paraan ng Pagkakalap ng mga Datos

Nagsimula sa pagbuo ng patnubay na talatanungan ang mga mananaliksik. Matapos itong maaprobahan at maipa-validate ay humanap ng 11 na mga potensyal na kalahok na siyang kinapanayam.

2.5 Paraan ng Pagsusuri ng mga Datos

Mula sa isinagawang pakikipanayam, sinuri ng mananaliksik ang mga sagot ng mga respondenteng *zoologists* na dalawampu't lima (25) hanggang limampung (50) taong gulang. Sinuri ang mga karanasan, hamon, at motibasyon nila sa pagtatrabaho batay sa mga nangingibabaw na tema.

3. RESULTA AT DISKUSYON

Batay sa isinagawang pagsusuri ang mga karaniwang gawain ng isang *zoologist* ay ang pagsasagawa ng mga eksperimento. Tuwing ginagawa nila ito, kadalasan na sa *field site* sila, o nasa loob ng laboratoryo. Narito ang isa sa mga halimbawang verbatim: *"Sumasama din ako sa mga fieldwork ng museum and we try to collect snake samples, frog samples um in the field."*

Isa rin sa mga karaniwang gawain nila ay ang paggawa at pagbabahagi ng mga pananaliksik. Ang mga nakuha nilang impormasyon galing sa mga eksperimento ay sinusuri, at ibinabahagi nila sa pamamagitan ng mga *publications* o sa mga kumperensya. Narito ang isa sa mga halimbawang verbatim: *"I presented some of our work in other countries. Yung most recently, or the best experience was when we went to Japan. So, we presented our work there. Uhmm, the, it was a conference, so the conference was, uhh, two days, two days,"*

Bukod dito, nagtuturo rin sila sa mga nais maging isang *zoologist*. Sapagkat maraming *zoologists* na nangangailangan magturo habang sila ay nagsasagawa ng mga pananaliksik. Narito ang isa sa mga halimbawang verbatim: *"So, I work in a university, so, for much of our time is spent teaching. So, we teach college students."*

Batay naman sa resulta para sa mga hamong kinahaharap ng mga *zoologists* sa trabaho, isa dito ay ang mga panganib na nakakasalubong nila tuwing nasa *field site* sila. Sapagkat marami silang nararanasan sa *field* na maaaring makapinsala sa kanilang kalusugan at kaligtasan kagaya ng mga problema sa kalikasan, mga taong hindi nakauunawa sa trabaho nila, at iba pang mga kadahilanan na hindi nila makontrol. Narito ang isa sa mga halimbawang verbatim: *"In the Philippines, most probably mosquitos, noh, mas, mas nakakatakot pa sila kasi they can bring, uhmm, highly pathogenic or, uhmm, yun very dangerous, uhh, pathogens or viruses in their bodies like Dengue, Malaria, so... Elephantiasis, so yun, they can bring a variety of parasites or pathogens."*

Isa ring hamong nararanasan nila ay ang kakulangan ng suporta at kamalayan ng gobyerno at ng mga lokal na tao. Dahil dito, ilan sa mga *zoologists* ay hindi nakagagawa nang maayos na pananaliksik. Kadalasan umaasa sila sa tulong galing ibang bansa upang magawa nila ang kanila trabaho na madalas hindi pinapansin ng mga Pilipino. Narito ang isa sa halimbawang verbatim *"It's-It's really hard to get funding from local agencies such as the government, they're very meticulous, and the government is not keen on, uhmm, basic research such as, uhmm, what we do. What the government wants, usually, is more on the applied, uhmm, side of research."*

Batay naman sa makikitang resulta sa motibasyon ng mga *zoologists* pagdating sa kanilang trabaho, isa dito ay ang mga oportunidad at gantimpala. Sapagkat ito ay nagbibigay ng pagkilala at mga koneksyon sa mga nasa larangan nila. Narito

ang isa sa mga halimbawang verbatim: "*I'm quite pleased with fact na in the scientific circle, for instance, if they say sinong gumagawa ng research sa lakes sa Pilipinas? O sinong gumagawa ng research sa zooplankton sa Pilipinas? They would think of our lab. And then, for me, that's enough, parang affirmation.*"

Isa ring motibasyon ng mga *zoologists* ay ang mga panlabas na impluwensya kagaya ng mga *advisers* nila, mga kasama nila sa trabaho, at magulang nila. Sila ay nagsisilbing motibasyon sapagkat ang mga taong ito ay naghihikayat sa kanila upang ipagpatuloy nila ang pagiging *zoologist*. Narito ang isa sa mga halimbawang verbatim: *"Yung mga naging professors ko, uhh, and they were instrumental in, uhmm, encouraging me to get into Herpetology or in the field of zoology."*

Bukod dito, ang nag-uudyok din sa mga kalahok ay ang kanilang adbokasiya at ang mga batayan kung bakit nila pinili ang kanilang trabaho kagaya ng kanilang personal na interes mula kabataan, mga layunin nila sa buhay, at ang mga panloob na kadahilanan. Sapagkat ito ay nagpapalalim sa kanilang dedikasyon para sa kanilang trabaho. Narito ang isa sa mga halimbawang verbatim: *"I just wanna conserve this natural heritage that we have. So if we get to reach the goal, I mean what my goal is really to have more protected areas just to prevent extinction." "Um, so since bata pa ako, I've been exposed sa environment so parang nag-start yun bilang camping activities and scouts."*

Diskusyon

Ipinapakita sa resulta na ang karaniwang gawain ng mga *zoologist* ay nangyayari sa loob ng laboratoryo, *field sites*, at unibersidad. Ang mga gawaing isinasagawa sa loob ng laboratoryo ay DNA *analysis* at ang pag-opera at pag-obserba ng mga organismo. Ayon kay Sunderland (2012), ang mga gawain tulad ng pag-oopera na kinakailangan para sa paglilipat ng mga nilalaman ng isang *amphibian* ay isinasagawa sa laboratoryo. Ang mga halimbawa naman ng mga gawain sa *field sites* ay ang pangongolekta ng mga sampol, paghahanap ng mga hayop, at ang mga panlabas na gawain katulad ng *camping* at *hiking*. Ang nakikitang mga *landscape* pagdating sa samahan ng hayop at ang kanilang kapaligiran ay nakatutulong sa perspektibong analitikal dahil pinapadali nito ang mga obserbasyon na maaaring dumagdag sa kaalaman ng mga *zoologist* (Sunderland, 2012). Ang huling karaniwang gawain ng isang *zoologist* ay ang pagtuturo ng *Zoology*. Bagaman hindi ito ang pangunahing trabaho nila, ito ay nakatutulong sa paghihikayat ng kanilang larangan. Ayon kay Hernawati, Amin, Irawati, Idriwati, at Aziz (2018), may mga guro ng *Vertebrate Zoology* na sinubukan ang pagsasama-sama ng mga *student teachers*, at natuklasan nila na may magandang epekto ito sa kakayahan at kagalingan ng mga estudyante sa pag-aaral ng *Zoology*. Makikita rito na malaki ang impluwensya ng mga *zoologists* sa pagpapaunlad ng kanilang larangan kapag sila ay nagtuturo. Isa pa sa ginagawa ng mga *zoologist* habang nagtuturo ay ang pagsusulat at pagbabahagi ng mga akademikong papel.

Bukod sa mga karaniwang karanasan ng mga *zoologists*, ipinakikita rin ng resulta ang mga hamon na natuklasan ng mga *zoologists* sa trabaho. Isa sa mga hamon nila ay ang mga panganib na natagpuan habang ginagawa nila ang kanilang trabaho, lalo na sa pagsasagawa ng *fieldwork*. Kasama sa mga panganib na maaari nilang maranasan ay ang pagkakaroon ng sakit. Ayon kay Stanhope, Carver, at Weinstein (2015), ang mga *entomologists*, isang uri ng *zoologist*, ay nagkakaroon ng iba't ibang uri ng sakit, lalo na sa balat. Nararanasan din nila magkaroon ng impeksyon at *delusional parasitosis*. Bukod pa rito, maraming hayop ay mayroong iba't ibang uri ng *parasite,* kaya kinakailangang magkaroon ng kamalayan tungkol dito upang maiwasan ang pagkalat ng mga *endoparasite* at *zoonose* na ito (Dărăbuş, Afrenie, Hotea, Imre, & Morariu, 2014). Maliban sa mga sakit, maaari din silang makaranas ng iba pang problema sa *field site*. Ang mga halimbawa nito ay ang mga isyu sa kalikasan. Dahil dito, nahihirapan ang mga *zoologists* magsagawa ng *fieldwork* sapagkat konti nalang ang nakukuha nilang mga sampol. Ayon kay Batool at Hussain (2016), maraming dahilan tulad ng pagbabago ng klima, pagbaha, *deforestation*, at iba pang mga isyu na nakaaapekto sa kalikasan, at dahil dito, hindi kaya ng mga hayop mamuhay sa ganitong klaseng kapaligiran. Maliban sa mga hamong nararanasan nila tuwing *fieldwork*, nagkakaroon din sila ng mga paghihirap sa labas nito. Ang hamon na ito ay ang kakulangan ng suporta at kamalayan sa mga Pilipinong *zoologists*. Ayon sa resulta, mahirap maging isang *zoologist* sa Pilipinas sapagkat hindi sila gaanong sinusuportahan ng gobyerno. Sa taong 2020, ang badyet na ibinigay sa Kagawaran ng Agham at Teknolohiya, o mas kilala bilang *DOST* ay nabawasan. Ang dating 20.26 bilyong piso ay naging 20.18 bilyong piso na lamang. Bukod pa rito, ayon kay Lamberte (2018), 6.3 na porsyento lamang ng buong badyet ng *DOST* ay ibinigay para sa sektor ng *research* at *development* (R&D) para sa taong 2019. Ipinakikita nito na hindi ito prayoridad ng gobyerno. Isa pang hamon na kinakaharap ng mga Pilipinong *zoologists* ay ang paghahanap ng trabahong pangmatagalan. Batay sa resulta, mahirap magkaroon ng trabaho sa larangang ito, maliban nalang kung propesor o guro ang nais maging ng isang nagtapos ng Dalubhayupan o Haynayan. Ayon kay Russell (2009), maraming idinagdag na bagong impormasyon tungkol sa larangan ng *Zoology* pati na

rin ang pagdaragdag ng iba't ibang mga *subclass* sa *biology* ng hayop. Dahil dito, pabago-bago ang kurikilum ng *Zoology*.

Bagama't may kahirapan sa propesyong kanilang napili, isa sa mga naging motibasyon nila ay ang mga oportunidad o gantimpala na makukuha nila sa trabaho. Batay sa resulta, maaari silang makakuha ng *monetary rewards*, o kaya makapunta sa ibang bansa upang mailahad ang kanilang mga gawa. Sa pamamagitan ng pagtatanghal ng kanilang mga pananaliksik, ito ay nagbibigay ng karangalan sa kanila bilang isang *zoologist*. Batay sa pagsisiyasat nina Lucrezi, Milanese, Danovaro, at Cerrano (2017), pinili ng mga respondente nila na kunin ang kursong Haynayan dahil gustong nilang pumunta sa ibang bansa, at magsagawa ng pananaliksik. Maliban sa mga makukuhang oportunidad at gantimpala, isa pang motibasyon nila ay ang mga panlabas na impluwensya, kagaya ng mga *advisers*, mga magulang, at *role models* nila. Ayon kina Cake, McArthur, Mansfield, Zaki, Carbonneau, at Matthew (2019), isa sa mga pangunahing impluwensya sa pagkukuha ng trabaho kasama ang mga hayop ay ang mga hinahangaan nilang tao o matuturing nilang *role models*. Base rito, makikita na hinahangaan ng mga *zoologists* ang kanilang mga *advisers* at ang mga magulang nila. Bukod sa mga panlabas na impluwensya, ang nag-uudyok din sa mga *zoologists* ay ang kanilang adbokasiya at ang mga batayan kung bakit nila pinili ang kanilang trabaho kagaya ng kanilang personal na interes mula kabataan, mga layunin nila sa buhay, at ang mga panloob na kadahilanan. Ayon sa resulta, maraming kalahok ang nagsabing mahilig sila sa mga hayop, sa mga gawaing panlabas, pati na rin sa kalikasan. Ang mga interes na ito ay nagsisilbing motibasyon sapagkat nagbibigay ito ng ligaya sa kanilang buhay. Ayon sa pananaliksik nina Cake et al. (2019), karamihan ng mga naging motibasyon ng mga kalahok nila ay mayroong kaugnayan sa kahiligan at ang maagang pagkakalantad sa mga hayop. Ang ideya na ito ay lalong pinagtibay ni Michael Oldham, isang *herpetologist*. Ayon kay Oldham (2016), noong bata pa siya, naging interesado na siya sa mga hayop, sa partikular ang mga *amphibians* at *reptiles*. Dahil nalantad siya sa interes na ito sa murang edad, naging impluwensya ito upang maging isang *zoologist*. Ayon din sa isa pang pananaliksik nina Cake et al. (2019), mayroong anim na salik na nag-impluwensya sa mga respondente nila, at ang mga ito ay layuning panlipunan, *animal orientation*, bokasyonal na pagkakakilanlan, mga hamon at pagkatuto, *career affordances*, at *people orientation*. Batay sa mga salik na ito, makikita na mayroong kaugnayan sa mga naging motibasyon ng mga *zoologists* upang kunin at ipagpatuloy ang kursong Zoology. Ngunit, mayroong isang salik na hindi nabanggit, at ito ay ang relihiyon. Ayon kay Hernandez, Foley, at Beitin (2010), malaki ang naging impluwensya ng relihiyon sa mga respondente nila sa pagpili ng karera. Nararamdaman ng mga respondente nila ang patnubay ng Diyos habang sila ay nasa proseso ng pagdedesisyon.

4. KONGKLUSYON

Hindi naging madali ang pagiging isang zoologist sa Pilipinas sapgkat marami silang mga hamon na nararanasan. Katulad ng mga panganib na natatagpuan nila sa *field site* o kaya naman ang kakulangan ng suporta ng gobyerno o mga lokal na tao. Gayunpaman kumukuha sila ng inspirasyon sa mga taong sumusuporta sa kanila, mga oportunidad at gantimpala na natatanggap nila, at sa pagmamahal nila sa kanilang larangan.

5. PASASALAMAT

Taus-pusong pasasalamat ang aming ipinaabot sa mga sumusunod na indibidwal at tanggapan dahil sa mahahalagang tulong, kontribusyon at/o suporta tungo sa matagumpay na reyalisasyon ng pananaliksik na papel na ito:

1. Sa labing-isang (11) *zoologists* galing sa Unibersidad ng Pilipinas, Unibersidad ng Santo Tomas, at ang Pambansang Museo ng Pilipinas sa paglalaan ng panahon at sa matapat na pagsagot sa aming inihandang kwestyuner,
2. Sa mga awtor, editor at mga mananaliksik ng mga akdang pinaghanguan naming ng mahahalagang impormasyong aming ginagamit sa pagsulat ng una at ikalawang kabanata ng pananaliksik na papel,
3. Kay Bb. Anna Patricia Gerong (Research in Daily Life 1), Bb. Abbygale C. Pinca (Pagbasa at Pagsusuri ng iba't ibang Teksto tungo sa Pananaliksik), at G. Jemyr B. Garcia (Pagsulat sa Filipino sa Piling Larangan), mga masisigasig naming dalubguro na gumabay sa amin sa tamang hakbangin sa pagsulat at paggawa ng isang pananaliksik na papel,
4. Sa aming mga magulang at pamilya, sa pagtulong nila sa amin sa gramatika ng aming papel, at sa pagsuporta nila sa aming pananaliksik,
5. Sa mga kaklase namin, lalo na sa aming *class beadle*, sa pagpaalala tungkol sa mga *due dates* at sa pagsasagot ng aming mga tanong,
6. Sa Panginoong Diyos, sa pagdinig sa aming mga dalangin lalung-lalo na sa mga panahong gusto naming sumuko, at sa pagbigay ng pag-asang matapos namin ang pananaliksik na ito nang maayos sa itinakdang-panahon.

Muli, maraming-maraming salamat po.

Eunice Gabrielle A. Galimpin
Natalie Teresita Romualdez

6. MGA SANGGUNIAN

Aryanti, F., & Suhaerah, L. (2019). The effectiveness of a field study on vertebrate zoology to improve the mastery of student concept. International Conference On Biology And Applied Science (Icobas). doi: 10.1063/1.5115715

Bagaria, A., & Sharma, A. K. (2015). A Knowledge and Practices study of health hazards among animal handlers in zoological gardens. International Journal of Occupational Safety and Health, 4(1), 1–4. doi: 10.3126/ijosh.v4i1.9146

Batool, S., & Hussain, M. (2016). Wildlife in the perspective of environmental degradation: A review. Journal of Entomology and Zoology Studies, 4(5), 508-511. Mula sa http://www.entomoljournal.com/archives/2016/vol4issue5/PartH/4-5-34-937.pdf

Cake, M., Mansfield, C., McArthur, M., Zaki, S., & Matthew, S. (2019). An Exploration of the Career Motivations Stated by Early-Career Veterinarians in Australia. Journal of Veterinary Medical Education, 46(4), 545–554. doi:10.3138/jvme.0717-093r

Cake, M., McArthur, M., Mansfield, C., Zaki, S., Carbonneau, K., & Matthew, S. (2019). Challenging identity: development of a measure of veterinary career motivations. Veterinary Record. doi:10.1136/vr.105510

Candrasekaran, S. (2014). Effectiveness of Synectics Techniques in Teaching of Zoology at Higher Secondary Level. International Journal of Humanities and Social Science Invention, 3(8), 37–40. Mula sa https://www.academia.edu/download/52421517/G0381037040Effectiveness_of_Synectics_Techniques_in_Teaching_of_Zoology_at_Higher_Secondary_Level.pdf

Commission on Higher Education. (2019, Hunyo 30). Higher education enrollment by discipline group. Mula sa https://ched.gov.ph/wp-content/uploads/2019-Enrollment-by-Discipline.pdf

Commission on Higher Education. (2019, Hunyo 30). Higher education graduates by discipline group. Mula sa https://ched.gov.ph/wp-content/uploads/2019-Graduates-by-Discipline.pdf

Dărăbuș, G., Afrenie, M., Hotea, I., Imre, M., & Morariu, S. (2014). Endoparasites In Mammals From Seven Zoological Gardens In Romania. Journal of Zoo and Wildlife Medicine, 45(2), 239–246. doi: 10.1638/2012-0170.1

Dubois, A. (2011). The International Code of Zoological Nomenclature must be drastically improved before it is too late. Bionomina, 2(1), p. 1–104. doi: 10.11646/bionomina.2.1.1

Find University. (n.d.). BS in Zoology in the Philippines. Mula sa https://www.finduniversity.ph/majors/bs-in-zoology-philippines/

Hernandez, E. F., Foley, P. F., & Beitin, B. K. (2010). Hearing the Call: A Phenomenological Study of Religion in Career Choice. Journal of Career Development, 38(1), 62–88. doi:10.1177/0894845309358889

Hernawati, D., Amin, M., Irawati, M., Indriwati, S., & Aziz, M. (2018). Integration of Project Activity to Enhance the Scientific Process Skill and Self-Efficacy in Zoology of Vertebrate Teaching and Learning. EURASIA Journal of Mathematics, Science and Technology Education, 14(6). doi:10.29333/ejmste/89940

Johnson, K. (2009). The Return of the Phoenix: The 1963 International Congress of Zoology and American Zoologists in the Twentieth Century. Journal of the History of Biology, 42(3), p. 417-456. doi: 10.1007/s10739-008-9160-1

Koene, J. (2012). Editorial: Zoology is dead, long live zoology! Animal Biology, 62(4), 379-380. doi:10.1163/15707563-00002403

Lamberte, M. (2018). Department of Science and Technology FY 2019. Mula sa Congressional Policy and Budget Research Department website: https://cpbrd.congress.gov.ph/images/PDF%20Attachments/ABN/ABN2018-22_DOST.pdf

Lucrezi, S., Milanese, M., Danovaro, R., & Cerrano, C. (2017). "Generation Nemo": motivations, satisfaction and career goals of marine biology students. Journal of Biological Education, 1–15. doi:10.1080/00219266.2017.1385509

Mauldin, M., Doty, J., Nakazawa, Y., Emerson, G., & Carroll, D. (2016). The Importance of Mammalogy, Infectious Disease Research, and Biosafety in the Field. Journal of Parasite Biodiversity, 3, p. 1-9. Mula sa https://www.researchgate.net/publication/307940544_The_Importance_of_Mammalogy_Infectious

_Disease_Research_and_Biosafety_in_the_Field/link/57d2caa608ae601b39a41c61/download

National Museum of the Philippines. (2014). Important recognitions awarded to members of the Zoology Division. Mula sa https://www.nationalmuseum.gov.ph/nationalmuseumbeta/Zoology/ZoologyQuest.html

National Museum of the Philippines. (2014). Role of the Zoology division. Mula sa https://www.nationalmuseum.gov.ph/nationalmuseumbeta/Zoology/ZoologyRole1.html

National Museum of the Philippines. (2014). Turning Points. Mula sa https://www.nationalmuseum.gov.ph/nationalmuseumbeta/Zoology/ZoologyHistory2.html

Oldham, M. (2016). Ramblings and Recollections from a Career in Herpetology. The Canadian Herpetologist, 6(2), p. 13-22. Mula sa https://www.researchgate.net/publication/325742252_Ramblings_and_Recollections_from_a_Career_in_Herpetology

Russell, A. (2009). Situating and teaching 21st century zoology: revealing pattern in the form and function of animals. Integrative Zoology, 4(3), p. 309–315. doi: 10.1111/j.1749-4877.2009.00165.x

Shalaby, I., El-Shenawy, N., Ghobasy, M., & Mohammadein, A. (2011). Enhancement the teaching and learning methods of some zoological courses (invertebrate, parasitology and animal physiology) in Taif University, KSA. Journal of American Science, 7(2), p. 232-238. Mula sa https://www.researchgate.net/publication/230815612_Enhancement_

the_teaching_and_learning_methods_of_some_zoological_courses_invertebrate
_parasitology_and_animal_physiology_in_Taif_University_KSA

Stanhope, J., Carver, S., & Weinstein, P. (2015). The risky business of being an entomologist: A systematic review. Environmental Research, 140, p. 619-633. doi:10.1016/j.envres.2015.05.025

Sunderland, M. E. (2012). Collections-Based Research at Berkeley's Museum of Vertebrate Zoology. Historical Studies in the Natural Sciences, 42(2), 83-113. doi:10.1525/hsns.2012.42.2.83

Ulicsni, V., Babai, D., Vadász, C., Vadász-Besnyői, V., Báldi, A., & Molnár, Z. (2018). Bridging conservation science and traditional knowledge of wild animals: The need for expert guidance and inclusion of local knowledge holders. Ambio. doi:10.1007/s13280-018-1106-z

Wit, L. (2020). Zoology. World Book Student. Mula sa https://worldbookonline.com/student-new/#/article/home/ar617440/zoology

Yermekbayeva, A. T., Shaimerdenova, G. Z., Ziyaeva, G., Kaliyeva, A. K., Yessimov, B. K., Childibayev, J. B., … Sergazynova, M. S. (2018). Implementation of New Approaches to Zoology and Ecology Teaching Based on the Bioecology of Snakes and Sarcosporidia Course. Ekoloji, 27(106), p. 249–255. Mula sa http://www.ekolojidergisi.com/download/implementation-of-new-approaches-to-zoology-and-ecology-teaching-based-on-the-bioecology-of-snakes-5357.pdf

The Effect of Spent Coffee Grounds to the Growth of *Solanum lycopersicum* (Tomato)

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Abstract: Six billion tonnes of spent coffee grounds (SCG) are thrown untreated into landfills, leading the spent coffee grounds to leach organic pollutants that may potentially harm bodies of water and emit methane, a greenhouse gas, into the atmosphere. Studies have confirmed that the ratio of carbon and nitrogen (C: N) of SCG is ideal for plant fertilizers. This study focused on determining the effects of SCG on the growth of tomato plants using four parameters: the number of leaves, the average leaf surface area, and the relative growth rate. The study used an experimental research design to study the causal relationship between SCG treatments and plant growth. Tomato seeds were grouped into four and sown on separate pots. The study used three trials, each containing different weights of SCG, namely: 0 g, 5 g, 9 g, and 14 g. The SCG treatments were applied after germination using the side-dressing method. The number of expanded leaves, leaf surface area, and relative growth rate of the tomato plants were observed every five days for 45 days. The researchers found that SCG treatments that exceeded SCG-5 displayed adverse effects on the growth of the tomato. Thus, the relative growth rate and SCG treatments of over 5 g are inversely related to one another. Results show that SCG-5 had the highest positive effect on plant growth in terms of all the parameters. The researchers can then conclude that SCG-5 is an effective alternative fertilizer that improves plant growth.

Key Words: tomato, spent coffee grounds, fertilizer, plant growth, ericaceous plant

1. INTRODUCTION

Solanum lycopersicum, commonly known as tomato, is an economically important and in-demand crop in the Philippines due to its versatility as a nutritious ingredient. This is clearly seen with the increased amount in terms of production in the country (Renna et al., 2018; Manzano & Mizoguchi, 2013). It is classified as an ericaceous plant, which thrives and grows better on soil with low pH, specifically with a 5.5 - 8.0 soil pH range, hence also being in favor of high acid fertilizers (Cubero & Baquiran, 2017).

Tomato has five growth stages, namely the germination stage (25 to 35 d), vegetative period (20 to 25 d), flowering stage (20 to 30 d), early fruiting stage (20 to 30 d), and mature fruiting stage (15 to 20 d). The number of days and success within each stage may vary depending on environmental conditions (Jones, 2013; Garcia et al., 2011). To produce and grow the standard requirements to achieve satisfactory results of plant growth, farmers usually resort to commercial fertilizers. However, the unnecessary overuse of these fertilizers results in increased soil salinity, metal accumulation, water eutrophication, and nitrate accumulation, leading to health hazards and the greenhouse effect (Savci, 2012). Therefore, a need for organic and convenient alternatives is needed to reduce the environmental impact of commercial fertilizers.

Spent coffee grounds (SCG) are the primary solid residual material obtained during the coffee brewing process. When dumped into landfills, they leach high concentrations of organic pollutants into bodies of water, affecting the organisms that live there and emit methane, a greenhouse gas that causes global warming (Cruz et al., 2012; Cervera-Mata et al., 2017; Thenepalli et al., 2017). SCG is known to have a pH level between 6.5 to 6.8 (Coffee Grounds and Composting, n.d.). It has been studied as a potential fertilizing agent throughout recent years due to its nitrogen and potassium content, together with its carbon and nitrogen (C: N) ratios that are ideal for fertilizers (Caetano et al., 2014).

Fertilizers play the role of supplementing the essential nutrients of a plant in order to promote efficient plant growth (Purbatanji et al., 2019). The plant growth of a plant can be assessed in a cost-effective and non-destructive way by measuring its number of expanded leaves, average leaf surface area, and relative growth rate (RGR). The expanded leaves account for the total and average leaf surface area of the plant. Meanwhile, leaf area growth is considered

an essential parameter in determining plant productivity as it determines light interception activities. It is also directly correlated to the RGR or the change in mass per day (Wood & Roper, 2000; Paproki et al., 2012 as cited in Pound et al., 2014; Koester et al., 2014).

Thus, this study aims to assess the effects of SCG on the growth of Solanum lycopersicum. Specifically, in terms of the number of expanded leaves, average leaf surface area, and RGR using varying amounts of SCG namely 0 g, 5 g, 9 g, and 14 g.

2. METHODOLOGY

2.1. Planting of Tomato Seeds

The researchers bought tomato seeds from a local nursery. The seeds were first planted on seedling bags, each containing 30 g of topsoil from a local area around Silang, Cavite. The germination phase lasted for 41 d. Once germination is complete, one strong strand from each seedling bag was transplanted into their respective pots each containing 1 L of soil. Given that there were four treatments SCG-0, SCG-5, SCG-9, and SCG-14 with 0 g, 5 g, 9 g, and 14 g respectively, each replicated three times, there were a total of 12 experimental units or pots (see Fig. 1).

Fig 1. Tomato plots

2.2 Application of SCG Treatments

All SCG used was a mixture of Coffea arabica and Coffea canephora beans gathered from Cafe Agapita on the day of application. The SCG treatments were applied through side-dress application during the second week since the plants were transplanted (see Fig. 2). They were furrowed 2 in. deep and at least 2 in. away from the plant in a circle around each plant and covered with soil. Netting was also done by setting up the wooden planks apart from each other and covering them entirely with 0.4 mm x 0.7 mm small mesh nets. The researchers introduced the SCG to the plants three times in equal amounts in a fifteen-day interval.

Fig 2. Side-dress application of SCG Treatments

The plants were examined every five days for 45 days for the changes in the number of the expanded leaves, leaf surface area, and relative growth rate (RGR). All leaves on the plant, no matter how small, were counted for the number of expanded leaves. The researchers used ImageJ software (Fig. 3) to measure the leaf surface area of all leaves on each plant. This data was then used to determine whether there is an increase or decrease in the RGR of the tomato plants.

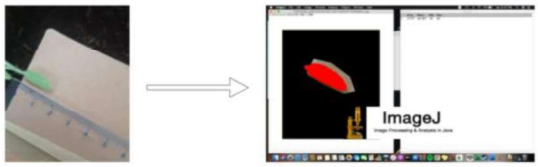

Fig 3. Leaf area measurement sample using ImageJ

3. RESULTS AND DISCUSSION

3.1 Number of Expanded Leaves

Fig. 4 shows the data on the number of expanded leaves collected over 45 days. The plants in SCG-9 have the highest number of leaves among the pots on the initial collection of data. However, an increase in the number of leaves on plants was seen on SCG-5 plants upon the second SCG application. Thus, SCG-5 garnered the highest number of leaves with 20 leaves leaving SCG-0 and SCG-9 with the second and third highest number of leaves and SCG-14 with the least number of leaves, 19 and 16 respectively.

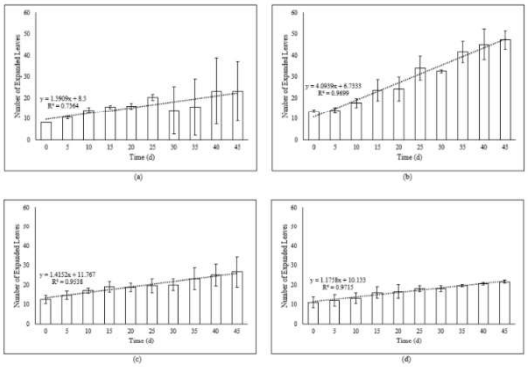

Fig 4. Average number of expanded leaves for (a) SCG-0, (b) SCG-5, (c) SCG-9, and (d) SCG-14.

After 15 d, a continuous increase was displayed by the plants in SCG-5. On the other hand, a slow rise in the growth of leaves in SCG-9 resulted in fewer leaves than SCG-0. SCG-5, followed by SCG-0, SCG-9, and SCG-14, displayed a decreasing trend in its number of expanded leaves which continued until the end of the data collection period.

A higher number of expanded leaves would, in turn, mean that SCG-5 observed the most considerable amount of growth (Wood & Roper, 2000). However, it is also worth noting that the control group, SCG-0, has the second-highest number of expanded leaves. This leaves a negative implication that greater amounts of SCG affect the emergence of leaves on the tomato plant.

The results imply that low concentrations of SCG applied are more effective in plant growth. This is evident by the data in the number of expanded leaves as SCG-5 showed the most significant increase in the number of expanded leaves.

3.2 Average Leaf Surface Area

Fig. 5 shows the average leaf surface area obtained on the 45th day of tomato plants grown in four varying SCG weights.

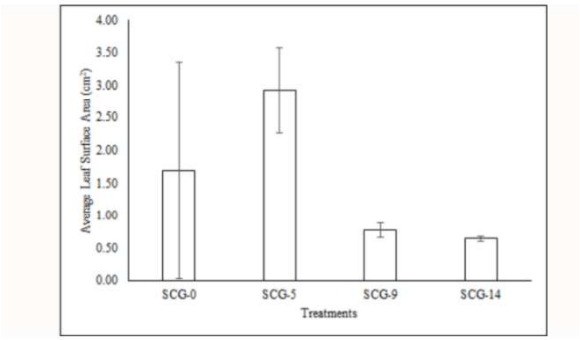

Fig 5. Average leaf surface area in respect to the amount of SCG at t = 45 d.

Upon the last day of data collection, SCG-5 had the highest average leaf area with a value of 2.92 cm2. SCG-0 came second with an average leaf area of 1.69 cm2, followed by SCG-9 with 0.77 cm2, and last was SCG-14 with 0.64 cm2.

The changes in leaf surface area may be due to varying environmental conditions such as climate, topography, and soils (Trimble, 2019). However, leaf surface area changes are more tightly related to soil nutrient status, specifically C: N ratios or N mineralization, than climate. Considering that the C: N ratios in SCG are ideal for fertilizers, the SCG is most likely to be the cause of the changes in leaf surface area (Gong & Gao, 2019; Ordonez et al., 2009; Caetano et al., 2014).

The plausible cause for affecting the soil nutrients status is overfertilization which may be rooted in the excessive amounts of fertilizer added at one time. The salinity of excessive SCG could have promoted the reduction of photosynthesis and an increase in leaf dehydration (Kozlowski et al., 1997; Ciesielczuk et al., 2018). Moreover, SCG may have caused high N-buildup in the soil that led to excessive vegetative growth, yet turning younger leaves into smaller sizes, delaying the growth of tomato plants (Sainju, Dris, & Singh, 2003). Thus, greater amounts of SCG applied resulted in lower leaf surface area values.

3.3 Relative Growth Rate

Fig. 6 shows the total leaf surface area of tomato plants treated with varying amounts of SCG throughout 45 d.

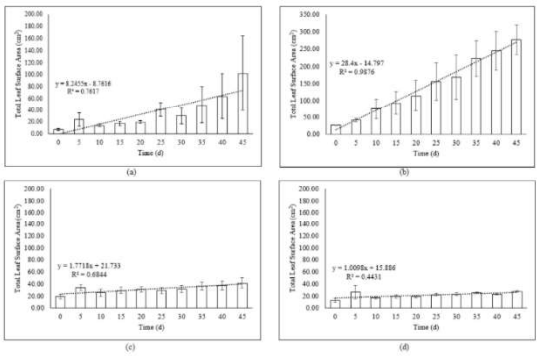

Fig 6. Total leaf surface area of (a) SCG-0, (b) SCG-5, (c) SCG-9, and (d) SCG-14.

Fig 6. Total leaf surface area of (a) SCG-0, (b) SCG-5, (c) SCG-9, and (d) SCG-14.

Table 1 summarizes the RGR of the tomato plants. The slope of the trendline for the total leaf surface area (as shown in Fig. 6) served as the RGR as it measures the change in total surface area, accounting for the mass of the plant, over the change in time.

Table 1. Relative growth rates of all treatments.

Treatment	RGR (cm^2/d)
SCG-0	8.2455
SCG-5	28.4
SCG-9	1.7718
SCG-14	1.0098

SCG-5 yielded the highest RGR among all the other SCG treatments with 28.4 cm2/d, followed by SCG-0, SCG-9, and SCG-14 with values 8.2455 cm2/d, 1.7718 cm2/d, and 1.0098 cm2/d, respectively.

From the data, the greater amount of SCG applied led to low RGR values. Factors that cause it may be the minerals and nutrients accumulated in the tomato plants as the incorporation of SCG increases the nitrogen, potassium, and phosphorus contents (Chrysargyris et al., 2020). As aforementioned in Section 3.2 of this paper, excess nutrient content is a sign of overfertilization resulting in the decline of the photosynthetic ability of the plant. Thus, creating smaller leaves, implying lower value for the mass of the plants, leading to the stunted growth rate of tomato plants. Moreover, overfertilization in potted plants also leads to very low or no plant growth at all (Woorman, 2011).

4. CONCLUSIONS

Results for all parameters showed that SCG-5 had the best plant growth results compared to SCG-9 and SCG-14, which displayed signs of overfertilization. It also surpassed the growth of the tomato plant without any treatments of SCG, making SCG-5 a viable fertilizer for tomato plants. To further support this finding, the most appropriate amount of SCG to be applied from 0 to 8 g can be identified in order to determine the highest amount for maximum efficiency properly. Other stages and parameters of plant growth that were not assessed in this study due to its limitations can also be evaluated. Moreover, future researchers may explore different methods of SCG or fertilizer application as well.

5. ACKNOWLEDGMENTS

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6. REFERENCES

Caetano, N. S., Silva, V. F., Melo, A. C., Martins, A. A., & Mata, T. M. (2014). Spent coffee grounds for biodiesel production and other applications. Clean Technologies and Environmental Policy, 16(7), 1423-1430. https://doi.org/10.1007/s10098-014-0773-0

Cervera-Mata, A., Pastoriza, S., Rufián-Henares, J. A., Párraga, J., MartínGarcía, J. M., & Delgado, G. (2017). Impact of spent coffee grounds as organic amendment on soil fertility and lettuce growth in two Mediterranean agricultural soils. Archives of Agronomy and Soil Science. https://doi.org/10.1080/03650340.2017.1387651

Chrysargyris, A., Antoniou, O., Xylia, P., Petropoulos, S., & Tzortzakis, N. (2020). The use of spent coffee grounds in growing media for the production of Brassica seedlings in nurseries. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-020-07944-9

Ciesielczuk, T., Rosik-Dulewska, C., Poluszyńska, J., Miłek, D., Szewczyk, A., & Sławińska, A. (2018). Acute Toxicity of Experimental Fertilizers Made of Spent Coffee Grounds. Waste Biomass Valor, 9, 2157–2164. https://doi.org/10.1007/s12649-017-9980-3

Coffee Grounds and Composting. (n.d.). Oregon State University. Retrieved March 20, 2021 from https://extension.oregonstate.edu/gardening/techniques/coffee-grounds-composting#:~:text=Some%20information%20about%20coffee%20grounds&text=Grounds%20are%20not%20acidic%3B%20the,excellent%20nitrogen%20source%20for%20composting.

Cruz, R., Cardoso, M. M., Fernandes, L., Oliveira, M., Mendes, E., Baptista, P., . . . Casal, S. (2012). Espresso coffee residues: A valuable source of unextracted compounds. Journal of Agricultural and Food Chemistry, 60(32), 7777-7784. https://doi.org/10.1021/jf3018854

Cubero, C. O. & Baquiran, P. B. (2017). Tomato production guide. Retrieved from http://rfo02.da.gov.ph/?smd_process_download=1&download_id=4 93

García, M., Medrano, E., Sánchez-Guerrero, M., & Lorenzo, P. (2011). Climatic effects of two cooling systems in greenhouses in the Mediterranean area: External mobile shading and fog system. Biosystems Engineering, 108(2), 133-143. https://doi.org/10.1016/j.biosystemseng.2010.11.006

Gong, H., & Gao, J. (2019). Soil and climatic drivers of plant SLA (specific leaf area). Global Ecology and Conservation, 20. https://doi.org/10.1016/j.gecco.2019.e00696

Jones, J. B. (2013). Instructions for growing tomatoes: in the garden and greenhouse. Anderson, SC: GroSystems.

Koester, R. P., Skoneczka, J. A., Cary, T. R., Diers, B. W., & Ainsworth, E. A. (2014). Historical gains in soybean (Glycine max Merr.) seed yield are driven by linear increases in light interception, energy conversion, and partitioning efficiencies. Journal of experimental botany, 65(12), 3311- 3321. https://doi.org/10.1093/jxb/eru187

Kozlowski, T. T., & Pallardy, S. G. (1997). 7 - Cultural Practices and Vegetative Growth. In T. T. Perry & S.G. Pallardy (Eds.), Growth Control in Woody Plants (pp. 352-393). Academic Press. https://doi.org/10.1016/B978-012424210-4/50007-3

Manzano, V. J., Jr., & Mizoguchi, M. (2013). Field Monitoring System and Analysis of Rainfall Data for Tomato Cropping Calendar in Batac City, Ilocos Norte, Philippines. Journal of Nature Studies, 12 (2), 11-17.

Ordoñez, J. C., Bodegom, P. M., Witte, J. M., Wright, I. J., Reich, P. B., & Aerts, R. (2009). A global study of relationships between leaf traits, climate and soil measures of nutrient fertility. Global Ecology and Biogeography, 18(2), 137-149. https://doi.org/10.1111/j.1466-8238.2008.00441.x

Pound, M. P., French, A. P., Murchie, E. H., & Pridmore, T. P. (2014). Automated recovery of three-dimensional models of plant shoots from multiple color images. Plant Physiology, 166(4), 1688-1698. https://doi.org/10.1104/pp.114.248971

Purbatanji, E. D., Slamet, W., Fuskhah, E., & Rosyida. (2019). Effects of organic and inorganic fertilizers on growth, activity of nitrate reductase and chlorophyll contents of peanuts (Arachis hypogaea L.). IOP Conf. Series: Earth and Environmental Science, 250. https://doi.org/10.1088/1755-1315/250/1/012048

Renna, M., Durante, M., Gonnella, M., Buttaro, D., D'Imperio, M., Mita, G., & Serio, F. (2018). Quality and nutritional evaluation of regina tomato, a traditional long-storage landrace of Puglia (Southern Italy). Agriculture, 8(6), 83. https://doi.org/10.3390/agriculture8060083

Sainju, U.M., Dris, R. and Singh, B. (2003) Mineral Nutrition of Tomato. Journal of Food, Agriculture and Environment, 1, 176-183.

Savci, S. (2012). An agricultural pollutant: Chemical fertilizer. International Journal of Environmental Science and Development, 3(1), 77-80. https://doi.org/10.7763/IJESD.2012.V3.191

Thenepalli, T., Ramakrishna, C., & Ahn, J. W. (2017). Environmental effect of the coffee waste and anti-microbial property of oyster shell waste treatment. Journal of Energy Engineering, 26(2), 39-49. https://doi.org/10.5855/ENERGY.2017.26.2.097

Trimble, S. (2019, April 16). Leaf Area - How & Why Measuring Leaf Area is Vital to Plant Research. Retrieved from https://cid-inc.com/blog/leaf-area-how-why-measuring-leaf-area-is-vital-to-plant-research/

Wood, A. J., & Roper, J. (2000). A simple & nondestructive technique for measuring plant growth & development. The American Biology Teacher, 62(3), 215-217. https://doi.org/10.2307/4450877

Woorman, G. (2011, April 27). Over-Fertilization of Potted Plants. PennState Extension. https://extension.psu.edu/over-fertilization-of-potted-plants

Bibliometric Analysis on Biosensors and their Applications in Agriculture

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Abstract: Biosensors are systematic devices that detect signals from biochemical substances and convert them into quantitative data. They aid in preventing and diagnosing potential diseases and pathogens. The ease of use and accessibility of these devices has paved the way for many technological advancements, especially in the agricultural sector. In this study, the impact of piezoelectric, electrochemical, optical, and molecular biosensors in agricultural settings were analyzed using a bibliometric analysis software called VOSviewer. Various parameters and data sets such as biosensor trends, keyword relationships, and biosensor citation prevalence were used. The created maps showed that in the variable for co-authorship, Chinese authors were among the most prominent; while in the variable for co-occurrence: biosensor, agriculture, and biosensing techniques were among the top three words used; and in citation analysis for countries: China, United States, India, and Italy were the top countries with the most research and contribution in the field of biosensors. The results in this research will aid future studies and workings on biosensors by highlighting plausible trends and prospects in the field of research.

Key Words: plant biosensor; agriculture; farming; advancements; bibliometric

1. INTRODUCTION

Biosensors are scientific devices that produce optical, thermal, or electrical signals in proportion to their analyte by using biochemical reactions (Kumar & Upadhyay, 2018; Oluwaseun et al., 2018). Most biosensors consist of the following parts: analyte, bioreceptor, transducer, electronics, and display (Bhalla et al., 2016). There are distinct qualities that biosensors need to attain optimum performance levels, namely: selectivity, reproducibility, stability, sensitivity, and linearity. In farming, they are used in preventing and detecting diseases, crop pests, and pathogens (Oluwaseun et al., 2018; Bagde & Borkar, 2013). Moreover, this technology can aid in maximizing the quality of crops or products that farmers grow, as stated by Bhalla et al. (2016). For instance, biosensors could monitor the quality of the soil, water, and air of the surrounding areas by noting the pollutants present.

Biosensors are classifiable according to the method by which signal is transduced from the specimen to the device, e.g., optical, electrochemical, thermometric, piezoelectric, and magnetic (Damborský et al., 2016). Recently, there has been another biosensor aside from what was mentioned that is considered as emerging, known as molecular biosensors. The research addresses four classifications of biosensors: piezoelectric, electrochemical, optical, and molecular biosensors. Piezoelectric biosensors, or acoustic biosensors, utilize mechanical waves to detect and obtain biochemical and biophysical information about the compound of interest. It detects changes in any physical property, e.g., mass elasticity and conductivity. Electrochemical biosensors can distinguish hybridized DNA, neuron tissue, bacteria, and enzyme reactions as biochemical events (Li et al., 2017), and convert these into electrical signals (Cho et al., 2020). Optical biosensors measure the responses of target analytes to illumination or light emission by utilizing various techniques. These techniques include light absorbance, reflectance, fluorescence, and more. Lastly, molecular biosensors utilize certain biochemical reactions moderated by biological materials, e.g., enzymes and cells, to detect chemical compounds through electrical, optical, or thermal signals (Campuzano, 2017). The research focuses on one specific type of molecular biosensor, the loop-mediated isothermal amplification (LAMP) biosensor.

Technological advancements in these devices have brought significant changes to the agricultural sector by playing a crucial role in protecting plant crops for quite some time. However, the gap in technological know-how and expensive developmental processes have hindered some countries from incorporating biosensors into the agricultural sector. Most of said countries are third-world countries where agriculture is still developing, and traditional farming methods are employed to maximize crop growth. If biosensor technology continues to advance, cheaper alternatives to current technology will emerge, giving

the marginalized agricultural sector the technological opportunity to improve crop production. With that being said, the need for cheaper alternatives for biosensor utilization and production requires further research and development.

This research is focused on biosensors often used in plant agriculture. The study aims to examine the importance of biosensors in plant crops, and to determine the trends of biosensor research according to the year they were published. Moreover, the roles, applications, and uses of biosensors in farming agriculture were explored and discussed. Hence, the results of this study serve as a basis for future research by means of highlighting the trends and important concepts of different biosensors used in plant agriculture. Recent studies about plant biosensors and their uses were also compiled and reviewed.

2. METHODOLOGY

2.1. Data Source

Scopus (https://www.scopus.com), is a bibliographic database containing a large variety of subject areas (E.g., Biochemistry, Arts and Humanities, Chemical Engineering, etc.). This navigation tool is generated by Elsevier, a Netherlands-based company, known for containing numerous published works from different publications and journals. This database was used as the primary bibliographic source for data and collecting articles relating to advancements or studies of biosensors for plant agriculture. The collected data, stored within a comma-separated value (CSV) file, was then processed through VOSviewer (ver. 1.6.15). CSV files collate data of different journal's various parameters from databases. These parameters include but are not limited to document title, authors, and DOI.

2.2. Data Collection

In the data mining and mapping, the search queries "agriculture AND biosensor" were used, and this premise only searches all journals with both words in the title or the abstract. The query string used was "TITLE-ABS-KEY (biosensor AND agriculture) AND DOCTYPE (ar) AND PUBYEAR > 2004", which translates to: articles with keywords "biosensor" and "agriculture" in the document title, abstract, or keyword, ranging from 2005 to present. The result yielded 153 documents in total. The "ar" in the query string denotes "article." Since the scope of this research is for the application of biosensors only in plants, the proponents checked each document to ensure the documents were suited only to plant agriculture. After thorough reviews, fifty-one (51) of the documents were removed, most of which were related to human medicine and animal livestock.

2.3. Bibliometric Maps

VOSviewer is a software capable of creating visual aid maps that connect data through relations between keywords, authors, publications, research, etc. (Van Eck & Waltman, 2011). This software is utilized by a wide user base for establishing correlations amongst data from a pool of journals and articles, which may take form in a distance-based, graph-based, or timeline-based mapping system (Van Eck & Waltman, 2014). The map produced by VOSviewer will be based on the various parameters as mentioned previously, and may also be interpreted in several ways, i.e., size, color, distance, and connections of the data. Furthermore, these interpretations dictate the several aspects of the data (Van Eck & Waltman, 2020). For instance, size difference may determine the number of times a specific term appeared in the data, distance may determine degree relation, and connections may determine presence of a relation between terms.

The data sets were then organized using the bibliographic-data-based using VOSviewer mapping, which is based on the bibliographic data extracted from Scopus. Three types of analysis were employed: co-authorship, co-occurrence, and citation (country).

2.3.1. Analysis of Co-authorship

In the analysis of co-authorship, VOSviewer found 446 authors. However, counting manually, a total of 461 authors, most of which had the same surname and initial (e.g., Liu, X.) were found. Consequently, the map was created based on the initial finding of 446 authors, as that was the number recognized by VOSviewer.

2.3.2. Analysis of Co-occurrence

In the analysis of co-occurrence, "all keywords" were considered, i.e., both "author" and Scopus "index" keywords. Full counting method was employed, and a thesaurus was used to eliminate terms with identical definitions, plural forms, and irrelevance to the study, thus, excluding words such as "organo-phosphorus compound/organophosphorus compound," "soils/soil," and "article."

The minimum number of occurrences that were used was five (5), preventing irrelevant words from being added to the map. The parameters resulted in a total of 57 keywords, after eliminating words with less than five occurrences and words excluded and combined by the thesaurus.

2.3.3. Analysis of Citation

In this analysis of citations, the measured quantity is the countries involved in publishing the articles. The threshold for minimum number of publications was set to one (1), ensuring inclusivity of the available countries. The total number of countries resulting from this set parameter is 44.

3. RESULTS AND DISCUSSION

The researchers conducted bibliometric mapping based on three types of analysis: co-authorship, co-occurrence, and citation, and accordingly, used authors, all keywords, and countries, respectively. The maps produced will be described and analyzed through their physical attributes and characteristics such as size, clustering, color, and line thickness. The data extracted from Scopus were divided into five (5) distinct categories. The central search premise was "biosensor AND agriculture."

3.1. Publication Growth Over the Past Years

From 2005-2020, there has been a significant growth in yearly publications about biosensors used in agriculture (Figure 1). In the years 2005-2010, the average number of publications was 2.67 articles a year. In 2016-2020, the average was 10.8, which indicated a 404.5% increase in mean publications per year. Kundu et al. (2019) attributed advancements in other fields of sciences such as material science and nanoengineering to the increased attention and production of journal articles in the field of biosensors.

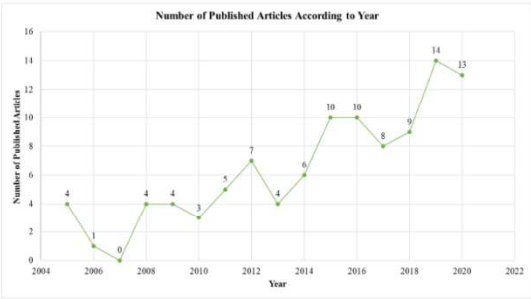

Fig. 1. Number of publications in the recent years from 2005-2020.

3.2. Co-authorship

For the search "biosensors" and "agriculture," consisting of 102 documents, VOSviewer only identified 446 total authors. However, 461 total individuals were found responsible for authoring the 102 articles. Some authors such as Liu, Y., Liu, X., and Wang, Y. have the biggest nodes for the (Figure 2), and although this signifies more written works, it was found that these authors are different individuals. However, other nodes showing the same size, such as He, H. and Wen, Y., signify an equal number of authored works.

The authors clustered are termed co-authors. A green cluster consisting of He, H., Wen, Y., etc. represents one article, while the pink cluster consisting of Pu, Y., Liang, G., etc. represents co-authors of another article. Bigger nodes, such as Liu, Y., Liu, X., and Wang, Y., are positioned to be proximally close to the authors they have worked with individually. According to the numerical data extracted from VOSviewer, Liu, Y. authored three articles; concurrently, three different authors named Liu, Y. were found to author the three different articles. The observations in color and line thickness show no significant role in identifying relations between the authors.

As mentioned, there were 446 total identified authors by VOSviewer. However, Figure 2 only represents a portion of the 446 authors since only the cluster with the most connection can be displayed. Other authors with high link strengths which are not connected to this big cluster are not shown in the map provided.

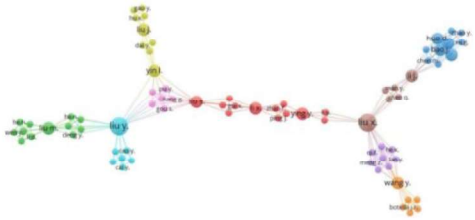

Fig. 2. Co-authorship mapping using VOSviewer.

3.3. Co-occurrence Variable

The top three most occurring keywords are biosensor, agriculture, and biosensing techniques (Figure 3). "Biosensor" and "agriculture", being the search premises, were the highest with 69 and 40 occurrences, respectively. Node size is directly proportional to the frequency of the keyword, Figure 3 has clusters which are grouped into distinct colors: red, yellow, green, purple, and blue. The colors represent a common theme or relation among the words, as observed in a study performed by Briones-Bitar et al. (2020).

The observed theme among the clusters are as follows: agriculture and biosensing (keywords: "agriculture," "biosensor;" red cluster), chemistry (keywords: "metabolism," "limit of detection;" blue cluster), pesticides and words associated to chemicals (keywords: "acetylcholinesterase," "organophosphate pesticide;" green cluster), chemical processes (keywords: "colorimetry," "chemical detection;" yellow

cluster), and metals and other materials (keywords: "graphene," "gold;" purple cluster).

The link strength of each keyword is attributed to the line thickness and size of its node. According to Md Khudzari et al. (2018), line thickness in the maps represent a higher link strength, and as observed, keywords such as biosensor and agriculture have thick lines running across the map and a link strength of 401 and 273, respectively.

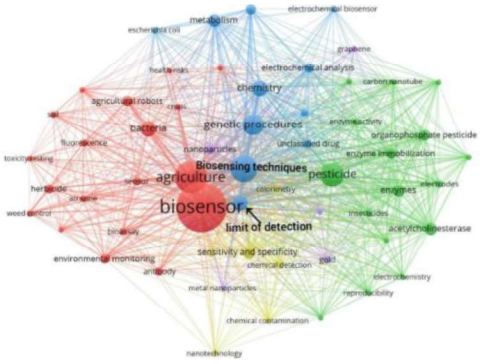

Fig. 3. Co-occurrence mapping from VOSviewer.

3.4. Country Variable

Countries mostly involved in the development and studying of biosensors in agriculture are highly developed countries. The countries with the most publications are China (24), United States (14), India (13), and Italy (13). The productivity of these countries is most likely a result of their high competitiveness and high funding allocation. China and India are two of the most populated countries in the world; hence, a large amount of agricultural production is required to support their country, which may explain the amount of effort they put into the pursuit of biosensor research.

The cluster or proximity of the nodes for Figure 4 indicate how closely countries work together in their research or how much the authors of each country cite each other's work. India is located at the center of the map, which indicates extensive collaborations with its corresponding countries in the map such as China, Poland, and Italy.

Among the top four, India and China have the highest link strengths (8). These two countries have not only published several articles for biosensors, but also have collaborated with other countries. The thickness of the lines that connect them with other nodes are significantly thicker than other countries, which possibly reveal the great strides these two countries have taken to enhance the use of biosensors in agriculture.

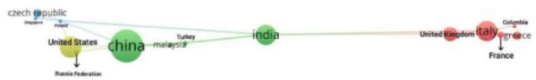

Fig. 4. Citation mapping with VOSviewer.

4. CONCLUSIONS

Overall, the results from the bibliometric analysis through VOSviewer show that in the link for co-authorship, most authors were clustered to be Chinese. For co-occurrence, on the other hand, the top words were biosensors, agriculture, and biosensing techniques. The citations for the country variable section indicate the top three biosensing research to be China, India, and Italy, with the first two countries being in the same field of biosensor research. In the future, the possible research in biosensor use and study will be heavily focused on by developing and agricultural-focused countries which is a highly relevant explanation as to why China and other similar countries have a high biosensor research footprint. As research on biosensors progresses further, it is important to be able to determine the trends in keywords and uses in citations by different authors and countries in order to foresee the possible direction this research is heading for.

5. REFERENCES

Bagde, V. L., & Borkar, D. B. (2013). Biosensor: Use in Agriculture. International Journal of Scientific Research: Biotechnology, 2(10), 2–4. ISSN: 2277-8179

Bhalla, N., Jolly, P., Formisano, N., & Estrela, P. (2016). Introduction to biosensors. Essays in Biochemistry, 60(1), 1–8. https://doi.org/10.1042/EBC20150001

Briones-Bitar, J., Carrión-Mero, P., Montalván-Burbano, N., & Morante-Carballo, F. (2020). Rockfall research: A bibliometric analysis and future trends. Geosciences (Switzerland), 10(10), 1–25. https://doi.org/10.3390/geosciences10100403

Campuzano, S., Yáñez-Sedeño, P., & Manuel Pingarrón, J. (2017). Molecular biosensors for electrochemical detection of infectious pathogens in liquid biopsies: Current trends and challenges.

Sensors (Switzerland), 17(11). https://doi.org/10.3390/s17112533

Chen, Y., Qian, C., Liu, C., Shen, H., Wang, Z., Ping, J., Wu, J., & Chen, H. (2020). Nucleic acid amplification free biosensors for pathogen detection. In Biosensors and Bioelectronics (Vol. 153). Elsevier Ltd. https://doi.org/10.1016/j.bios.2020.112049

Cho, I. H., Kim, D. H., & Park, S. (2020). Electrochemical biosensors: Perspective on functional nanomaterials for on-site analysis. Biomaterials Research, 24(1), 1–12. https://doi.org/10.1186/s40824-019-0181-y

Damborský, P., Švitel, J., & Katrlík, J. (2016). Optical biosensors. Essays in Biochemistry, 60(1), 91–100. https://doi.org/10.1042/EBC20150010

Kumar, N., & Upadhyay, L. S. B. (2018). Polymeric gels for biosensing applications. In Polymeric Gels (pp. 487–503). Elsevier. https://doi.org/10.1016/b978-0-08-102179-8.00019-3

Kundu, M., Krishnan, P., Kotnala, R. K., & Sumana, G. (2019). Recent developments in biosensors to combat agricultural challenges and their future prospects. Trends in Food Science and Technology, 88, 157–178. https://doi.org/10.1016/j.tifs.2019.03.024

Li, H., Liu, X., Li, L., Mu, X., Genov, R., & Mason, A. J. (2017). CMOS Electrochemical Instrumentation for Biosensor Microsystems: A Review. Sensors, 17(74), 1–26. https://doi.org/10.3390/s17010074

Md Khudzari, J., Kurian, J., Tartakovsky, B., & Raghavan, G. S. V. (2018). Bibliometric analysis of global research trends on microbial fuel cells using Scopus database. Biochemical Engineering Journal, 136, 51–60. https://doi.org/10.1016/j.bej.2018.05.002

Oluwaseun, A. C., Phazang, P., & Sarin, N. B. (2018). Biosensing Technologies for the Detection of Pathogens - A Prospective Way for Rapid Analysis. In Biosensing Technologies for the Detection of Pathogens - A Prospective Way for Rapid Analysis. InTech. https://doi.org/10.5772/intechopen.74668

Panno, S., Matić, S., Tiberini, A., Caruso, A. G., Bella, P., Torta, L., Stassi, R., & Davino, S. (2020). Loop mediated isothermal amplification: Principles and applications in plant virology. Plants, 9(4), 1–28. https://doi.org/10.3390/plants9040461

Papadakis, G., Skandalis, N., Dimopoulou, A., Glynos, P., & Gizeli, E. (2015). Bacteria murmur: Application of an acoustic biosensor for plant pathogen detection. PLoS ONE, 10(7). https://doi.org/10.1371/journal.pone.0132773

Scognamiglio, V., Antonacci, A., Arduini, F., Moscone, D., Campos, E. V. R., Fraceto, L. F., & Palleschi, G. (2019). An eco-designed paper-based algal biosensor for nanoformulated herbicide optical detection. Journal of Hazardous Materials, 373, 483–492. https://doi.org/10.1016/j.jhazmat.2019.03.082

Seo, J. S., & Kim, J. (2020). Plant Science Nitrogen molecular sensors and their use for screening mutants involved in nitrogen use efficiency. Plant Science, 298(June), 110587. https://doi.org/10.1016/j.plantsci.2020.110587

Van Eck, N. J., & Waltman, L. (2011). Text mining and visualization using VOSviewer. Centre for Science and Technology Studies, Leiden University, The Netherlands. www.vosviewer.com.

Van Eck, N. J., & Waltman, L. (2014). Visualizing Bibliometric Networks. In Measuring Scholarly Impact (pp. 285–320). Springer International Publishing. https://doi.org/10.1007/978-3-319-10377-8_13

Van Eck, N. J., & Waltman L. (2020). User Interface. In Manual for VOSviewer 1.6.15. https://www.vosviewer.com/getting-started.

Studies on the Morphological and Mechanical Properties of Oil Palm Empty Fruit Bunch-derived Nanocellulose for Supercapacitor Applications

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Abstract: Electricity is an essential resource and aspect of our daily lives. To cope with its high demands, supercapacitors and more efficient batteries have been introduced to the market; the separator is an integral part in the performance of supercapacitors. This study determined the morphology, chemical composition, and mechanical properties of oil palm empty fruit bunch nanocellulose as a separator for supercapacitors and compared its performance with other agricultural materials (e.g. eggshell membrane, cotton textile, and tree leaves) and an membrane electrode assembly. The OPEFB nanocellulose has the morphology and mechanical properties that make it a possible supercapacitor separator material. The porous agglomerate of microfibers and surface nanostructures provide higher effective surface area and may aid in the diffusion of ions. Measured Young's modulus of 6.00 MPa/%, yield strength of 3.20MPa, and tensile strength of 5.30MPa are comparable to separators used in commercial supercapacitors and the reported eggshell membrane separator. This study provides sustainable and "green" alternatives for current commercial supercapacitor separators.

Key Words: nanocellulose, separator, supercapacitor, mechanical strength

1. INTRODUCTION

A supercapacitor is an electrochemical energy storing device used to power technology in various fields ranging from the military to the automotive industry. It has four major components: electrodes, current collectors, electrolytes, and a separator (Nor et al., 2014). The positive and negative electrodes are divided by a non-conductive material called a separator and a small distance to allow for greater storage of electrical energy in a smaller area of space (Dume, 2017).

Separators act as a barrier to prevent short-circuiting by the direct contact of the opposite polarities and to allow the easy flow of electrolytes (He et al., 2017). Present supercapacitor separators use polyolefins for electrochemical stability; however, their low porosity does not meet the high energy needs of the supercapacitor (Du et al., 2017), and the mechanical deformability (Azais et al., 2016) can lead to circuit shortage. Polyolefins are also nonrenewable, unsustainable for mass production, and hold around 20 to 30% of space in landfills (Longo et al., 2011). An example of a polymer-based separator is a Membrane Electrode Assembly (MEA) commonly used in fuel cells (Fuel Cell Store, n.d.). One of the most common membranes in the commercial market is Nafion™, a perfluorosulfonic acid polymer membrane (Kundu et al., 2005).

Cellulose, and its nanoscale forms, is a natural polymer with innovative applications in materials science (Klemm et al., 2018). Moreover, nanocellulose (NC) has emerged as a promising material for separators. Aside from being sustainable, NC separators have electrochemical and mechanical stability which are essential in a supercapacitor (Guo et al., 2020).

In this study, NC from oil palm empty fruit bunch (OPEFB) was characterized as a separator material for supercapacitor applications. OPEFB is a major waste product of the palm oil industry. As of 2013, the Philippines produces an average of 120,000 tons of oil palm (Philippine Coconut Authority, n.d.). With the rise of agricultural waste, waste management methods have been proposed which include waste recycling and deriving energy from waste (Abdullah & Sulaim, 2013). The OPEFB can be collected during the recycling process of agricultural wastes, and then made into a separator. It has been successfully made as a bioplastic (Iriani et al., 2019) and used as an electrode (Nor et al., 2014). Furthermore, NC has proved to have excellent electrochemical and mechanical properties; its rich carbon content and high porosity ensure outstanding

electrochemical performance (Guo et al., 2020). Separators made from agricultural products can be locally produced, making technology more accessible to developing countries. This study will benefit the fields of materials science and electrochemistry while also encouraging sustainable energy initiatives from the government.

In this study, the morphological, chemical, and mechanical properties of OPEFB NC as a separator were investigated. Specifically, the authors:

characterized the OPEFB nanocellulose in terms of its surface morphology and chemical composition by scanning electron microscopy and energy dispersive spectroscopy and mechanical properties, i.e. mechanical strength, and stiffness, by a comprehensive materials testing system;

measured the stiffness of the separator material through Young's modulus, its yield strength, and tensile strength; and

compared the morphological and mechanical properties of OPEFB nanocellulose with that of MEA 144A and other separator materials made from agricultural wastes reported from previous studies.

2. Cellulose-based Materials for Supercapacitors

2.1 Oil Palm Empty Fruit Bunch (OPEFB)

OPEFB is a byproduct of palm oil production (Han and Kim, 2018) composed of cellulose, hemicellulose, and lignin (Rosli et al., 2017). It contains around 40-44% of cellulose (Foo et al., 2020), so it may be deemed a potential source of NC (Septevani et al., 2020). Aside from its content being notable, it has high availability due to its abundance in Southeast Asian countries. OPEFB also accounts for ⅓ of oil palm biomass (Geng, 2013). Thus, it is a reliable and sustainable source of NC for supercapacitor applications.

In the study of Teow et al. (2020), the OPEFB diameter decreased from 228.88 ± 6.63 µm to 13.63 ± 3.10 µm after cellulose extraction as seen in the scanning electron microscope (SEM) analysis displayed in Figure 1. It can be inferred that it is possible to use cellulose as a separator as its size can be reduced to fit the supercapacitor.

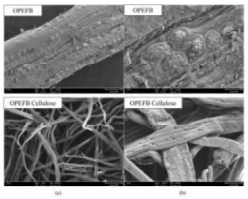

Figure 1. *SEM micrographs of the OPEFB and cellulose extracted from the OPEFB under different magnification: (a) 250 × (scale bar 20 µm) and (b) 1.00 k (scale bar 10 µm) (Teow et al., 2020)*

Previous works have applied OPEFB in supercapacitor electrodes (Ishak et al, 2015; Dolah et al, 2014; Farma et al., 2013); however, no study has used it as a separator.

2.2 Mechanical Properties of Previous Studies

Mechanical properties play a big role in characterizing the quality of cellulose material. Through these, the performance of a separator may be expected. Given the position of a separator, it needs to have minimal resistance from the movement of electrolyte ions (Yu et al., 2012). Properties that could predict the performance of the separator include surface morphology, mechanical strength, and stiffness. The surface morphology of a material can be utilized to characterize the porosity and material structure (Adeleke et al., 2019). The mechanical strength and stiffness of a separator also play a crucial part in characterizing the possible life span of the supercapacitor and other energy storage devices. The study conducted by Mandake and Karandikar (2016) showed that thicker separators would correspond to lower porosity. Considering that high porosity is needed in a separator, it should be thin enough for high porosity while maintaining a good mechanical strength and stiffness. In the studies of Gao (2015) on cotton textile as a separator, Yu et al. (2012) on eggshell membrane as a separator, and Jin et al. (2019) on tree leaves as a separator, the results showed excellent mechanical strength and properties alongside high porosity and superb electrochemical properties.

A source that has been used as a separator material is eggshell membrane (ESM) (Yu et al., 2012). It has high mechanical strength, with reported maximum stress and maximum strain values of σmax = 6.59 ± 0.48 MPa and εmax = 6.98 ± 0.31%, respectively. Figure 2 displays the surface morphology of the eggshell membrane showing shell membrane fibers of thickness 0.5 to 1 µm, and pore sizes of 1 to 3 µm.

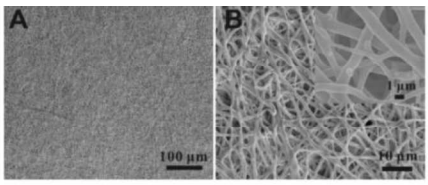

Figure 2. *SEM photographs of ESM at low (A) and high (B) magnifications (Yu et al., 2012)*

The cotton textile was also reported to show ideal surface morphology as a separator material. The nanostructure and nanowires found on the surface of the material (Figure 3) were found to have minimum

dimensions of 5µm and 20µm, respectively (Gao, 2015).

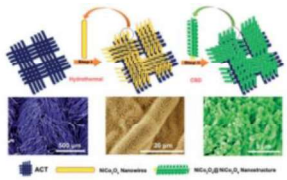

Figure 3. *Illustration of the nanostructures of NiCo2O4@NiCo2O4 covering activated carbon textiles (ACTs) (Gao, 2015)*

The application of four different tree leaves to create a separator for a graphene-based supercapacitor was investigated by Jin et al. (2019). These four tree leaves are cinnamomum camphora (CC), magnolia grandiflora (MG), platanus orientalis (PO) and osmanthus fragrans (OF). The separator made from activated CC showed most promising results. Figure 4 shows the surface morphology of the 4 leaves at a bar of 10 µm. The mechanical properties of the separator materials based on agricultural sources discussed are summarized in Table 1.

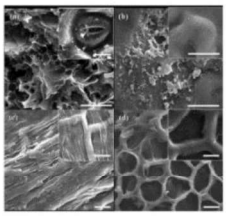

Figure 4. *SEM images of the 4 different activated tree leaves: (a) CC; (b) MG; (c) PO; (d) OF. All bars are at 10 µm. (Jin et al., 2019)*

Table 1. *Comparative Summary of Mechanical Properties of Separators Based on Agricultural Sources*

Paper Title and Author	Agricultural Source	Mechanical Properties		
		Surface Morphology	Mechanical Strength	Stiffness
Using eggshell membrane as a separator in supercapacitor (Yu et al., 2012)	Eggshell membrane	0.5 to 1 µm (shell membrane fibers) and 1–3 µm (macropores)	σ_{max} = 6.59 ± 0.48 MPa (maximum stress) and ε_{max} = 6.98 ± 0.31% (maximum strain)	xxx
Cotton textile enabled, all-solid-state flexible supercapacitors (Gao, 2015)	Cotton Textile	5 µm (nanostructure) and 20 µm (nanowires)	xxx	xxx
Tree leaves-derived three-dimensional porous networks as separators for graphene-based supercapacitors (Jin et al., 2019)	Tree Leaves	10 µm	xxx	xxx

2. METHODOLOGY

The separator material used in this study is an oil palm empty fruit bunch nanocellulose (OPEFB NC) film. The OPEFB NC material was characterized to determine its morphological and mechanical properties, as well as chemical composition. A comparative study was done with other agricultural-product based NC separator materials from previous studies and the OPEFB NC investigated in this work on the basis of mechanical strength and surface morphology.

2.1. Research Design

The quantitative characterization techniques used in studying the properties of OPEFB NC are scanning electron microscopy, energy dispersive spectroscopy, and stress-strain test. The surface morphology of the OPEFB NC was measured using a JEOL JSM 5310 scanning electron microscope (SEM). Elemental analysis was done using the EDAX energy dispersive spectroscopy (EDS) system attachment of the JEOL JSM 5310 SEM to determine the elemental composition of the sample (Intertek, n.d.). Furthermore, a PASCO Comprehensive Materials Testing System ME-8244, an equipment used for tensile testing (PASCO, n.d.), was utilized to obtain the stress vs. strain and force vs. position graphs for the OPEFB NC sample. From the stress-strain plot, the mechanical properties, specifically the Young's modulus, yield strength, and tensile strength of the sample were determined. The measured morphology and mechanical properties of the OPEFB NC separator material were then compared with those of eggshell membrane, cotton textile, and tree leaves.

2.2. Data Analysis

For most metals and plastics polymers, stress σ (in Pa) and strain ε are directly proportional to each other, i.e. $\sigma = E\varepsilon$, wherein E is Young's modulus (in Pa) or the modulus of elasticity. In this study, the measure of stiffness of the sample, i.e. Young's modulus, was determined from the slope of the linear portion of the stress-strain curve. As the stress on the sample was increased during testing, the sample experiences a gradual elastic-plastic transition. The yield strength (in Pa) was determined at the point on the stress-strain curve when the curve starts to depart from linearity; this is the amount of stress that the sample can take without undergoing plastic deformation. After passing the yield point, the stress needed to continue the plastic deformation of the sample increases and then reaches a maximum point. The tensile strength (in Pa) is simply the stress at the maximum point of the stress-strain curve. This is the maximum stress the sample can sustain when in tension.

3. RESULTS AND DISCUSSION

The SEM images of the OPEFB NC in Figure 5 show the surface morphology at x10000, x1000, and x500 magnification, respectively. The microfibers of cellulose (~2 to 6 µm) are a disordered agglomeration interspersed with nanoparticles, which are possibly silica on fiber surface, consistent with the report of Mohammad et al. on thermally pre-treated OPEFB used for biofuel production (2020). The presence of silica in supercapacitor electrode or separator materials was shown to exhibit excellent stability and flexibility (Pérez-Madrigal et al., 2016). The size of the microfibers in the OPEFB are comparable to those found in eggshell membranes and cotton textile. The nanoparticles and interwoven microfibers on the surface of the OPEFB sample indicate larger effective surface area, which may aid in better diffusion of ions and in turn good electrochemical performance. The OPEFB surface morphology is smoother compared to that of the eggshell membrane fibers, cotton textile, and tree leaves. This is ideal for a supercapacitor separator material as it allows good contact between the electrodes; however, the OPEFB sample's lower porosity as compared to the other three materials may reduce the ion mobility.

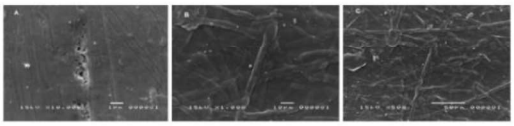

Figure 5. *SEM images of the OPEFB at (A) x10000, (B) x1000, and (C) x500 magnifications, respectively*

The results of the elemental analysis of the OPEFB sample obtained from EDS are shown in Figure 6. The EDS spectra shows that the sample consisted of C (41.26 wt%), O (51.59 wt%), Al (0.58 wt%), Si (0.56 wt%), S (5.44 wt%) and Cu (0.57 wt%).

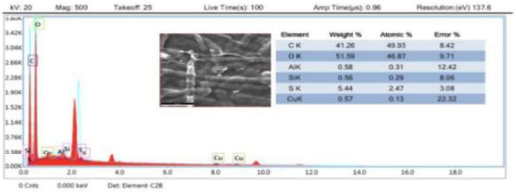

Figure 6. *EDS elemental analysis of OPEFB sample*

The mechanical properties of the OPEFB sample were determined from the plot of the stress-strain data as depicted in Figure 7. On the stress-strain curve, the linear portion of the elastic region is until the applied stress rose to 3.20MPa. Calculating the slope of this linear portion resulted in a Young's modulus of 6.00MPa. At a stress level of 3.20 MPa (yield strength), the curve starts to depart from linearity. This is the point when yielding occurs and plastic deformation of the sample begins. As further stress was applied to the sample, it then fractured when the applied stress reached 5.30 MPa (tensile strength).

Table 2. *Comparison of Mechanical Properties of OPEFB NC, eggshell membrane, and MEA 144A*

Paper Title and Author	Material	Young's Modulus (MPa/%)	Yield Strength (MPa)	Tensile Strength (MPa)	Maximum Strain (%)
Authors' Paper	OPEFB NC	6.00	3.20	5.30	3.45
Using eggshell membrane as a separator in supercapacitor (Yu et al., 2012)	Eggshell Membrane	xxx	xxx	6.59	6.98
Mechanical Properties of Nafion™ electrolyte membranes under hydrated conditions (Kundu et al., 2005)	MEA 144A	3.23	2.19	xxx	xxx

The tensile strength of the OPEFB NC is slightly lower than that of the eggshell membrane separator material (Table 2). However, compared to the MEA 144A separator used in commercial supercapacitors, the Young's modulus of OPEFB NC is almost twice. This implies that OPEFB NC separator has sufficient strength to prevent contact between electrodes and will be able to maintain integrity during manufacturing and transport. This structural integrity in OPEFB NC is also necessary as separators swell and deform during the charge-discharge process.

4. CONCLUSIONS

The OPEFB NC separator has the morphology and mechanical properties that make it a possible supercapacitor separator material. The porous agglomerate of microfibers and surface nanostructures provide higher effective surface area and may aid in the diffusion of ions. Measured Young's modulus of 6.00 MPa/%, yield strength of 3.20MPa, and tensile strength of 5.30MPa are comparable to separators used in commercial supercapacitors and reported separator material from eggshell membrane. For future studies, the electrochemical properties should also be investigated to further assess its suitability as a supercapacitor separator.

5. ACKNOWLEDGMENTS

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6. REFERENCES

Abdullah, N., & Sulaim, F. (2013). The oil palm wastes in Malaysia. Biomass Now - Sustainable Growth and Use. https://doi.org/10.5772/55302

Adeleke, O. A., Latiff, A. A., Saphira, M. R., Daud, Z., Ismail, N., Ahsan, A., Aziz, N. A. A., Mohammed, N., Kumar, V., Adel, A., Rosli, M. A., Hijab, M. (2019). Locally derived activated carbon from domestic, agricultural and industrial wastes for the treatment of palm oil mill effluent. Nanotechnology in Water and Wastewater Treatment, 35-62. https://doi.org/10.1016/b978-0-12-813902-8.00002-2

Azais, P., Tamic, L., Huitric, A., Paulais, F. and Rohel, X. (2016). Separator film, its fabrication method, supercapacitor, battery and capacitor provided with said film, US. Pat. 9,461,288. https://patents.google.com/patent/US9461288B2/en

Dolah, B. N. M., Deraman, M., Othman, M. A. R., Farma, R., Taer, E., Basri, N. H., Talib, I. A., Omar, R., & Nor, N. S. M. (2014). A method to produce binderless supercapacitor electrode monoliths from biomass carbon and carbon nanotubes. Materials Research Bulletin, 60, 10-19. https://doi.org/10.1016/j.materresbull.2014.08.013

Du, X., Zhang, Z., Liu, W., & Deng, Y. (2017). Nanocellulose-based conductive materials and their emerging applications in energy devices-A review. Nano Energy, 35, 299-320. https://doi.org/10.1016/j.nanoen.2017.04.001

Dume, I. (2017). Graphene supercapacitor breaks storage record. https://physicsworld.com/a/graphene-supercapacitor-breaks-storage-record/

Farma, R., Deraman, M., Awitdrus, A., Talib, I. A., Taer, E., Basri, N. H., Manjunatha, J. G., Ishak, M. M. Mollah, B. N. M., & Hashmi, S. A. (2013). Preparation of highly porous binderless activated carbon electrodes from fibres of oil palm empty fruit bunches for application in supercapacitors. Bioresource technology, 132, 254-261. https://doi.org/10.1016/j.biortech.2013.01.044

Foo, M. L., Ooi, C. W., Tan, K. W., & Chew, I. M. L. (2020). A step closer to sustainable industrial production: Tailor the properties of nanocrystalline cellulose from oil palm empty fruit bunch. Journal of Environmental Chemical Engineering, 104058. https://doi.org/10.1016/j.jece.2020.104058

Fuel Cell Store. (n.d.). Membrane electrode Assemblies (MEA). https://www.fuelcellstore.com/fuel-cell-components/membrane-electrode-assembly

Gao, Z., Song, N., Zhang, Y., & Li, X. (2015). Cotton textile enabled, all-solid-state flexible supercapacitors. RSC advances, 5(20), 15438-15447. https://doi.org/10.1039/C5RA00028A

Geng, A. (2013). Conversion of oil palm empty fruit bunch to biofuels. Liquid, gaseous and solid biofuels. London: InTech Open Access Publisher, 479-90. https://doi.org/10.5772/53043

Guo, R., Zhang, L., Lu, Y., Zhang, X., & Yang, D. (2020). Research progress of nanocellulose for electrochemical energy storage: A review. Journal of Energy Chemistry. https://doi.org/10.1016/j.jechem.2020.04.029h

Han, J., & Kim, J. (2018). Process simulation and optimization of 10-MW EFB power plant. Computer Aided Chemical Engineering, 43, 723-729. https://doi.org/10.1016/B978-0-444-64235-6.50128-5

He, T., Jia, R., Lang, X., Wu, X., & Wang, Y. (2017). Preparation and electrochemical performance of PVdF ultrafine porous fiber separator-cum-electrolyte for supercapacitor. Journal of The Electrochemical Society, 164(13), E379. https://iopscience.iop.org/article/10.1149/2.0631713jes/meta

Intertek. (n.d.). Energy dispersive x-ray analysis (EDX). https://www.intertek.com/analysis/microscopy/edx/

Iriani, E. S., Permana, A. W., Yuliani, S., Kailaku, S. I., & Sulaiman, A. A. (2019). The effect of agricultural waste nanocellulose on the properties of bioplastic for fresh fruit packaging. IOP Conference Series: Earth and Environmental

Science, 309, 012035. https://doi.org/10.1088/1755-1315/309/1/012035

Ishak, M. M., Deraman, M., Talib, I. A., Basri, N. H., Awitdrus, Farma, R., Taer, E., Omar, R., Nor, N. S. M., & Dolah, B. N. M. (2015). Effect of carbonization temperature on the physical and electrochemical properties of supercapacitor electrode from fibers of oil palm empty fruit bunches. AIP Conference Proceedings, 1656(1), 030005. https://doi.org/10.1063/1.4917094

Jin, L., Wei, K., Xia, Y., Liu, B., Zhang, K., Gao, H., Chu, X., Ye, M., He, L., Lin, P. (2019). Tree leaves-derived three-dimensional porous networks as separators for graphene-based supercapacitors. Materials Today Energy, 14, 100348. https://doi.org/10.1016/j.mtener.2019.100348

Klemm, D., Cranston, E. D., Fischer, D., Gama, M., Kedzior, S. A., Kralisch, D., Kramer, F., Kondo, T., Lindstrom, T., Nietzsche, S., Petzold-Welcke, K., & Rauchfuß, F. (2018). Nanocellulose as a natural source for groundbreaking applications in materials science: Today's state. Materials Today, 21(7), 720-748. https://doi.org/10.1016/j.mattod.2018.02.001

Kundu, S., Simon, L. C., Fowler, M., & Grot, S. (2005). Mechanical properties of Nafion™ electrolyte membranes under hydrated conditions. Polymer, 46(25), 11707-11715. https://doi.org/10.1016/j.polymer.2005.09.059

Longo, C., Savaris, M., Zeni, M., Brandalise, R. N., & Grisa, A. M. C. (2011). Degradation study of polypropylene (PP) and bioriented polypropylene (BOPP) in the environment. Materials Research, 14(4), 442-448. http://dx.doi.org/10.1590/S1516-14392011005000080

Mandake, P., & Karandikar, D. (2016). Significance of separator thickness for supercapacitor. International Journal for Research in Applied Science & Engineering Technology (IJRASET), 4(2), 214-218. https://www.ijraset.com/fileserve.php?FID=3910

Mohammad, I. N., Ongkudon, C. M., & Misson, M. (2020). Physicochemical properties and lignin degradation of thermal-pretreated oil palm empty fruit bunch. Energies, 13(22), 5966. https://doi.org/10.3390/en13225966

Nor, N. S. M., Deraman, M., Omar, R., Taer, E., Awitdrus, Farma, R., Basri, N. H., & Dolah, B. N. M. (2014). Nanoporous separators for supercapacitor using activated carbon monolith electrode from oil palm empty fruit bunches. AIP Conference Proceedings, 1586(1), 68-73. https://doi.org/10.1063/1.4866732

PASCO. (n.d.). Comprehensive materials testing system • ME-8244. https://www.pasco.com/products/lab-apparatus/mechanics/materials-testing/me-8244

Pérez-Madrigal, M. M., Edo, M. G., & Alemán, C. (2016). Powering the future: Application of cellulose-based materials for supercapacitors. Green Chemistry, 18(22), 5930-5956. https://doi.org/10.1039/c6gc02086k

Philippine Coconut Authority. (n.d.). Philippine Palm Oil Industry Roadmap. https://pca.gov.ph/images/brochure/oilPalms.pdf

Rosli, N. S., Harun, S., Jahim, J. M., & Othaman, R. (2017). Chemical and physical characterization of oil palm empty fruit bunch. Malaysian Journal of Analytical Sciences, 21(1), 188-196. http://dx.doi.org/10.17576/mjas-2017-2101-22

Septevani, A. A., Rifathin, A., Sari, A. A., Sampora, Y., Ariani, G. N., Sudiyarmanto, & Sondari, D. (2020). Oil palm empty fruit bunch-based nanocellulose as a super-adsorbent for water remediation. Carbohydrate Polymers, 229, 115433. https://doi.org/10.1016/j.carbpol.2019.115433

Teow, Y. H., Amirudin, S. N., & Ho, K. C. (2020). Sustainable approach to the synthesis of cellulose membrane from oil palm empty fruit bunch for dye wastewater treatment. Journal of Water Process Engineering, 34, 101182. https://doi.org/10.1016/j.jwpe.2020.101182

Yu, H., Tang, Q., Wgu, J., Lin, Y., Fan, L., Huang, M., Lin, J., Yan, L., & Yu, F. (2012). Using eggshell membrane as a separator in supercapacitor. Journal of Power Sources, 206, 463-468. https://doi.org/10.1016/j.jpowsour.2012.01.116

The Potential Electrospinnability and Filtration Capabilities of Pea-Protein Isolate/Polyvinyl Alcohol Air Filter Nanofabrics: A Systematic Review

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Abstract: Given the pervasiveness of air pollution with varying components and the shortcomings of conventional air filter mats, multifunctional air filters are becoming increasingly important. This has led to the development of air filter nanofabrics comprising bio-based components (such as chitin and proteins) and polymers (such as polyvinyl alcohol and pullulan). Electrospun air filter nanofabrics containing pea protein isolate (PPI) and polyvinyl alcohol (PVA) have yet to be developed to the researchers' knowledge. In this study, the potential electrospinnability and filtration capabilities of PPI and PVA were assessed and elaborated via a systematic review. Since PPI's globular morphology lacks molecular entanglement, PVA, an auxiliary spinning polymer with protein binding capabilities, is needed to aid PPI. Combining the two has successfully produced electrospun homogenous nanofabrics. Additionally, the nanofabrics likely possess physical and chemical filtration capabilities due to desirable material properties and powerful intermolecular interactions. Thus, PPI/PVA nanofabrics show great potential for multifunctional air filtration applications.

Key Words: air filter; nanofabric; pea protein isolate; polyvinyl alcohol; electrospinnability

1. INTRODUCTION

Clean air is crucial to maintaining good health. According to WHO (2019), nine out of ten people inhale toxic air—often leading to strokes, chronic respiratory diseases, and lung cancer. While traditional air filter mats can effectively filter larger particulate matter (PM) through size-based mechanisms, polluted air also contains toxic chemicals (like nitrogen dioxide, methane, and formaldehyde), viruses, and bacteria not easily captured by these filters. Furthermore, conventional filters often comprise chemically synthesized materials—such as polyethylene and polypropylene—producing secondary pollution when disposed of (Souzandeh et al., 2016). Therefore, multifunctional and eco-friendly air filters are needed to fill this significant gap in air filtration technology.

Souzandeh et al. (2016) helped fill this gap by developing multifunctional soy protein isolate/polyvinyl alcohol (SPI/PVA) air filter nanofabrics. Protein isolates are highly concentrated protein fractions produced for their prominent nutritional and functional properties (Sandberg, 2011). Polyvinyl alcohol (PVA) is a water-soluble polymer synthesized by hydrolyzing polyvinyl acetate in ethanol with potassium hydroxide. It has several applications due to its cohesiveness, film toughness, and biocompatibility (Wu et al., 2019). The nanofabrics were developed by electrospinning, which is among the simplest and most effective methods for creating nanofabrics. It is a voltage-driven process governed by the electrohydrodynamic phenomena where fibers and particles are made from a polymer solution (Nanoscience Instruments, 2019). The nanofabrics' efficient particulate and chemical removal efficiency and overall eco-friendliness due to their biodegradable components make them highly desirable. Since bio-based nanofabrics can potentially revolutionize air filtration technology, expanding upon relatively little existing knowledge is imperative. Thus, alternative protein isolate components should be explored.

Pea exhibits similar properties with soy, given they are both members of the legume family. Since pea protein shares the globular nature of soy protein, an auxiliary spinning polymer such as PVA must be employed to enhance the nanofabric morphology. Therefore, this study aims to expand upon existing knowledge by assessing the feasibility of integrating pea protein isolate (PPI) and PVA to be electrospun into nanofabrics by conducting a systematic review.

A systematic review is an assessment of information and evidence for pre-defined questions using systematic methods of searching, selecting, and evaluating relevant primary studies and thorough extraction, analysis, and synthesis of the studies

included in the review (Wright et al., 2007). By utilizing the systematic review process, the study seeks to answer two main questions:

Are PPI, PVA, and a solution of the two compatible with electrospinning?

Would a nanofabric comprising PPI and PVA exhibit multifunctional filtration capabilities?

2. METHODOLOGY

2.1. Study Design

The systematic review structure was adapted from the Cochrane Handbook For Systematic Reviews of Interventions and The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to formulate a suitable systematic review design. The Cochrane Handbook is a guide that meticulously explains all the necessary steps in preparing for and executing a Cochrane systematic review. This type of literature review produces high-quality evidence and great credibility due to its strict, predefined methods of data collection and risk assessment (Handoll et al., 2008). PRISMA served as a guide for summarizing and reporting the study selection and screening process.

The Cochrane Risk of Bias Tool formed the basis for the Risk of Bias Assessment phase. This phase improves the study's transparency by potentially spotting flaws or biases within each selected article's methodology and reporting of results. Thus, the researchers assessed each of the final articles for possible bias through four of the six Cochrane bias domains. Each domain was given a rating of high risk, low risk, or unclear risk of bias based on signaling questions.

2.1. Search Strategy

The researchers conducted a comprehensive literature search using the databases and keywords listed in Tables 1 and 2.

Table 1. List of databases used

Databases
Elsevier
ScienceDirect
Researchgate
PubMed Central
SciFinder
Scopus
Talyor & Francis Online

Table 2. Summary of search strategy and keywords utilized

Search Strategy	Keywords used
Identification of similar literature related to the proposed topic	"pea protein isolate", "soy protein isolate", "soy protein", pea protein", "legumes"
Identification of studies integrating pea protein isolate and polyvinyl alcohol	"pea protein", "pea protein isolate", "polyvinyl alcohol", "integration"
Efficacy of pea protein isolate and polyvinyl alcohol nano fabric as a potential multi-functional air filter	"pea protein", "pea protein isolate", "nano fabric", "air filters", "polyvinyl alcohol", "multi-functional air filter", "potential", "chemical and physical filtration"
Integration of the electrospinning process	"morphology", "molecular entanglement", "pea protein electro spin ability", "polyvinyl alcohol electro spin ability", "nano fabric"

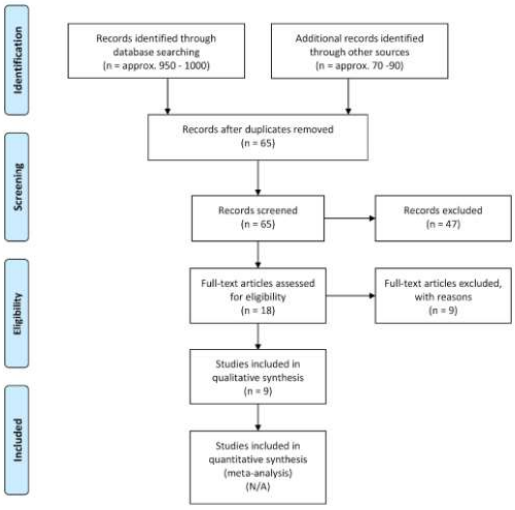
The inclusion and exclusion criteria set boundaries and confinements for the study. Since pea protein isolate (PPI) and polyvinyl alcohol (PVA) have been included in various studies, the researchers found it suitable to set criteria for their research.

Table 3. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Studies concerning PPI and/or PVA in electrospinning applications Studies concerning the viscosity, electrical conductivity and/or morphology of PVA and/or PPI nanofibers Studies concerning the capability of PVA and PPI to capture particles Studies concerning the physical or chemical properties of PPI and PVA Studies concerning the functional groups and amino acids of PVA and PPI	Studies concerning the feasibility of the PPI-PVA nanofabric being integrated with other working air filter designs Studies not written in the English language

2.3. Study Selection

For organized documentation, the PRISMA statement flow diagram was utilized (Figure 1).



Sixty-five articles were selected through their titles. After collecting and organizing the articles, a color-coding method was used to decide whether the article was usable (green), usable but needs further reading (purple), or unusable (red). After the initial screening, the researchers conducted a full-text assessment of eligibility for systematic review, wherein the researchers used the color-coded method to decide if the article's information would be the key for answering research questions included in the review (green), helpful information to supplement the review (blue), or information deemed unhelpful for the review (red). Subsequently, eligible articles were assessed and categorized into research objectives one or two.

2.2 Risk Assessment of Bias

Each selected article was given a color-coded assessment for bias using the following colors: Green (Low Risk), Yellow (Uncertain), and Red (High Risk). From Figure 2, the "majority" method was utilized to classify whether an article is a high risk or low risk. The assessment showed 88.8% of the final articles had a low risk. This means that most of the studies are not prone to different biases.

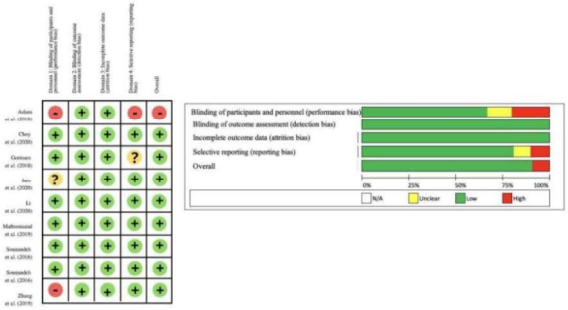


Figure 2. Summary of Risk of Bias Assessment (Tabular and Graph)

3. RESULTS AND DISCUSSION

3.1 Compatibility of PPI, PVA, and a solution of two with electrospinning

Creating bio-based PPI/PVA nano fabrics begins with electrospinning; therefore, the electro spinnability of these components is crucial for successful fiber formation. PPI's globular nature and lack of molecular entanglement hampers its electrospinnability. Therefore, an auxiliary polymer is vital to improving PPI's electrospinnability. PVA, a proven spinnable polymer, complements PPI in electrospinning due to its biodegradability, non-toxicity, biocompatibility, and protein binding capabilities through hydrogen bonding (Li et al., 2020). The two notable parameters that must be considered when electrospinning PVA are alcoholysis degree and solution viscosity (Table 4.a). An alcoholysis degree of 87-89% and a relatively lower solution viscosity are recommended for optimal nano fabrics. Moreover, several studies provide supporting evidence on the electro spinnability of PPI and PVA, both with other components and with each other. Although, the following parameters must be considered: viscosity, the pH level of concentration, the ratio of PPI to PVA, electrical conductivity, and distance from tip to the collector, each of which is elaborated in Table 4.b. It is evident that PPI and PVA could be electrospun as long as similar parameters are followed.

Table 4.a. Factors affecting electrospinnability of PVA and its corresponding effects

Factors Affecting Electrospinnability of PVA	Effects/ Results of Nanofabrics
Alcoholysis Degree	• Higher alcoholysis degree (~98-99%) makes nanofabrics too water resistant. • Slightly lower alcoholysis degree (~87-89%) produces optimal nanofabrics
Solution Viscosity	• Relatively lower solution viscosity would produce better electrospun nanofabrics. • If the PVA solution is too viscous, when the solvent volatilizes, the polymer chains in the solution entangle and are unable to produce the appropriate fiber-like structure needed for air filtration.

Table 4.b. PPI/PVA electrospinning parameters with corresponding fiber formation effects

Parameters for Electrospinning PVA and PPI	Effects/Results on Fiber Formation
PPI/PVA Solution Concentration	➢ 20:80, 30:70, 50:50, and 40:60 PPI/PVA concentrations formed homogenous nanofabrics ➢ SPI/PVA ratio of 50:50 worked best
PPI/PVA Solution pH Level	➢ pH 12 → gel-like consistency ➢ pH 2 and 7 → bead formation ➢ pH9 → most homogenous
PPI/PVA Solution Viscosity	➢ Lower viscosity is more efficient, as a decreasing apparent viscosity creates more homogenous nanofibers ➢ Extremely low or extremely high viscosity values are not recommended. ➢ Viscosity could only be increased through the range of 0.120 and 0.253 Pa·s.
PPI/PVA Solution Electrical Conductivity	➢ Solutions with electrical conductivity below a critical value would fail. ➢ A flow rate of 1 ml/h and voltage of 15 kV was used to form nanofibers.
Electrospinning Distance from Tip to Collector	➢ Shorter distance = less homogenous fibers with beads ➢ Longer Distance = thinner beads ➢ A 15 cm distance from tip to collector worked for PPI/PVA solution.

Generally, a 50:50 PPI:PVA ratio concentration is found to form fibers successfully. As seen from Figure 3, the fibers formed from the concentrations: 20/80, 30/70, 50/50, and 40/60 were more homogeneous (fewer beads) than other concentrations.

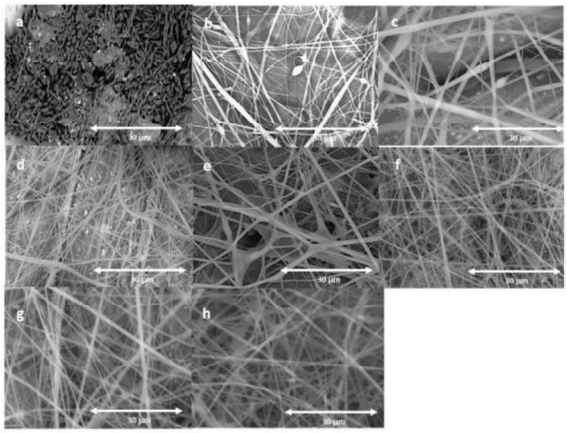


Figure 3. SEM images of PPI/PVA nanofibers at different ratios: a.) 80:20, b.) 70:30 c.) 60:40, d.) 50:50 e.) 40:60 f.) 30:70, g.) 20:80 and h.) 5% PVA from Maftoonazad et al. (2019)

As for the pH level of the solution, Figure 4 shows that a basic solution (pH 9) provides more fiber-like results with no bead formation.

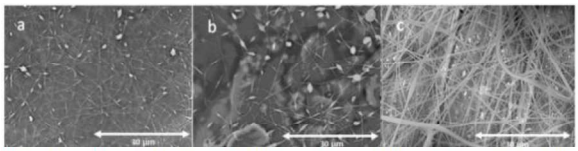


Figure 4. SEM images of PPI/PVA (50:50) Concentration at pH levels 2, 7, and 9 (from left to right) from Souzandeh et al. (2016)

Meanwhile, the solution viscosity and electrical conductivity are summarized in Table 5, where a viscosity range of 0.120 and 0.253 Pa·s and a low electrical conductivity form nanofibers. The parameters allow pea protein isolate and polyvinyl alcohol to be electrospun; therefore, homogenous fibers could be created.

Table 5. Influence of concentration on characteristics of PPI/PVA solution and mat from Maftoonazad et al. (2019)

PPI:PVA Ratio	K ($Pa \cdot s^n$)	Electrical Conductivity (S/m)	Apparent Viscosity at $50s^{-1}$	Nanofiber diameter (nm)	Nanofiber morphology
80:20	5.57 ± 0.74^a	0.0809 ± 0.0075^a	0.330 ± 0.026^a	-	No fibers/bead formation
70:30	4.92 ± 0.44^{ab}	0.0781 ± 0.0045^b	0.301 ± 0.031^a	567 ± 94.1	Nanofiber/ bead formation
60:40	2.34 ± 0.14^c	0.0816 ± 0.0039^a	0.0179 ± 0.0019^b	542 ± 110	Nanofibers with some beads
50:50	1.08 ± 0.09^d	0.0898 ± 0.0025^c	0.0120 ± 0.0011^b	498 ± 85.0	Nanofiber
40:60	0.235 ± 0.04^e	0.0905 ± 0.0042^c	0.0138 ± 0.0032^b	492 ± 41.2	Nanofiber
30:70	0.317 ± 0.09^e	0.0873 ± 0.0015^d	0.0240 ± 0.0043^b	474 ± 42.8	Nanofiber
20:80	0.280 ± 0.04^e	0.0854 ± 0.0069^d	0.0253 ± 0.0019^b	448 ± 61.5	Nanofiber

3.2.Multifunctional filtration capabilities of nanofabric comprising PPI and PVA

3.2.1 Physical Filtration Capabilities

Specific material properties of PPI/PVA nanofabrics are the primary parameters that would influence its physical filtration capabilities through size-based mechanisms. Nanofiber diameter affects the capturing of larger particles, as the sieving mechanism entails trapping large particles in between fiber pores. Areal density affects the capturing of smaller particles (micrometer to nanometer range). It controls the contact possibilities between these particles and the nanofibers, thereby influencing the inertial impact, interception, and diffusion mechanisms (Souzandeh et al., 2016). Thermal stability is necessary to avoid nanofiber deformation and fracturing when filtering high-temperature pollutants (Król-Morkisz and Pielichowska, 2019).

Protein/PVA nanofabrics are extremely capable of filtering PM10-2.5 (Table 6). These filtration efficiencies are attributed to fiber diameter and the nanofiber pores being smaller than the particles. For example, the SPI/PVA nanofabric maintained near 100% filtration efficiency with its pore size of 4.4 μm. Given that 10 μm is equivalent to 10,000 nm, the fiber diameter and pores are generally smaller than particulate matter (PM). Consequently, capturing efficiency is indirectly related to the fiber diameter. Though the PPI/PVA nanofabric's air filtration efficiency was not tested, its diameter of ~495 nm falls within the range that has successfully captured particles through sieving. Therefore, PPI/PVA nanofabrics show great potential for physical filtration, although the ideal fiber diameter has yet to be defined.

Table 6. $PM_{10-2.5}$ filtration efficiencies and average fiber diameters of protein/PVA nanofabrics

Type of electrospun nanofabric	Filtration efficiency for $PM_{10-2.5}$	Average fiber diameter
SPI/PVA	99.90% - 99.99%	100 - 200 nm
Zein/PVA	99.99%	60 - 600 nm
Gelatin/PVA	99.63 ± 0.11 %	100 - 600 nm

Figure 5 displays the importance of areal density in filtering PM smaller than 1 μm. Increasing the areal density improved the capturing of 0.3 μm particles, which are among the most challenging sizes to capture. However, there is a point where increasing areal density stops improving filtration efficiency. Therefore, finding an appropriate combination of fiber diameter and areal density is crucial to filtering larger and smaller particles.

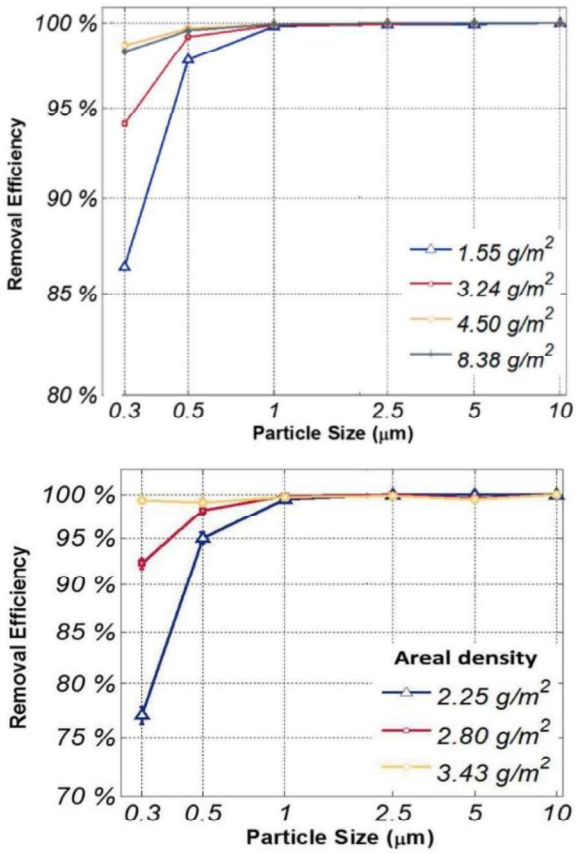


Figure 5. PM removal efficiencies of SPI/PVA (left) and gelatin/PVA (right) nanofabrics with varying areal densities for different particle sizes from Souzandeh et al. (2016)

Nanofabrics utilizing PPI/PVA have good melting points—an indicator of thermal stability. Their thermal stability is ascribed to fiber uniformity and hydrogen bonding between solution components. Polymers are generally composed of amorphous molecular chains; thus, the chains experience elongation from the electrostatic field during electrospinning. The resulting well-aligned, uniform molecular chains are necessary for the stable transferring of phonons (Asmatulu and Khan, 2019). Hydrogen bonding between the various functional groups of proteins and polymers restricts the movement of the intermolecular chains and the segmental rotations of the nanofiber molecules (Zhang et al., 2014). This restriction and uniformity in the molecules improve particle capturing. PPI/PVA nanofabrics with good thermal stability are feasible since Maftoonazad et al. (2019) have successfully developed homogenous nanofibers using these components. Furthermore, the hydrogen bonds present within the PPI/PVA nanofabrics slow down the oxidation and elimination of hydroxyl present within the nanofibers; thus, suppressing its thermal degradation.

3.2.2 Chemical Filtration Capabilities

The amino acid and functional group content of PPI/PVA nanofabrics are the main parameters that would influence its chemical filtration capabilities. PPI contains amino acids with ionizable side chains—such as lysine, histidine, and arginine—meaning they may accept or donate protons. Their surface charge due to electrospinning and their affinity for acid-base reactions have proven essential for antibacterial activity and attracting smaller charged pollutants such as gaseous particles (Dickson & Koohmaraie, 1989). Aside from ionizable side chains, amino acids also contain functional groups such as carboxyl, amino, and hydroxyl (Figure 6). PVA also has functional groups like hydroxyl, carboxyl, alkyl, carbonyl, and ether. In particular, the abundant hydroxyl groups attached to its carbon chain can form multiple hydrogen bonds. These functional groups exhibit chemical reactivity, meaning they can generate interactions (such as hydrogen bonding, ionic bonding, and charge-charge) with pollutants. Like the ionizable side chains, the functional groups attract electronegative particles using the positive charge gained from electrospinning (Lubasova et al., 2014). This charge-based interaction is referred to as electrostatic attraction and is the predominant mechanism of nanofabrics for dealing with toxic chemicals and bacteria.

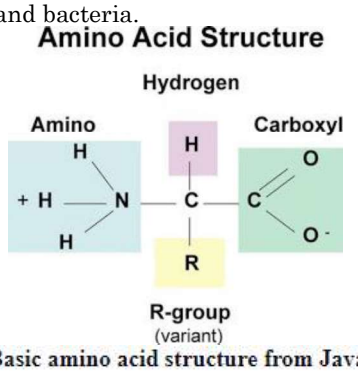


Figure 6. Basic amino acid structure from Javaid (2011).

Table 7 showcases the comparison of amino acid profiles between soy and pea protein isolates. The amino acids highlighted in the table contain ionizable side chains, and pea protein isolate contains equal or even greater amounts of these amino acids. The amino acids of SPI have proven essential in filtering toxic chemicals, as incorporating SPI into PVA nanofabrics tremendously raised the removal efficiency of formaldehyde and carbon monoxide (Table 8) Therefore, the similar amino acid content in PPI means PPI/PVA nanofabrics show great potential for chemical filtration. However, PPI must first be denatured to expose these functional groups fully.

	Pea	Soy		Pea	Soy
Non-essential amino acids			**Essential amino acids**		
Serine	2.5	2.3	Threonine	2.5	2.3
Glycine	0.3	0.3	Methionine	0.3	0.3
Glutamic acid	3.7	3.2	Phenylalanine	3.7	3.2
Proline	1.6	1.5	Histidine	1.6	1.5
Cysteine	4.7	3.4	Lysine	4.7	3.4
Alanine	2.7	2.2	Valine	2.7	2.2
Tyrosine	2.3	1.9	Isoleucine	2.3	1.9
Arginine	5.7	5.0	Leucine	5.7	5.0

Table 7. Amino acid content of pea and soy protein isolates measured in g per 100 g from Gorissen et al. (2018)

	SPI/PVA	PVA	HEPA Filter
Formaldehyde (HCHO)	62.50 %	31.23 %	< 5 %
Carbon monoxide (CO)	76.90 - 90.90 %	55.67 %	< 3 %

Table 8. Formaldehyde and Carbon monoxide removal efficiencies for different nanofabrics and HEPA filter

Further evidence for similar functional group content between PPI/PVA nanofabrics and other nanofabrics with similar components can be seen by analyzing their respective FTIR spectra (Figure 7). The various peaks at corresponding wavenumbers throughout the FTIR spectra signify the functional groups' presence within the nanofibers. Some examples include the peaks at wavenumbers 3000-3500 cm-1 representing hydroxyl groups and Amide I & II groups at wavenumbers 1500-2000 cm-1. The FTIR spectrum of the PPI/PVA nanofabric exhibited peaks at similar wavenumbers compared to the other nanofabrics, meaning a combination of PPI and PVA contain similar functional groups after being electrospun. These functional groups have proven essential for filtering PM2.5 and toxic chemicals due to the strong interactions they may exhibit; therefore, a PPI/PVA nanofabric for chemical filtration shows excellent promise.

4. CONCLUSIONS

The research aimed to assess the feasibility of developing PPI/PVA air filter nanofabrics via electrospinning by conducting a systematic review. PPI's globular nature and lack of molecular entanglement make it largely incompatible with electrospinning, while PVA is a polymer that has successfully been implemented in many electrospinning applications. A combined PPI/PVA solution is compatible with electrospinning under specific parameters and has resulted in nanofabrics with desirable properties. PPI/PVA nanofabrics have also shown potential filtration capabilities based on their similarity with other bio-based air filter nanofabrics. Specifically, its physical filtration function stems from its sufficient fiber diameter, appropriate areal density, and high thermal stability. Its chemical filtration function stems from its desirable amino acid and functional group content and the robust intermolecular interactions between them and pollutants.

These findings serve as a foundation for developing another multifunctional and eco-friendly nanofabric that serves as an alternative to traditional air filters. Although the results were synthesized from many credible sources, they remain inferences without experimental evidence. Therefore, it is highly recommended that future researchers conduct laboratory experiments to truly develop PPI/PVA nanofabrics to verify this study's results. It is hoped that this study will contribute to the budding field of air filter nanofabrics and help readers further understand the importance of preserving clean, quality air.

5. ACKNOWLEDGMENTS

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6. REFERENCES

Aslam, M., Kalyar, M. A., & Raza, Z. A. (2018). Polyvinyl alcohol: A review of research status and use of polyvinyl alcohol based nanocomposites. Polymer Engineering & Science, 58(12), 2119-2132. https://doi.org/10.1002/pen.24855

Asmatulu, R., & Khan, W. S. (2019). Chapter 12 - Electrospun nanofibers for photonics and electronics applications. Synthesis and Applications of Electrospun Nanofibers, 239–256. https://doi.org/10.1016/b978-0-12-813914-1.00012-2

Choy, S., Moon, H., Park, Y., Jung, Y. M., Koo, J. M., Oh, D. X., & Hwang, D. S. (2020). Mechanical properties and thermal stability of intermolecular-fitted poly (vinyl alcohol)/α-chitin nanofibrous mat. Carbohydrate

Polymers, 244, 116476. https://doi.org/10.1016/j.carbpol.2020.116476

Dickson, J. S., & Koohmaraie, M. (1989). Cell surface charge characteristics and their relationship to bacterial attachment to meat surfaces. Applied and environmental microbiology, 55(4), 832-836.

Gorissen, S. H., Crombag, J. J., Senden, J. M., Waterval, W. A., Bierau, J., Verdijk, L. B., & Van Loon, L. J. (2018). Protein content and amino acid composition of commercially available plant-based protein isolates. Amino Acids, 50(12), 1685-1695. https://doi.org/10.1007/s00726-018-2640-5

Handoll, H., Gillespie, W., Gillespie, L., & Madhok, R. (2008). The Cochrane collaboration: A leading role in producing reliable evidence to inform healthcare decisions in musculoskeletal trauma and disorders. Indian Journal of Orthopaedics, 42(3), 247-251. https://doi.org/10.4103/0019-5413.41849

Jain, R., Shetty, S., & Yadav, K. S. (2020). Unfolding the electrospinning potential of biopolymers for preparation of nanofibers. Journal of Drug Delivery Science and Technology, 57, 101604. https://doi.org/10.1016/j.jddst.2020.101604

Król-Morkisz, K., & Pielichowska, K. (2019). Thermal Decomposition of Polymer Nanocomposites With Functionalized Nanoparticles. Polymer Composites with Functionalized Nanoparticles, 405–435. https://doi.org/10.1016/b978-0-12-814064-2.00013-5

Li, K., Li, C., Tian, H., Yuan, L., Xiang, A., Wang, C., Li, J., & Rajulu, A. V. (2020). Multifunctional and efficient air filtration: A natural nanofilter prepared with zein and polyvinyl alcohol. Macromolecular Materials and Engineering, 305(8), 2000239. https://doi.org/10.1002/mame.202000239

Lubasova, D., Netravali, A., Parker, J., & Ingel, B. (2014). Bacterial filtration efficiency of green soy protein based nanofiber air filter. Journal of Nanoscience and Nanotechnology, 14(7), 4891-4898. https://doi.org/10.1166/jnn.2014.8729

Maftoonazad, N., Shahamirian, M., John, D., & Ramaswamy, H. (2019). Development and evaluation of antibacterial electrospun pea protein isolate-polyvinyl alcohol nanocomposite mats incorporated with cinnamaldehyde. Materials Science and Engineering , 94, 394-402. https://doi.org/10.1016/j.msec.2018.09.033

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & Prisma Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. https://doi.org/10.1371/journal.pmed.1000097

NanoScience. (2019). Electrospinning. Nanoscience Instruments. https://www.nanoscience.com/techniques/electrospin/

Souzandeh, H., Wang, Y., Johnson, K., & Bhamidipaty, K. (2016). Soy Protein-Based Nano-Fabrics for High Efficient and Multi-Functional Air Filtration. ACS Applied Materials & Interfaces, 8(31). https://doi.org/10.1021/acsami.6b05339

Souzandeh, H., Wang, Y., & Zhong, W. H. (2016). "Green" nano-filters: fine nanofibers of natural protein for high efficiency filtration of particulate pollutants and toxic gases. RSC advances, 6(107), 105948-105956. https://doi.org/10.1039/C6RA24512A

Sandberg, A.-S. (2011). Developing functional ingredients: a case study of pea protein. Functional Foods, 358–382. https://doi.org/10.1533/9780857092557.3.358

Wright, R. W., Brand, R. A., Dunn, W., & Spindler, K. P. (2007). How to write a systematic review. Clinical Orthopaedics and Related Research, 455, 23–29. https://doi.org/10.1097/blo.0b013e31802c9098

Wu, G., Zhai, M., & Wang, M. (2019). Radiation technology for advanced materials:: From basic to modern applications. Academic Press.

Zhang, R., Liu, C., Hsu, P., Zhang, C., Liu, N., Zhang, J., Lee, H., Liu, Y., Qiu, Y., Chu, S., & Cui, Y. (2016). Nanofiber air filters with high-temperature stability for efficient PM2.5 removal from the pollution sources. Nano Letters. https://pubs.acs.org/doi/abs/10.1021/acs.nanolett.6b00771

Zhang, T., Wu, X., & Luo, T. (2014). Polymer nanofibers with outstanding thermal conductivity and thermal stability: Fundamental linkage between molecular characteristics and macroscopic thermal properties. The Journal of Physical Chemistry. https://pubs.acs.org/doi/10.1021/jp5051639

Zhang, L., Yuan, W. L., Zhang, Z., Zhang, G. H., Chen, H., Zhao, N., ... & Tao, G. H. (2019). Self-assembled ionic nanofibers derived from amino acids for high-performance particulate matter removal. Journal of Materials Chemistry A, 7(9), 4619-4625.https://doi.org/10.1039/C8TA11382C

Characterizing Perceptions on Factors Associated with Cycling Behavior in the "New Normal"

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Abstract: The COVID-19 pandemic hindered transport systems globally. Its transmission is quick due to the dense living condition in metropolises, and mass transit systems soon became a hotspot for contracting the virus. As a result, individualized forms of transport became favorable. The study investigated other forms of individualized transport that hinders the spread of the virus and deters increasing the patronage for private cars. It also seeks to aid in the development of sustainable transport policies in Metro Manila. Accomplishing this required the perceptions of Metro Manila travelers on bicycling, their socio-demographic characteristics, and trip behavior. The data was gathered through an online survey, which were then analyzed and modeled using the descriptive statistics functions of MS Excel to determine which parameters motivate or demotivate travelers from using a bicycle. Results of the survey led to the conclusion that the cyclist's security is a significant motivator and demotivator, and unlike its motivator counterpart, cost does not necessarily demotivate travelers from bicycling, but it is also advised to proceed with caution when interpreting the results for the cost motivator since these may also indicate a demotivation for private car use instead of primarily a motivation to use a bicycle for travel. These results were also disaggregated by trip length. It was found that long trip motivators generally held higher significance but this trend is not followed for both short and long trip demotivators which makes it seem that travelers are more easily demotivated to cycle.

Key Words: bicycle; active transport; barriers; opportunities; Metro Manila

1. INTRODUCTION

The COVID-19 pandemic brought upon a challenging hurdle for transportation around the world. Quarantine has been implemented, limiting public transportation operations because of the contact between people (Yoo et al., 2020). Higher capacities of mass transit do not correlate with an increase in volume inside the spaces, since high density of commuters in a space decreases the effectiveness of social distancing (Evans & Wener, 2007). However, using private vehicles is also not ideal. To compare, influenza, which has a similar transmission, is estimated to have a higher risk in a car as opposed to air travel with one infected person in the plane (L.D. Knibbs, L. Morawska, S.C. Bel, 2012).

Citizens who regularly travel have begun to use active transport as an alternative for the lack of public transportation due to its one-person capacity and compliance with existing quarantine protocols (Cruz & Ives, 2020). Active transport provides essential mobility, physical fitness, and enjoyment (Litman, 2016). Lastly, the decrease of private vehicle use and increased physical activity may result in a reduced risk of diabetes, depression, and dementia in the general population (Woodcock et al., 2010).

The main objective of this research is to investigate the perceptions of Metro-Manila travelers toward bicycling as an alternative. Specifically, this study analyzed a few successful programs and to determine how to implement these in the local setting best. Determining these will aid the development of bicycling policies for the country.

The following section discusses the methodology. Section 3 covers the data analysis, while Section 4 concludes the study.

2. METHODOLOGY

2.1 Conceptual Framework

Contributing factors to implementation of bicycle policies were gathered from literature. The hypotheses are then formulated from the identified factors, which are evaluated through data gathering. An online survey with questions on both the motivators and demotivators for bicycling measured the perceptions of the respondents toward these factors. Socio-demographic characteristics of the respondents were also gathered. Measures of central tendency were used to compare relative significance among the factors. Finally, disaggregated data were analyzed in a similarly.

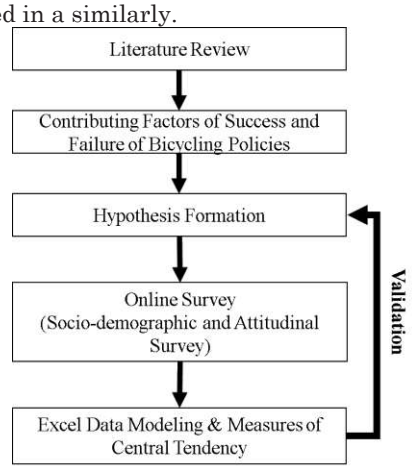

Figure 1. Conceptual framework

2.3 Materials and Procedure

On Appendix A, 233 samples were gathered using an online survey conducted using Google Forms from October 2020 to January 2021. Perceptions were quantified as the respondents' level of agreement with statements of the different factors on Table 1.

Table 1. Motivators and barriers for cycling

VARIABLE	BICYCLING MOTIVATORS	BICYCLING BARRIERS	ASSIGNED VALUES
Comfort and Convenience	There are establishments along the bicycle lanes	The frequency of extreme weather	Very likely (1) – Very unlikely (4)

Qualitative variables such as sex and educational attainment were assigned either 1 (Yes) or 0 (No) values. On the other hand, values of categorical class were used for scalar variables like travel frequency, while age utilized the actual values. Lastly, a Likert Scale from 1 to 4 (very likely and very unlikely, respectively) measured their perceptions. These numbers were assigned values 2, -1, 1, and 2, respectively.

3. RESULTS AND DISCUSSION

Demographic, Trip Conditions and Situations, and Bicycling Trip Preferences of Metro Manila Travelers

The percentage of sexes in Table 2 show similar results from the 2020 Labor Force Survey of the Philippine Statistics Authority. Next, respondent's age ranges from 22 to 54 years, the majority being young adults, employed, single, earn on average Php 29,206.01/month (est. 1 USD = Php 48.44) which reflects the high unemployment proportion, and all have finished compulsory education.

Table 2. Socio-demographic traits and travel behavior (general and by bicycle)

VARIABLES	PARAMETERS	COUNT(%)	MEAN (S.D.)
Sex	Male Female	105(45.06%) 128(54.94%)	-
Age (years)	Exact value	-	29.3 (10.43)
Marital Status	Single Married Annulled Widow	164(70.39%) 66(28.33%) 1(0.43%) 2(0.86%)	-
Educational Attainment	No formal education Elementary diploma High School diploma College degree Masteral or higher	0(0%) 0(0%) 89(32.8%) 113(48.5%) 31(13.3%)	-
Employment Status	Employed Unemployed	122(52.36%) 111(47.64%)	-
Monthly Income (Php)	Less than 10,000 10,000 –25,000 25,000 –45,000 45,000 –70,000 70, 000 –100,000 More than 100,000	92(39.5%) 43(18.5%) 48(20.6%) 21(9.0%) 13(5.6%) 16(6.9%)	29,206.01 (29,215.65)
Trip Purpose	Work Supermarket Market Others	89(40%) 72(32%) 29(13%) 35(15%)	-
Travel Frequency (days/month)	< 1 4 – 8 12 – 16 20 – 24 Everyday	40(17%) 85(37%) 23(10%) 52(22%) 33(14%)	-
Transport Mode	Walk Bicycle Mass Transit Rideshare Carpool Private Car	18(8%) 36(16%) 34(15%) 10(4%) 10(4%) 122(53%)	-
Travel Duration (minutes)	< 15 15 – 30 30 – 60 60 – 120 > 120	49(21%) 84(36%) 55(24%) 34(14%) 11(5%)	39.11 (31.76)
Bicycle Ownership	Yes No	134(58%) 99(42%)	-
Travel Frequency by Bicycle (days/month)	Never < 1 4 – 8 12 – 16 20 – 24 Everyday	124(53.22%) 32(13.73%) 37(15.88%) 19(8.15%) 9(3.86%) 12(5.15%)	4.56 (8.14)
Travel Duration on Bicycle (minutes)	< 5 5 – 15 15 – 30 30 – 60 > 60	4(3.67%) 16(14.68%) 33(30.28%) 29(26.61%) 27(24.77%)	35.20 (19.03)

Most travel for work and supermarket, implying these are prioritized trips as seen on table 2. On the same table, majority report traveling for at most 4 to 8 days a month, and the disparity between private car users and the other modes (n=108) depicts people's fear of the virus when using mass transit. Lastly, bicycle users are slightly greater than mass transit users, implying an increase in bicycling activity.

Figure 2 presents that Metro Manila travelers usually depart from their homes at 8:00 AM and return at 5:00 PM, and most trips, both on and off the bicycle, last for 15 to 30 minutes as seen on Table 2. However, the higher responses for longer durations present the city's underdeveloped bicycling infrastructure. Furthermore, the high amount of long duration trips is likely a result of peak hours, especially since mass transit currently operate at limited capacities leading to increased private car usage (Abad, 2020).

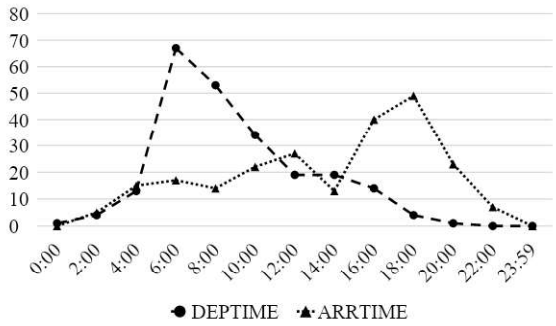

Figure 2. Usual departure and arrival time

Approximately 21% and 49% of bicycle owners have never or sparingly use their bicycles for travel, respectively as presented on Table 3, but the development of the bicycling infrastructure may increase these proportions (Cameña & Castro, 2016; Rissel et al., 2015).To add, Table 4 presents that respondents prefer: flexible pavement, leveled roads, and free-flowing traffic, but most built roads in Metro Manila are constructed with rigid pavement, have steady traffic, and are level. Thus, the problems lie with the current pavement type and traffic situation.

Table 3. Number of bicycle owners by travel frequency

PARAMETER (DAYS/MONTH)	COUNT(%)
Never	28(20.90%)
< 1	29(21.64%)
4 – 8	37(27.61%)
12 – 16	19(14.18%)
20 – 24	9(6.72%)
Everyday	12(8.96%)

Table 4. Bicycling preference of the respondents

VARIABLE	PARAMETER	CURRENT COUNT (%)	PREFERRED COUNT (%)
PAVEMENT TYPE	Rigid	57 (52.30)	58 (24.89)
	Flexible	42 (38.53)	163 (69.96)
	Unpaved	10 (9.170)	12 (5.150)
TERRAIN	Level	77 (70.64)	199 (85.41)
	Rolling	10 (9.170)	10 (4.290)
	Mountainous	22 (20.18)	24 (10.30)
TRAFFIC SITUATION	Free-flowing	32 (29.36)	188 (81.39)
	Steady	47 (43.12)	30 (12.99)
	Congested	30 (27.52)	13 (5.630)

3,2 An Overview on the Average Traveler's Perceptions on Bicycling

On Table 5, COST motivator parameters for an increase in fuel costs or parking fees likely motivates travelers to use a bicycle while the availability of cheaper bikes weakly do so. However, because 53% regularly use private cars, this may also be viewed as a demotivation for private car use rather than solely a motivator for bicycling. Equipping lanes with streetlamps and having a large cycling community shows promise for increasing ridership. However, SCRT presents the presence of traffic enforcement as a weak motivator. This is likely due to fear of encountering corrupt enforcers who accept incentives to drop a motorist's violations, a practice observed called 'kotong'. Finally, Figure 3 further proves the significance of security when traveling by bicycle as it is the most significant motivator.

Table 5. Summary of cycling motivators

VARIABLES (CODE)	PARAMETERS	MEAN(S.D.)
Cost (COST)	Vehicle fuel costs are increasing	1.03 (1.30)
	Vehicle parking fees are increasing	0.76 (1.39)
	Locally manufactured bicycles are promoted	0.34 (1.52)
Security (SCRT)	Installation of streetlamps along the bicycling lanes	1.26 (1.13)
	Seeing other bicyclists use the bicycling lanes	1.15 (1.16)
	Traffic enforcement is present	0.56 (1.44)
Safety (SFTY)	Bicycle repair stations or air stations are present along	0.41 (1.53)

	the bicycling lanes	
	Use of helmets and compliance w/ safety policies is strictly enforced	0.47 (1.58)
	Bicycle safety accessories are easily accessible for purchase	1.18 (1.13)
Information (INFO)	Bicycling lanes are clearly marked and separated from motor vehicle lanes	0.42 (1.67)
	Development and improvement of bicycling facilities are being covered by news reports	0.60 (1.47)
	Awareness campaigns on bicycling laws are promoted to motor vehicle drivers	0.29 (1.57)
Comfort&Convenience (COCV)	Bicyclists are not affected by vehicular traffic congestion	0.24 (1.60)
	Adequate lane widths for bicycling lanes are provided	0.00 (1.68)
	Presence of establishments along the bicycling lanes	1.12 (1.20)
Reliability (RLBT)	LGUs conduct routine road clearing operations	0.40 (1.57)
	Bicyclists have full control over their departure time	1.14 (1.24)
	Availability of first aid stations along the bicycling lanes	-0.40 (1.70)

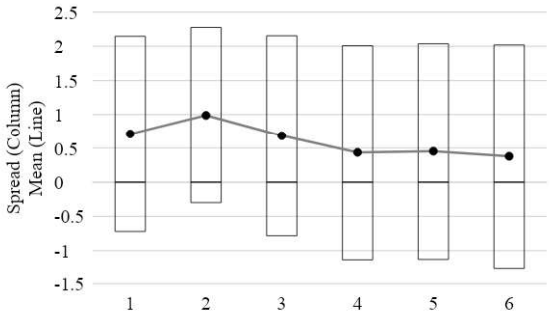

Figure 3. Plot of spread and mean of each motivator variable

SFTY on Table 5 shows that by making bicycle safety equipment more accessible, bicycling may improve patronage while the remaining show less significant results. Thus, it is advisable to plan a relationship that will benefit both stores and the bicycle infrastructure. To add, INFO presents the sensitivity of travelers toward news regarding bicycling. Thus, updating the public on the state of a city's bicycle infrastructure may increase ridership depending on how news is viewed.

Constructing bicycling lanes along establishments may increase bicycle ridership, however COCV on Table 5 shows that if these lanes occupy existing roads and further worsen traffic, dedicated lanes alone weakly motivate bicycle ridership. Thus, policies should achieve coexistence between bicycles and vehicles in Metro Manila. Interestingly, first aid on lanes weakly motivates Filipinos to cycle because they are likely already accustomed to frequent accidents. Furthermore, RLBT on the same table presents the preference of travelers to have full control over their departure time implying that they plan the shortest travel route and time possible.

On Table 6, COST shows most find owning bicycling locks unnecessary, expecting that establishments have these. Emphasis on the value of reducing crime rates along routes is visible from the SCRT results. Next, clearing the lanes of hazards and adding bicycle safety measures at intersections is necessary for them to consider bicycling. However, for the SFTY variable, insufficient bicycle lane networks may detract travelers from bicycling. Furthermore, bicycle safety knowledge, information on the bicycle infrastructure's state and the environment it is built on, and knowledge of bicycle routes that cyclists can take may avoid detracting travelers from cycling.

Table 6. Summary of cycling demotivators

VARIABLES	PARAMETERS	MEAN(S.D.)
COST	No bicycle available for use	-0.01(1.76)
	Bicycle locks are needed	0.95(1.46)
	Helmets and safety accessories are required by law	0.36(1.57)
SCRT	Prevalence of bike theft	1.15(1.27)
	General threat of crime	0.73(1.35)
	Lack of secure parking spaces for bicycles	1.18(1.29)
SFTY	Insufficient bicycle lane networks in my area	1.09(1.31)
	Obstructions are found on the bicycle lanes	0.96(1.29)
	"Bike boxes' are not provided at intersections	1.14(1.28)
INFO	Maps of bicycle routes in the city are unavailable	0.65(1.57)
	Areas with bicycle lanes are reported to have low air quality index	0.67(1.40)
	Lack of bicycle safety classes	0.98(1.27)
COCV	Extreme weather occurs frequently	0.94(1.30)
	Bicycling for long periods results in body aches	0.21(1.53)
	Bicycle lane networks are disconnected across neighboring towns and cities	1.18(1.28)
RLBT	Bicycle lanes are not consistently maintained	1.15(1.20)
	LGUs do not strictly enforce bicycling laws	1.06(1.30)
	Bicycle chains require frequent maintenance	0.41(1.49)

Table 6 shows the COCV variable presents the preference of travelers for weatherproof and continuous bicycle lanes. Thus, policies should mitigate both the issue of disjoined bicycle lanes and effects of extreme weather. Lastly, the respondents show more concern toward maintaining the infrastructure and policing system rather than the bicycle itself as seen on RLBT.

Figure 4 further proves that addressing SCRT, SFTY, RLBT of using bicycle lanes may improve the chances of increasing patronage. Thus, policies may primarily address the cyclists' security, bicycle lanes' safety, and bicycles' qualities sold at stores.

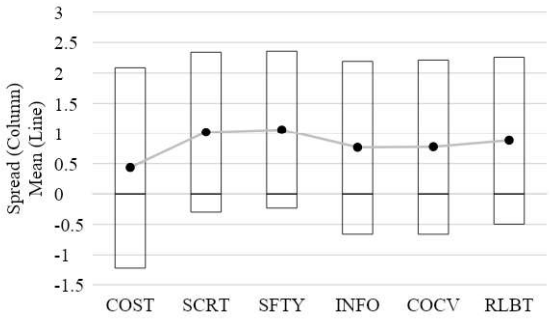

Figure 4. Plot of spread and mean of each demotivator variable

3.3 The Average Traveler's Attitudes on Bicycling by Trip Length

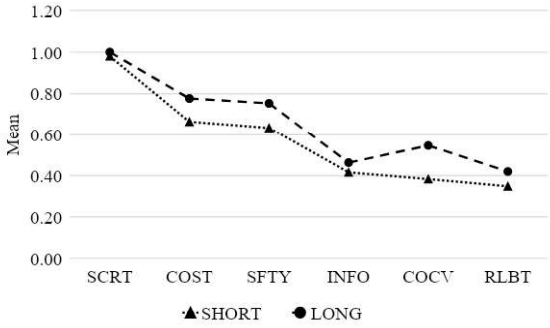

Figure 5. Trip motivators disaggregated by length

Generally, longer trips result in higher significance of a variable. Thus, the higher significance for long trip motivators on Figure 5 implies that most respondents cycle for longer periods which presents them to be more sensitive of these variables' effects. Lastly, the relatively low significance of INFO, COCV, and RLBT for both trip durations requires deeper investigation because results from earlier present that these variables are essential for increasing bicycle ridership.

Unlike on Figure 5, SFTY holds the most significance for both trip durations. Thus, increasing

bicycling patronage may require resolving the issues of rider safety when using the bicycle lanes. Furthermore, minute differences between the SFTY and INFO demotivators may indicate that travelers similarly value these variables for both durations. However, RLBT during longer trips becomes more significant, indicating a change in the trend observed earlier. The increase in RLBTs significance may indicate that travelers are more easily demotivated to cycle regardless of trip length.

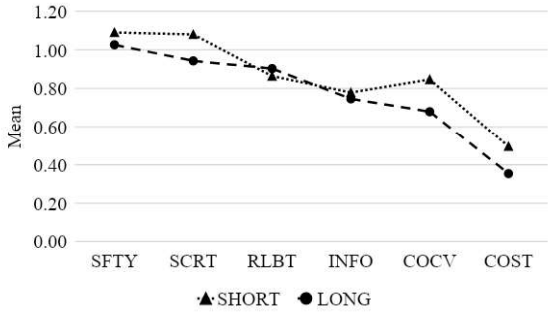

Figure 6. Trip demotivators disaggregated by length

4. CONCLUSIONS

This section will cap the study with recommendations for bicycle policy development, and the conduction of research for this topic.

The following are the recommendations for bicycle policy development based on the findings of this study: make bicycle safety equipment and accessories accessible to the public, present the benefits of bicycling while addressing the barriers and providing the preferences of the travelers for the bicycle lanes, identify the type of bicycle safety equipment that travelers want to personally own or expect to be shared then look into subsidizing the shared equipment, seek to achieve the coexistence of bicycling with the other transport modes, lastly is to not rely on data from studies conducted on foreign countries as Metro Manila travelers have shown behavior that deviate from the results of those studies.

Subsequent studies should take the succeeding recommendations into account. First is to replicate the methodology of this study in a normal, non-pandemic setting of Metro Manila to gain a point of comparison of the travelers' changes in perception during and after the pandemic. Second, enlarge and specify the study area in order to gain a comprehensive understanding of the perceptions of Metro Manila travelers from several locations of Metro Manila. Third, evaluate the parameters to be used by either replacing these with more appropriate parameters or by reframing the currrent parameters for these to better fit the main idea of each variable. Finally, establish communication with other researchers, LGUs, and government agencies who or which are involved in the research and development of the bicycle infrastructure of the city.

5. ACKNOWLEDGMENTS

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6. REFERENCES

Abad, M. (2020, June 8). FAST FACTS: State of Metro Manila's public transport system. Rappler. https://www.rappler.com/newsbreak/iq/things-to-know-about-metro-manila-public-transport-system?fbclid=IwAR00HvYLojl38DptDAhLZjGUoIx-JRggnLTwNiVgQhx_D35NVc1Nzu3V8I.

Cameña, J. P., & Castro, J. T. (2016). Identifying the Determinants of Walkability and Use of Non-Motorized Transport in a Medium-Sized City : The Case of Iloilo City , Philippines. 23rd Annual Conference of the Transportation Science Society of the Philippines, August. http://ncts.upd.edu.ph/tssp/wp-content/uploads/2016/08/Camena-Castro.pdf

Cruz, K. D. L., & Ives, M. (2020, December 13). When the Trains Stopped, Cyclists Dodged Manila's Choking Traffic. The New York Times. https://www.nytimes.com/2020/12/13/world/asia/philippines-manila-bicycles-coronavirus.html?fbclid=IwAR2f3AxzUikCdhsre1OIdIY7aUDHq251MHYsOgz8Y27kIfup9dE-P8x9NV8.

Evans, G. W., & Wener, R. E. (2007). Crowding and personal space invasion on the train: Please don't make me sit in the middle. Journal of Environmental Psychology. https://doi.org/10.1016/j.jenvp.2006.10.002

L.D. Knibbs, L. Morawska, S.C. Bel. (2012). International Laboratory for Air Quality and Health , Queensland University of Technology , Thoracic Medicine , The Prince Charles Hospital , Brisbane , Australia Corresponding author : L . D . Knibbs , International Laboratory for Air Quality and Health.

Rissel, C., Greaves, S., Wen, L. M., Crane, M., & Standen, C. (2015). Use of and short-term impacts of new cycling infrastructure in inner-Sydney, Australia: A quasi-experimental design. International Journal of Behavioral Nutrition

and Physical Activity, 12(1), 1. https://doi.org/10.1186/s12966-015-0294-1

Woodcock, J., Edwards, P., Tonne, C., Armstrong, B. G., Ashiru, O., Banister, D., Franco, O. H., Haines, A., Hickman, R., Lindsay, G., Tiwari, G., Woodward, A., & Roberts, I. (2010). Public health benefi ts of strategies to reduce greenhouse-gas emissions : Urban land transport Delhi CO2 emissions transport Submitted to Ministry of Urban Development Government of India New Delhi Indian Institute of Technology Delhi. April.

Yoo, J. Y., Dutra, S. V. O., Fanfan, D., Sniffen, S., Wang, H., Siddiqui, J., Song, H. S., Bang, S. H., Kim, D. E., Kim, S., & Groer, M. (2020). Comparative analysis of COVID-19 guidelines from six countries: a qualitative study on the US, China, South Korea, the UK, Brazil, and Haiti. BMC Public Health, 20(1), 1–16. https://doi.org/10.1186/s12889-020-09924-7

Mung beans (Vigna radiata) as a Main Component in Bioplastic Synthesis: An Exploratory Research

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Taytay Senior High School, Taytay, Rizal

Abstract: Non-biodegradable and single-use plastics became helpful to the masses, yet harmful to the environment. Thirty-five percent of plastics made for packaging, typically used once, are usually scattered or littered (Davis, 2015). Bioplastics are recently consolidated to potentially become an alternative to traditional plastics, which can reduce the dependency of plastic to petroleum and better disposal of plastic. With this in mind, investing in research and development with regards to bioplastics is much needed for our environment. Hence, promoting it as an advocacy should be uplifted (Thompson et al., 2009 cited in Pathak et al., 2014).This study aims to synthesize Mung beans (Vigna radiata) based bioplastic film as an alternative for non-biodegradable plastics gathering data on its properties using Solubility Test, Swelling Test, and Biodegradability Test.The result of the Solubility test revealed that the bioplastic material is soluble in the strongly acidic solvent and insoluble in the remaining solvents including distilled water after the soaking period. The Swelling test showed that there is a minimal difference in weight after the material was submerged in distilled water making it more preferable when it comes to manufacturing of bioplastic material. The Biodegradability test revealed that there is a massive change in weight after the soil burial period. Therefore, we conclude that the Mung bean starch based bioplastic film can be an alternative to single-use and non-biodegradable plastics and can be a solution to the existing and rising environmental issues caused by the continued use of non-biodegradable materials in numerous fields.

Key Words: bioplastic; biodegradable; mung beans; starch; environment

1. INTRODUCTION

The relevance of plastic to humans has grown immensely. This has led researchers to innovate an alternative plastic that is non-polluting, in hopes of solving the environmental problems. However, environmental problems are not yet fully resolved. This gave an opportunity for the destructive effect of plastic to increase exponentially (Koushal et al., 2014). On the grounds that garbage bins are still filled with plastic bags, pollution (land and water) and sewage problems continue to be a major issue of society. Consequently, floods have been said to be caused artificially by plastics followed by sewage problems, land, water, and air pollution. In addition, these lightweight packaging materials also carry adverse impacts, due to the fact that wind can carry them to undesired critical public places like trees, roadside ditches, or even in drains, rivulets, and rivers (Kakoti, 2017).

Bioplastics are recently consolidated to potentially become an alternative to traditional plastics, which can reduce the dependency of plastic to petroleum, as well as, better disposal of plastic. With this in mind, investing in research and development with regards to bioplastics is much needed for our environment. Hence, promoting it as an advocacy should be uplifted (Thompson et al., 2009, cited in Pathak et al., 2014).

Mung beans belong to the family of legumes. Two of the main parts of legumes are protein and starch. Legume starch pastes are said to be more adherent than cereal starches because of higher resistance to swelling and rupture (Lineback & Ke, 1975, cited in Abdel-Rahman et al., 2008). Galvez and Resurreccion (1993), cited in Abdel-Rahman et al. (2008), exemplified that the amount of starch from mung beans is contingent on seed coats, the medium where it was soaked, and the length of time it was grinded.

Bio-based plastic exhibited high degradability in soil and compost systems, but most are not capable of finding ways in aquatic systems (Gil-Castell et al., 2016 cited in Thakur et al., 2018). The community's way of living may be magnified through the utilization of various bioplastic materials which can be useful to various fields such as agriculture, medicine, and the like; because the closest materials that may

potentially beat petrochemical based plastic in the future are biodegradable polymeric materials (Raza et al., 2018, cited in Thakur et al., 2018).

1.1. Central Problem

The use of non-biodegradable plastics gave rise to various environmental problems, it's also one of the modern days' biggest environmental issues. The widespread use of single-use plastics in product packaging caused public outrage over the environmental disasters caused by these wastes.

Hence, this study aims to synthesize an alternative for non-biodegradable plastics with the use of Mung Beans as its main component in the form of bioplastic.

1.2. Theoretical Framework

Eventually, usage and production of biodegradable polymer materials has been increasing in the interest of the public and scientific field over the past two decades as an alternative to plastics. Which is still needed to develop chemical and physical properties of synthetic plastics. As a result, a solution was proposed for the current problem of plastic waste (Reddy et al., 2003, cited in Pathak et al., 2014).

Bioplastic production is considered to be costly compared to petroleum based plastics. Theoretically, the plant provides a substitute solution to making these materials less expensive. In return, the plant hypothetically gives an elective answer for integrating these mass item products effortlessly. While the handling of PHA in microbes and yeast includes a costly aging interaction with outer wellsprings of energy, like power, it is more affordable in plant frameworks since it depends on water, soil nutrients, CO2 and daylight. Moreover, a plant processing system is also more environmentally friendly (Bastoli, 1998, cited in Gill, 2014).

1.3. Existing Model

Given the theories gathered, the researchers used the methods of Prabhavat (1988) and Singh et al. (1989), as cited in Abdel-Rahman et al. (2008), in order to determine the efficient way of extracting mung bean starch that will be used in the bioplastic synthesis.

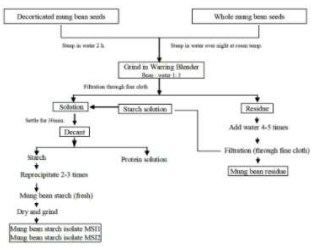

Figure 1. *Isolation of Mung Bean Starch from Whole (MSI1) and Decorticated (MPI2) Mung Bean Seeds*

Note. Figure 1 shows the process of Mung bean starch extraction. From "Isolation and Physicochemical Characterization of Mung Bean Starches" by Abdel-Rahman et al., 2008, International journal of food engineering, 4(1), Materials section, Figure 1 (https://doi.org/10.2202/1556-3758.1184). CC BY.

Hence, this study proposes that these theories can be used to explore the said topic through prototype development and formulation with the use of the gathered related literature.

1.4. Research Questions

1.4.1. In what solvent/s is/are the Mung bean based bioplastic film soluble?

1.4.2. What is the result of a swelling test in each solvent after 2 hours of saturation?

1.4.3. In what depth is the Mung Bean based bioplastic the highest in terms of weight loss percentage after 7 days of soil burial process?

1.4.4. Is there a significant difference between the depth of soil burial and the weight loss percentage?

Ho . There is no significant difference between the weight loss percentage and the given depths.

1.5. Significance of the Study

This study aims to synthesize Mung bean based bioplastic as an alternative for non-biodegradable single-use plastics. This study may greatly affect single-use plastic consumers, entrepreneurs, future researchers, the community, the environment, and others as they can be aware and knowledgeable about the environmental effects of the plastics that they use and they can see how bioplastic can change one's way of living.

2. METHODOLOGY

This study aims to develop an alternative for non-biodegradable plastics with the use of Mung Beans (Vigna radiata) as its main component in the form of bioplastic. This study will use True Experimental Research design in product development and formulation.

In order to test the Swelling, Solubility and Degradation characteristics of the biofilm, the researchers will be using the instruments for the data collection process.

2.1. Preparation of Mung Bean Starch

Starch was extracted from Mung Beans bought from Taytay Public Market, Taytay, Rizal using the method adapted from Prabhavat (1988) and Singh et al. (1989), as cited in Abdel-Rahman et al. (2008).

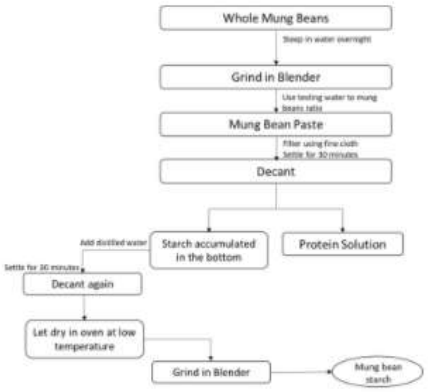

Figure 2. *Mung Bean Starch Extraction Process*

2.2. Preparation of Mung Bean Based Bioplastic Film

In order to make the bioplastic film, 25g of extracted Mung bean starch was put into the beaker followed by the addition of VG/PG glycerin, stirred using a stirring rod. Hydrochloric Acid (HCl) is then added while stirring to incorporate the mixture well. Dissolved Sodium Hydroxide (NaOH)-water solution (1:10 ratio) is then added in order to neutralize pH to 7. The mixture was poured into a petri plate and baked in the oven at 125 degree Celsius for drying. The petri plate was cooled in order to scrape the bioplastic film from the plate.

Figure 3. *Mung Bean based Biofilm*

2.3. Presentation of Data Collection Process

2.3.1 Solubility Test of Synthesized Mung Bean based Bioplastic in Different Solvents

Solubility test of the bioplastic material was conducted by following the procedure of Jayachandra (2016) as cited in Rizwana et al. (2020). The sample was cut into 2cm by 2 cm square weighing approximately 0.75 grams and was placed inside of 16x150 individual test tubes containing 15 ml of specific solvents – distilled water, methanol, ethanol, and muriatic acid (HCl) for 30 minutes. Deliberate selection of solvents was done to distinguish the activity of material with variables such as polar, non-polar, and high acidic solvent.

2.3.2 Swelling Test of Synthesized Mung Bean based Bioplastic in Different Solvents

Swelling test of the specimen is conducted to observe the change in the material's original properties after synthesis by following the procedure of Jayachandra (2016) as cited in Rizwana et al. (2020). To validate the protuberance and other morphological changes, a pre-weighed piece of sample was utilized. Using the beaker test method, the samples were submerged in different beakers containing different solvents. Multifarious solvents such as water, methanol, and ethanol were used to soak the samples for approximately 2 hours and data were recorded appropriately.

2.3.3 Biodegradability Test of Synthesized Mung Bean based Bioplastic in Different Depths

Biodegradability test of the bioplastic material, was conducted by pre-weighting the specimen and using soil burial method. A garden soil that had 58.38% moisture content was measured at 800 grams. Afterwards, it was stored inside a container.

The samples were buried in depths of 2cm, 3cm and 4cm for 7 days having the same condition of soil moisture content and an average outside temperature of 32 degree celsius. The weight of each specimen was measured before conducting the test. Samples were periodically removed on the 1st, 3rd, 5th and 7th day of the burial period, washed with distilled water and dried before analysis. The dried films were weighed for monitoring weight loss (Jain and Tiwari, 2015). The biodegradability test was measured by Equation (Marichelvam et al., 2019):

Weight Loss (%) = $[(Wo - W)/Wo] \times 100$,

Wherein: Wo is the weight before the soil burial (initial) and W is the weight after the test (7th day)

2.4. Scope and Delimitation

This study focuses on the Mung beans as a main component in bioplastic synthesis through product development with the use of the gathered related literature wherein the researchers reviewed and explored the evident components of Mung beans that contribute to its possibility to be used in bioplastic synthesis, which leads to testing its solubility, swelling and biodegradability.

The study limits the development of bioplastic using Mung beans with other active ingredients and tests on solubility, swelling, and biodegradability only and

does not include tensile strength test, SEM analysis, and other tests. The researchers may also gather data about the other topics or focuses stated above.

2.5. Ethical Consideration

We understand that as researchers we have the responsibility to uphold the ethics in research such that no animal or human will be used as a sample or during the trial period. Also, this is also to assure that we will observe ingenuity of our output, hence, if there are replications of similarities to other existing research projects it is not intentional.

3. RESULTS AND DISCUSSION

Through unit/thematic analysis and based on the research question/s the following findings were presented:

3.1. Presentation and Interpretation of Data

3.1.1. In what solvent/s is/are the Mung bean based bioplastic film soluble?

Figure 4. *Solubility Test of Synthesized Mung Bean based Bioplastic in Different Solvents*

Table 1. *Solubility Test of Synthesized Mung Bean based Bioplastic in Different Solvents*

Solvent Number	Solvents Used	Insoluble	Partially Soluble	Completely Soluble
1	Distilled Water	+	-	-
2	Methanol	+	-	-
3	Ethanol	+	-	-
4	Muriatic Acid (HCl)	-	-	+

The results of the solubility test were shown in Table 1. The results of the test presented that the sample was insoluble in water after 30 minutes of saturation making it more acceptable to be a material used in bioplastic based products. It is also insoluble in methanol (polar) and ethanol (non polar) and it is completely soluble in muriatic acid or HCl (strongly acidic). Solubility plays a major role in bioplastic synthesis as the material should have the capability of holding its structure after submerging it in different organic solvents.

3.1.2. What is the result of a swelling test in each solvent after 2 hours of saturation?

Figure 5. *Swelling Test of Synthesized Mung Bean based Bioplastic in Different Solvents*

Figure 6. *Residue of Bioplastic film after Swelling Test*

Table 2. *Swelling Test of Synthesized Mung Bean based Bioplastic in Different Solvents*

Solvent Number	Sample	Solvent Medium	Quantity (ml)	Initial Weight (g)	Final Weight (g)	Difference in Weight (g)
1	Synthesized Mung	Distilled Water	200	5.19	6.77	1.58
2	Beans Bioplastic	Ethyl Alcohol	200	5.54	4.06	-1.48
3	film	Methyl Alcohol	200	5.5	2.81	-2.69

The results of the swelling test were shown on Table 2. This showed that there is a slight negative change in the weight of the sample when it was soaked in ethanol and methanol, but slight increase in weight when soaked in distilled water with the same amount of solvent for 2 hours. The results from swelling tests show that there is a low amount of engorgement in water which is more ideal to be a bioplastic material.

3.1.3. In what depth is the Mung Bean based bioplastic the highest in terms of weight loss percentage after 7 days of soil burial process?

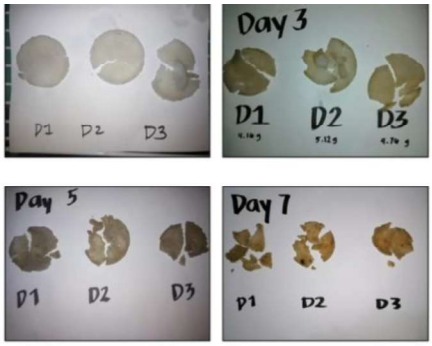

Figure 8. *Bioplastic Film on 1st, 3rd, 5th, and 7th Day of Soil Burial Period in Different Depths*

Table 3. *Biodegradability Test of Synthesized Mung Bean based Bioplastic in Different Depths*

Depth Number	Depth Used (cm)	Initial Weight (g)	Weight in Specific Number of Days				Difference in Weight (g)	Weight Loss Percentage
			Day 1	Day 3	Day 5	Day 7		
1	2	6.20	6.11	4.16	2.43	2.06	4.14	66.77%
2	3	6.50	7.33	5.12	2.59	2.18	4.32	66.46%
3	4	6.81	7.44	4.76	2.58	2.21	4.60	67.54%

The results of the biodegradability test were shown on Table 3. There is an evident change in the structure of the material before and after the test. A substantial variation in the texture was also shown by the bioplastic film. The table showed the biodegradability progression that occured, with the existence of flaws and loss of filmy nature. Therefore, from the soil burial method and weight loss percentage result, it could be concluded that the bioplastics synthesized having Mung bean starch as its main component are biodegradable. The environmental factors such as temperature, moisture, and biological activity would affect the rate of degradation.

Biodegradability of 66.54% was achieved in 7 days for the sample placed in the soil at a depth of 4 cm, 66.46% in 3 cm, and 66.77% in 2 cm.

Table 4. *Statistical Treatment of Biodegradability Test using One-way ANOVA*

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
D1	5	20.96	4.192	3.84047
D2	5	23.72	4.744	5.28153
D3	5	23.8	4.76	5.65995

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F cri*
Between Groups	1.045973	2	0.522987	0.10614	0.900133	3.885
Within Groups	59.1278	12	4.927317			
Total	60.17377	14				

D1 vs D2	D1 vs D3	D2 vs D3	Critical Value
0.872789	**0.898087**	0.025298	2.17881283

3.1.4. Is there a significant difference between the depth of soil burial and the weight loss percentage?

From the results of the experiment, it may be concluded that there is no significant difference between the burial depth and the weight loss percentage as the P-value shown in Table 4 is .900133 using alpha 0.05. However, there is a significant difference between D1 vs D2 and D1 vs D3 with the LSD test result of 0.87279 and 0.89809 respectively

4. CONCLUSIONS

The result of the solubility test revealed that the bioplastic material is soluble in the strongly acidic solvent and insoluble in the remaining solvents including distilled water after the soaking period. The swelling test revealed that there is a minimal difference in weight after the material was submerged in distilled water which makes it more preferable when it comes to manufacturing of bioplastic based commercial products. The biodegradability test revealed that there is a change in weight after the soil burial period. Therefore, we conclude that the Mung bean starch based bioplastic film can be an alternative to single-use and non-biodegradable plastics.

The results of the study showed the properties of the material that makes it an ideal alternative to be used in packaging and other activities and it can be a solution to the existing and rising environmental issues caused by the use of non-biodegradable materials in numerous fields. In order to study the properties of the material further, we recommend the utilization of other testing methods and manipulation of other factors such as pH level, humidity, soil moisture, solvent selection, and the likes. We also recommended the FTIR Analysis, Thermogravimetry Analysis, SEM examination, Tensile strength test, and other tests. We also recommend further study on the possible products that can be made using the material.

5. ACKNOWLEDGMENTS

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6. REFERENCES

Abdel-Rahman, E. S. A., El-Fishawy, F. A., El-Geddawy, M. A., Kurz, T., & El-Rify, M. N. (2008). Isolation and physico-chemical characterization of mung bean starches. International journal of food engineering, 4(1). https://doi.org/10.2202/1556-3758.1184

Davis, H. (2015). Life & death in the Anthropocene: A short history of plastic. Art in the anthropocene: Encounters among aesthetics, politics, environments and epistemologies, 347-358.

Gill, M. (2014). Bioplastic: a better alternative to plastics. Int. J. Res. Appl. Nat. Soc. Sci, 2, 115-120.

Jain, R.; Tiwari, A. Biosynthesis of planet friendly bioplastics using renewable carbon sources. J. Environ. Health Sci. Eng. 2015, 13, 11. https://doi.org/10.1186/s40201-015-0165-3

Kakoti, R. (2017). Uses of plastic bags and environmental hazard-A study in Guwahati city. Int. J. Appl. Res., 3(46), 1088-1094.

Koushal, V., Sharma, R., Sharma, M., Sharma, R., & Sharma, V. (2014). Plastics: issues, challenges, and remediation. International Journal of Waste Resources, 4(1), 2-6.

Marichelvam, M. K., Jawaid, M., & Asim, M. (2019). Corn and rice starch-based bioplastics as alternative packaging materials. Fibers, 7(4), 32. https://doi.org/10.3390/fib7040032

Pathak, S., Sneha, C. L. R., & Mathew, B. B. (2014). Bioplastics: its timeline based scenario & challenges. Journal of Polymer and Biopolymer Physics Chemistry, 2(4), 84-90.

Rizwana Beevi, K., Sameera Fathima, A. R., Thahira Fathima, A. I., Thameemunisa, N., Noorjahan, C. M., & Deepika, T. (2020). Bioplastic Synthesis Using Banana Peels And Potato Starch And Characterization. Int. J. Sci. Technol. Res, 9, 1809-1814.

Thakur, S., Chaudhary, J., Sharma, B., Verma, A., Tamulevicius, S., & Thakur, V. K. (2018). Sustainability of bioplastics: Opportunities and challenges. Current Opinion in Green and Sustainable Chemistry, 13, 68-75. https://doi.org/10.1016/j.cogsc.2018.04.013

A Prototype of D.I.Y. Landslide Alarm

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Abstract: Landslides can be described as a movement of soil, debris or rock down a slope caused by earthquake, rainfall or rapid snow melts. Many years back, it was considered as a potential hazard that can kill dozens of lives when not properly addressed. In the Philippines, many areas around certain regions are located in the possible hazardous places of a landslide. In order to address this problem, the researchers have created a device that can alert people regarding an upcoming landslide event. A wide array of literature has also created this kind of device and many of them are very successful. The researchers used different sensors like Acceleration and Gyroscope Sensor, Water Flow Sensor, and Soil Moisture Sensor to determine certain thresholds which can foretell an upcoming landslide. Each sensor has been tested in a variety of methods to establish the accuracy and functionality which is crucial for this kind of device. The researchers have found out the correct configuration of sensors so that they can be effective and useful. Just like any other mechanisms, a false alarm can always be expected. That is why the researchers are continuing to improve the prototype's functionality. The researchers recommend determining the quality of the sensors that are going to be used so that false alarms and other malfunctions can be prevented.

Key Words: low-cost; landslide alarm; do-it-yourself; sensors; modules; microcontroller

1. INTRODUCTION

Background of the Study

Landslides are one of the most dangerous geohazards world-wide and constitute a serious menace for public safety leading to human and economic losses (Park, 2011, cited by Formetta et al., 2016). Every year, thousands of lives are taken away by this unexpected slope failure while also destroying economical and infrastructural assets. It is impossible to stop a slope from failing but there are ways to mitigate or reduce the risk of slope failure (Akbar & Chen, 2017). The production and creation of different landslide alarms is evolving every day to perfectly suit the phenomenon itself (Ismail et al., 2017). In conceptualizing an early warning device, the possible threats like slope failure and heavy rainfall must be considered and taken into account. Possible ground movements require mechanisms that can detect slight changes in a slope's altitude and shall therefore be also present in the prototype's start up (Arbanas et al., 2011).

The phenomenon leads to the development of different types of early warning systems specifically designed to take the attention of the local community living in a landslide prone area. Early Warning Systems (EWSs) are defined as monitoring devices that can be applied to reduce the risk of natural hazards. They can warn a certain area for an incoming phenomenon that may otherwise be lethal if not acted upon immediately (Medina-Cetina & Nadim, 2008 cited by Intrieri et al., 2013).

Many scientific groups have already created certain landslide alarms that use different methods of gathering data. An example of this is the utilization of ALOS / PALSAR imagery based on geomorphological satellite data interpretation to monitor landslide events (Schlögel et al., 2015). Certain research used a Geocube system with GPS sensors that span at a distance of at least 5 km which is capable of observing and monitoring the behavior of avalanches (Benoit et al., 2015).

Central Problem

As the future progresses, the locals need a more precise and accurate way of predicting landslides. A landslide alarm system that is cost-effective and easily understood without that need of increasingly complex mechanisms too advanced for those who are living near a landslide prone area, will significantly affect their living. This study aims to explore the possibility of creating a practical and simple landslide alarm system that can warn locals regarding a possible landslide incident in their area.

Theories

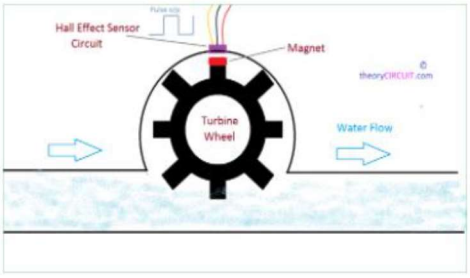

Figure 1. *Hall Effect Theory*

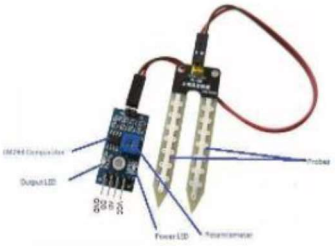

Figure 2. *Soil Moisture Sensor Mechanism*

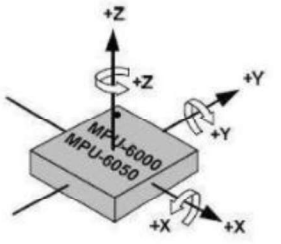

Figure 3. *MPU-6050 Sensitivity*

Theoretical Framework

As shown in the first theory, the Hall Effect is utilized by a sensor called, Water Flow Sensor. The Hall Effect is the production of a voltage difference across an electrical conductor, transverse to an electric current in the conductor and a magnetic field perpendicular to the current Hall Effect sensors are used for proximity switching, positioning, speed detection, and current sensing applications (Suresh et al., 2014). The sensor can measure the flow rate of the fluid within the range of 1-30 liters per minute and can withstand water pressure less than or equal to 2.0 MPa. This sensor can be used to determine the volume of water that has passed through it. Therefore, it can be applicable as a rain gauge that will measure the volume of the rain that has already penetrated it.

The second theory pertains to the mechanism of a sensor called Soil Moisture Sensor. The soil moisture sensor is provided as a pair of cylindrical rods each coated with a thin layer of dielectric material, which is buried in the soil or other medium and is connected to a conversion circuit in which the electrodes act as a variable capacitance (Gluck et al., 1994). The soil moisture content of land masses affects the capability of soil to be stable. The higher soil moisture content the soil has, the more possible a landslide incident will occur.

The third theory talks about the sensor called MPU 6050. The MPU-6500 sensor is a 3-axis accelerometer and 3-axis gyroscope that can detect changes in a system's movement. It has a power consumption of 3-5 volts and can detect even the slightest concussions. This kind of sensor is also used for fall detection for senior citizens (Jefiza et al., 2017). Landslide systems shall have this kind of sensor to monitor the movement of the soil. The sensor, integrated to the prototype, can increase the functionality of the system.

Research Questions

Below are the proposed research questions that will be discussed in this study:

Proposed research questions:

What is the functionality level of the sensors?

soil moisture sensor b. water flow sensor

What is the difference between the functionality levels of the Prototype in terms of types of soil?

Is there a significant difference between the functionality levels of the Prototype in terms of types of soil?

Ho: There is no significant difference between the functionality level of the Prototype in terms of types of soil.

2. METHODOLOGY

2.1 Product Design

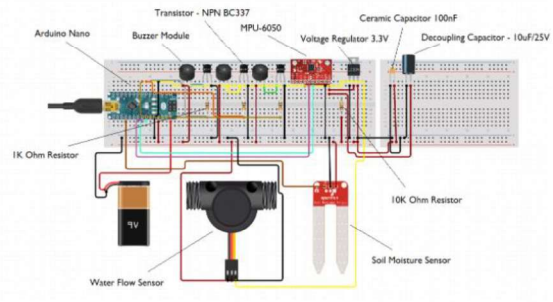

Figure 4. *Pictorial representation of the Prototype*

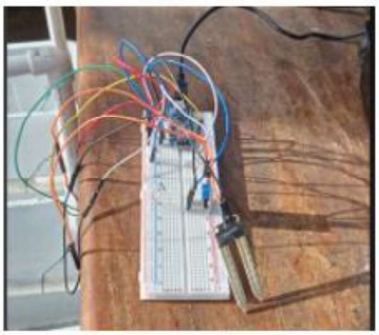

Figure 5. *Actual design of the Prototype*

2.2 Research Method

To ensure the functionality and efficacy of the prototype, the researchers have created several testing simulations for each of the sensors. The water flow sensor, soil moisture sensor, and the MPU-6050 were tested accordingly with different procedures to obtain necessary data that will then be used in further processing. The researchers were guided by a professional when the sensors were tested.

2.3 Data Collection Tool

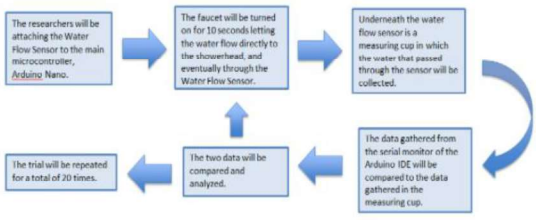

Figure 6. *Water Flow Sensor Trial*

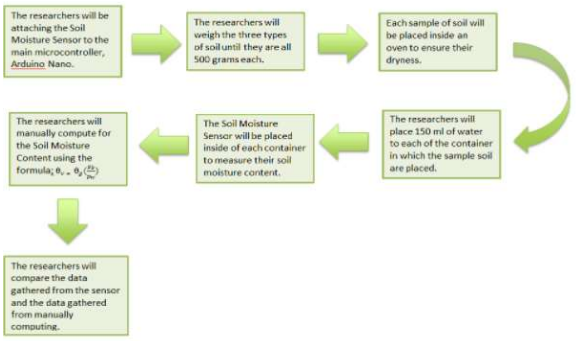

Figure 7. *Soil Moisture Sensor Trial*

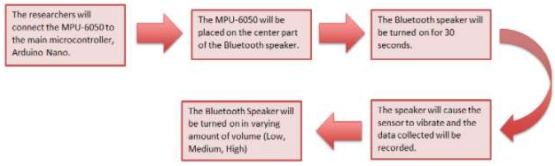

Figure 8. *MPU-6050 Sensor*

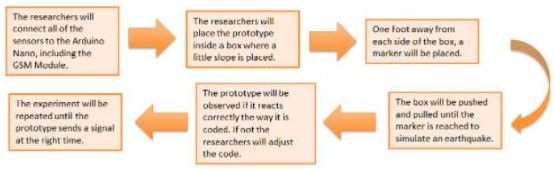

Figure 9. *Movement Trials*

2.4 Data Analysis

The statistical tool used by the researchers was One-way Analysis of Variance.This method is defined by the comparison of means from two or more samples. The statistical tool Percent Error was also used to determine the Accuracy and Reliability.

3. RESULTS AND DISCUSSION

Presentation of Data

The data gathered was based on the inquiry and presented by the research questions as follows:
What is the functionality level of the sensors? (Accuracy Rate)
Soil Moisture Sensor
Water Flow Sensor

Table 1. *Soil Moisture Sensor Trials*

	Wet Weight	Dry Weight	Soil Moisture Data (Experimental)	Computed Data (Expected)
Sand	655 g	500 g	42%	45.6%
Loam	694 g	500 g	55%	40%
Clay	641 g	500 g	42%	42%

Table 2. *Water Flow Sensor Trials*

Experimental (ml)	Expected (ml)
66	120
171	140
207	160
117	250
184	145
232	165
173	155
128	140
63	115
150	150
47	105
458	260
74	80
52	80
94	125
88	120
74	120
60	130
35	100
211	155
192	130
175	170

Based on the gathered data from the trials conducted, the percentage error of the soil moisture sensor on sand, loam, and clay is approximately equal to 37.5%, 7.9%, and 0% respectively. To calculate these values, the researchers have used the formula stated on the methodology that relates the bulk density of each type of the soil to the volumetric soil moisture content.

After the Volumetric Soil Moisture Content is calculated, the percentage error can now be computed using the Percentage Error formula. This gives rise to the percentage error presented above.

The computation for the Percentage Error of the Water Flow Sensor comes from the mean value of both the experimental value and the expected values, which are 152.55ml and 155.75 ml, respectively. The formula for the Percentage Error, that is used for both the Soil Moisture Sensor and the Water Flow Sensor, is as follows:

$$Percentage\ Error = \frac{experimental - expected}{expected} * 100 \qquad (1.1)$$

The water flow sensor gave off a percentage error of 2.07%, significantly lower, thus, can be concluded, more accurate. The researchers have conducted the same experiment 22 times to gather enough data for this value to be derived. This percentage error value can signal that the water flow sensor can be fully integrated to the prototype to increase its overall functionality.

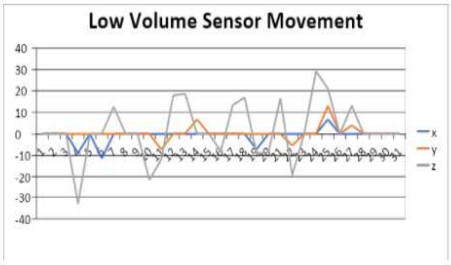

Figure 10. *Low Volume Gyroscope Trials*

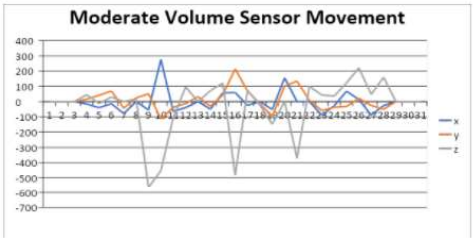

Figure 11. *Moderate Volume Gyroscope Trials*

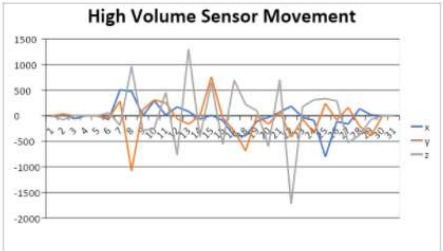

Figure 12. *High Volume Gyroscope Trials*

The MPU-6050 / Gyroscope's trials gave the result that the researchers expected. The ups and downs of the graph are proportional to the volume of the speaker which causes the vibration. The movements caused by this commotion reflect the expected outcome thus, proving its nonparametric functionality.

2. What is the difference between the functionality levels of the Prototype in terms of types of soil?

Table 3. *Prototype Trials*

Sand	Loam	Clay
5.23s	3.22s	4.46s
2.17s	4.26s	3.51s
4.5s	3.39s	4.07s

Note. The amount of time the prototype took to send an output signal (seconds)

The researchers have found out that the type of soil on which the soil moisture sensor is inserted affects the output data it can collect. As presented in Figure 15, the type of soil with the highest percentage error is loam. The researchers hypothesized that this phenomenon happens because of the impurities found in loam soil that affects the conductivity of the sensor itself. The variety of sawdust, rice straw and other organic materials are insulators that prevent the sensor from giving the right output, thus having a higher percentage error.

Trials conducted in sand gave off a significantly lower percentage error compared with loam. The fact that sand has more spaces in between each particle means that water can easily sink at the bottom of the container. This means that the data collected from the sensor can be off, the researchers hypothesized, for a certain margin because of this phenomenon.

The clay seems to be the best type of soil on which the sensor could work on. With a percentage error of 0%, the researchers believed that this is because of the fact that clay naturally sips water and distributes it equally in all parts. That is why the sensor readings are far more reliable since there are no impurities nor does water easily sink. This data however, is still inconclusive. Further trials must be conducted to truly identify the sensor's functionality.

3. Is there a significant difference between the functionality levels of the Prototype in terms of types of soil?

Table 4. *ANOVA: Single Factor for the three type types of Soil*

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.2721556	2	0.136078	0.131965	0.878847	5.143253
Within Groups	6.187	6	1.031167			
Total	6.4591556	8				

The researchers have also found out that the variety of soil did not affect the efficiency of the prototype's signal efficiency as shown in Figure 16. Also, in Figure it showed that the p-value is greater than the level of significance, hence, the null hypothesis is accepted.

Based on the works of Purnomo (2019), who had used a very similar methodology to this research, an instantaneous distance shift within the smallest scale of 0.4 mm can indicate a landslide event. They have created a system on which the significant data input came from the soil; whereas this research mostly relies on the data given by the atmosphere for it may also indicate a landslide event. The difference in this data structure can be varying at different times for there is a more suitable environment for the prototype to be tested.

4. CONCLUSIONS

The very purpose of this study is to create a landslide alarm system that could warn locals regarding a possible landslide incident in their area. The data gathered by the researchers using various trials have proven that the soil moisture sensor, water flow sensor, and the MPU-6050 are capable of such requirements. The soil moisture sensor was tested on different types of soil and based on the results, it can work best on clay soil. The water flow sensor has a percentage error of 2.07%. The MPU-6050, although no statistical treatments were applied, was observed to be functional.

As said above, the researchers have found out that the types of soil do not matter to the functionality of the prototype. The time it takes for the prototype to send an output signal (buzzer), is roughly the same whether the type of soil is changed. This means that the prototype can work with the same signal-sending efficiency even though the overall environment is changed. It can also be concluded that the prototype does not pick any particular soil on which it can work the best.

DISCUSSION AND RECOMMENDATION

The data gathered, together with the prototype created, has been found out to be effective and accurate on different aspects. After the trials, the researchers have realized several features that must

be done in order to improve the system. The prototype's functionality can definitely fulfill its goals if a little more time and effort is put into it. Even though some problems were experienced along the way, the researchers worked hard in order to put this product into its initial stages. The development will definitely be sure to follow because the researchers will work on it more after this study has been presented.

After the entire study is done, the researchers recommend to

Create a more stable enclosure for the sensors to sit in

Attach a solar panel module to increase the prototype's lifespan

Increase the prototype's functionality by adding another sensor called DHT22 (Temperature and Humidity Sensor)

Create a more rigid experimental design to test the functionality of the sensors.

Further, parametric statistical treatment is suggested to get the empirical data to determine the functionality of the MPU-6050.

5. ACKNOWLEDGMENTS

The researchers acknowledge all the authors who created the literature presented in this study. All of the data gathered are based on their hard work and commitment in the field of research and also for the sake of saving lives.

The researchers also acknowledge their research adviser for helping them create the entirety of the study. Without her intellect and passion, this study may have gone off the scratch since the beginning.

Also, the researchers would like to acknowledge themselves for the passion and determination they have given off. The hard work and effort will certainly pay off in the end.

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6. REFERENCES

Akbar, A. Q., & Chen, G. (2018). Comparison of major statistical methods and their combination using matrix validation for landslide susceptibility mapping. Lowland Technology International, 20(3, Dec), 401-412

Arbanas, Ž., Vivoda, M., Jagodnik, V., Dugonjić Jovančević, S., & Ljutić, K. (2011, December). Consideration of early warning system on the Grohovo Landslide. In Proceedings of the 2nd workshop of the project's risk identification and land-use planning for disaster mitigation of landslides and floods in Croatia', Rijeka (pp. 51-54)

Arduino and Soil Moisture Sensor -Interfacing Tutorial. (n.d.). CircuitsToday. https://www.circuitstoday.com/arduino-soil-moisture-sensor

Basics: Project 020a MPU 6050 GY 521 (GY-521) module 3 Axis Gyroscope and Accelerometer. (n.d.).Acoptex.https://acoptex.com/project/118/basics-project-020a-mpu-6050-gy-521-gy-521-module-3-axis-gyroscope-and-accelerometer-at-acoptexcom/

Beltran Jr, A., Dizon, K. J., Nones, K., Salanguit, R. L., Santos, J. B., & Santos, J. R. (2021). Arduino-based Disaster Management System. Journal of Robotics and Control (JRC), 2(1), 24-28.

Formetta, G., Capparelli, G., & Versace, P. (2016). Evaluating performance of simplified based models for shallow landslide susceptibility. Hydrology and Earth System Sciences, 20(11), 4585-4603.

Gluck, I., Friedman, A., & Feniger, N. (1995). U.S. Patent No. 5,424,649. Washington, DC: U.S. Patent and Trademark Office.

Intrieri, E., Gigli, G., Casagli, N., & Nadim, F. (2013). Brief communication" Landslide Early Warning System: toolbox and general concepts".

Ismail, E. S. B., Habaebi, M. H., Ibrahimy, M., & Islam, M. R. (2018). Low-Cost Vibration Chamber for Landslide Sensory and Alarm System. Indonesian Journal of Electrical Engineering and Computer Science, 10(1), 110-119.

Jefiza, A., Pramunanto, E., Boedinoegroho, H., & Purnomo, M. H. (2017, September). Fall detection based on accelerometer and gyroscope using back propagation. In 2017 4th International Conference on Electrical Engineering, Computer Science and Informatics (EECSI) (pp. 1-6). IEEE.

Nano, A. (2018). Arduino Nano.

Pecoraro, G., Calvello, M., & Piciullo, L. (2019). Monitoring strategies for local landslide early warning systems. Landslides, 16(2), 213-231.

Piciullo, L., Siano, I., & Calvello, M. (2016, June). Calibration of rainfall thresholds for landslide early warning purposes: applying the EDuMaP method to the system deployed in Campania region (Italy). In Proceedings of the International Symposium on Landslides (pp. 1621-1629).

Purnomo, F. A., Yoeseph, N. M., & Abisatya, G. W. (2019, February). Landslide early warning system based on arduino with soil movement and humidity sensors. In Journal of Physics: Conference Series (Vol. 1153, No. 1, p. 012034). IOP Publishing.

Schlögel, R., Doubre, C., Malet, J. P., & Masson, F. (2015). Landslide deformation monitoring with ALOS/PALSAR imagery: A D-InSAR geomorphological interpretation method. Geomorphology, 231, 314-330.

Srivastava, D., Kesarwani, A., & Dubey, S. (2018). Measurement of Temperature and Humidity by using Arduino Tool and DHT11. International Research Journal of Engineering and Technology (IRJET), 5(12), 876-878.

Suresh, N., Balaji, E., Anto, K. J., & Jenith, J. (2014). Raspberry PI based liquid flow monitoring and control. International Journal of Research in Engineering and Technology, 3(07), 122-125.

Water Flow Sensor YF-S201 Arduino Interface. (n.d.). TheoryCircuit. https://theorycircuit.com/water-flow-sensor-yf-s201-arduino-interface/

TERPENES PROPERTIES AS BIOPESTICIDES

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Abstract: Biopesticide consists of many different types like plants, fungi, bacteria, microalgae and nowadays it is not yet widely introduced and rarely available in the market; common available pesticides are chemical-based pesticides that harm not only the environment but also humans. Plant essential oils are created from different plant resources, most of them are members of the mint family (Lamiaceae) and a multiple combination of a class of terpenes that consist of two-isoprene units or called monoterpenes composed of oils. It linked an aromatic compound with a molecular formula of C6H5OH or called phenols and a sesquiterpenes. Further research is needed in the emerging or happening of organic pesticides with showing the possible control agents, formulation, delivery and commercialization. Since the availability of biopesticides are minimal, the researchers come up with the idea of synthesizing a prototype of biopesticides from lemon peel, neem leaves, cinnamon bark and garlic using steam distillation as a mode of extraction of the essential property which is terpenes that holds a promising role in killing pest particularly aphids. The findings of this study aim to test the efficacy of the prototype made by the researchers which is the biopesticides that has extracts from lemon peel, neem leaves, garlic and cinnamon bark. The researchers are recommending the application of the prototype to the other pests and insects in order to know the effectiveness of it besides aphids.

Key Words: control agent; terpenes; aphids; biopesticides; steam distillation

1. INTRODUCTION

1.1. Background of the Study

Throughout the world, pesticides are widely used to secure a variety of crops (Desai et. al., 2017). There is a harmful impact on using chemical pesticides and fertilizers that causes impotence of the soil, water hardness, genetic differentiation in plants, development of insect resistance, increase in toxic remains through food chain and animal feed that makes an escalation in health issues and many more (Srijita, 2015).

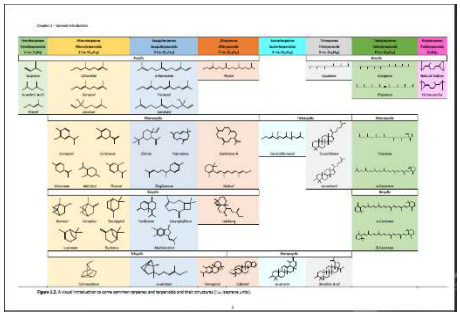
Due to the presence of pests that leads to damage of plant crops, the use of synthetic pesticides raises the call for secured foods as well as the ecological costs that it brings, which only shows the status of emerging studies in the field of biopesticides (Costa et al., 2019).

Residues that came from pesticide may cause a remarkable source of contamination of ecological factors such as air, soil, and water (Jayaraj et al., 2016). They have been reported to contaminate our environment as their residues accumulate in air, soil, water, animal tissue samples, and humans around the world (Desai et al., 2017). More usage by pesticides for the increased agricultural manufacture that brought to rise pollution of environmental sections (Jayaraj et al., 2016). Regardless of their repressive effects on pests hazardous to plants and animals, pesticides can also be dangerous to human health and contaminate the environment (Mostafalou & Abdollahi, 2017; Albuquerque et al., 2018; Gomiero, 2018 cited by Costa et al., 2019).

A key role acts during this contact is that the Plant Secondary Metabolites (PSM) that may also act as nurturing deterrents through controlling the food intake of herbivores (Dearing et al., 2005, cited by Costa et al., 2019), changing hunting actions (Roy & Bergeron, 1989, cited by Costa et al., 2019) or breeding (Tran & Hinds, 2012, cited by Costa et al., 2019). Essential oils are believed to be one in all the very pleasing botanical pesticides because they are nontoxic to mammals, similarly not harmless within the environment (Isman, 2000 cited by Costa et al., 2019).

In 1995, the study by Pimentel presented that just a small percentage (0.3%) of valuable pesticides were set to the target pest; however the 99.7% moved anywhere else in the environment (Jayaraj et al., 2016). According to Aneja et al. (2016), further research is needed in the emerging or happening of organic pesticides with showing the possible control agents, formulation, delivery and commercialization.

1.2. Central Problem



Due to pest infestation in crops and plants non-organic pesticides are invented and are widely used in the society and as an effect its residues leave traces in soils, air, and bodies of water that is adding to the pollution and more importantly causes harm to us.

On the other hand, plants are everywhere and most of all it has a lesser amount of danger to use. Based on the previous published researches terpenes properties are abundant in plants and have the possibility to be a component of biopesticide. In line with this, the researchers aim to synthesize a prototype of biopesticide with the property mentioned above which is terpenes.

1.3. Theoretical Framework

Multiple combination of a class of terpenes that consist of two isoprene units or called monoterpenes composing the oils. It linked an aromatic organic compound with a molecular formula of C6H5OH or called phenols and a sesquiterpenes (Nnamonu & Onekutu, 2015).

Essential oils (EO) biological activity and their components on pest insects comprise behavior and changes in feeding behavior, soap toxicity, and lethal toxicity via contact was reported by Castro et al. Their favorable mammalian toxicity and nonpersistance in the environment is the most attractive aspect of using Eos, that makes it exempted from registration in the United States of America (Vickers et al., 2009, cited by Boncan et al., 2020).

Volatile oils can be used for plants matrices using any kind of method categorized as conventional like using distillation with the use of water by heat as a way to bring out the total important material, and advanced which focus on the development in extraction competence by reducing extraction time, usage of energy, solvent, and CO2 emission (de Matos et al., 2019).

Modes of EO extraction are precise to their hydrophobic and volatile nature. Hydro distillation and steam distillation that is accommodated in usual ways are for the majority of herb parts, and cold expression for citrus rind (Pejin et al., 2011, cited by Maes et al., 2019).

Figure 2: Pesticidal Properties

Agriculture	
Pesticides	Pyrethrins, limonene
Plant protectors	Farnesene
Animal feed	Zeaxanthin
Phytohormones	Fusicoccanes, abscisic acid

1.4. Existing Model

Figure 1: A visual introduction to some common terpenes and terpenoid and their structures (i.e., isoprene units).

These theories are also applied in the study of terpenes properties as biopesticides as well as the possibility that is related to these theories.

Hence, this study proposes that these theories can be true to explore the said topic through experimentation, and development of a prototype that will lead to answer the following questions.

Figure 3: Raw materials with pesticidal properties

Brazil nut family (Lecythidaceae)	S-methylmethionine,	Wood-boring longicorn beetles (Cerambycidae)	deterrent to specialist beetle seeking oviposition sites	[81]
Lavender (*Lavandula angustifolia*)	β-trans-ocimene, (+)-R-limonene	Aphids	deterrent to pest	[82]
Cucumber (*Cucumis sativus*)	Tetracyclic terpenes: Cucurbitacins	Spider mite (*Tetranychus urticae*)	antibiotic effect on spider mites but attractive to the pest cucumber beetle	[83,84]
Cinnamon and clove	Eugenol, caryophyllene oxide, α-pinene, α-humulene and α-phellandrene	*Sitophilus granarius*	toxic and repellent effects to adult pest	[58]
Water primrose (*Ludwigia octovalvis*)	α-pinene, linalool oxide, geraniol, and phytol	Weber (*Altica cyanea*)	attractive to pest females	[85]
Rice (*Oryza sativa*).	(S)-linalool, 4,8-dimethyl-1,3,7-nonatriene, (E)-caryophyllene, and (R/S)-(E)-nerolidol	African rice gall midge (*Orseolia oryzivora*)	attractive to mated female pest in intact rice, but repellent with different concentrations of the same volatiles in infested plant	[60]
Eucalyptus grandis	α-pinene, γ-terpinene	*Leptocybe invasa*	potentially attractive to pest	[86]
Various plant species	Geraniol	*Bemisia tabaci*	encapsulated geraniol shows attraction to *B. tabaci*	[87]

1.5. Research Questions

1.5.1. What is the effect of terpenes on the plant's aphids after applying it for 7 days?

1.5.2. Is there a significant difference between the result of treated and untreated?

1.5.3. Is there a significant difference between the results in three cases (mild, moderate, and extreme)?

1.5.4. What is the effect of terpenes on the leaves?

1.6. Significance of the study

This study will help:

Farmers

- this study can help them in minimizing the population of the pest.

-give them knowledge about terpenes properties.

Businessman

-this will give them an opportunity to develop biopesticide and improve what's in the market.

Experts

-this will serve as a reference for them to innovate ideas and the possibility of terpenes as biopesticide.

Future Researchers

-will give them additional ideas about the topic of biopesticide as well as the terpenes properties.

1.7. Scope and Delimitation Scope

The study through meta-synthesis and meta-analysis wherein the researchers gathered review of related literatures and synthesizes it to explore their chosen topic which is terpenes properties as biopesticides and produce a prototype out of it focuses on raw materials, formulation and the properties of the developed biopesticides.

Delimitation

The study limits only on terpenes properties and the formulation of biopesticides which

means that the researchers will only collect information about raw materials connected to the

topic. It also limits on the mentioned focuses above.

2. METHODOLOGY

This study aims to test the efficacy of the prototype made by the researchers which is the biopesticide that has extracts from lemon peel, neem leaves, garlic and cinnamon bark in controlling tomato plant's aphids.

2.1. Prototype of Terpenes Properties as Biopesticide

Figure 4. Sample of the Prototype of Terpenes Properties as Biopesticide

2.2 Research Design

The researcher used posttest only control design wherein the treated tomato leaves will be observed as well as the untreated to have a comparison between the two data after experimentation.

2.3. Experimental Design

2.3.1. Sampling procedure for the selection

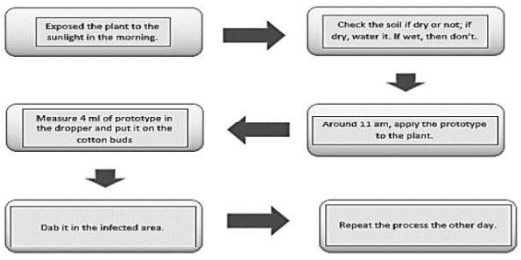
The cases are classified as mild, moderate, and extreme wherein specific measurements are assigned:

Fig. 5.1. Mild - (1-15 mm of aphids)

Fig. 5.2. Moderate - (16-30 mm of aphids)

Fig. 5.3. Extreme - (31-45 mm of aphids)

2.3.2 Application of Terpenes Properties as Biopesticides



A prototype of pesticide is being tested on the leaves of tomatoes. The control group of leaves to be treated will be classified as a) mild case, b) moderate case, c) extreme case.

2.3.3. Data Gathering Procedure

Using the validated observation sheets, the researchers proceeded to the experimentation, in a span of seven days the tomato leaves' color and aphids' infection were observed as well as the untreated with

continuous application of the prototype. After the data gathering, the collected data was analyzed through statistical tools.

Cases	Day of Application						
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
NT							
T							

Changes	Cases Day(s)						
	1	2	3	4	5	6	7
Green							
Light Green							
Yellow							
Brown							
Dried Up							

2.4. Data Analysis

The data gathered were tallied in a tabular form using Microsoft Excel and it is analyzed using non-parametric (frequency, percentage and mean) and parametric (two sample t-test and one-way analysis of variance) statistics.

2.4.1. Formula

2.4.1.1. Two-sample T-test

$$t = \frac{x_1 - x_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

2.4.1.2. One-way Analysis of Variance

$$SS_{total} = \sum_{j=1}^{p}\sum_{i=1}^{n_j}(x_{ij} - \overline{x})^2$$

$$SS_{between} = \sum_{j=1}^{p} n_j(\overline{x}_j - \overline{x})^2$$

$$SS_{within} = \sum_{j=1}^{p}\sum_{i=1}^{n_j}(x_{ij} - \overline{x}_j)^2$$

3. RESULTS AND DISCUSSION

Based on the research questions the following data are presented:

3.1. What is the effect of terpenes on the plant's aphids after applying it for 7 days?

3.2. Is there a significant difference between the result of treated and untreated?

Presentation of Data

Table 1. Observation Sheets (Aphid's Growth Infection – Mild Case)

Cases	Day of Application						
Mild	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
NT	14	20	35	51	56	71	100
T	14	7	5	2	0	0	0
Moderate	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
NT	28	38	48	62	100	100	100
T	25	11	8	5	5	0	0
Extreme	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
NT	38	38	47	55	66	100	100
T	35	24	14	9	3	1	0

T – Treated NT – Not Treated

Fig. 6.1. Graph that shows the growth of aphid's infection in mild case.

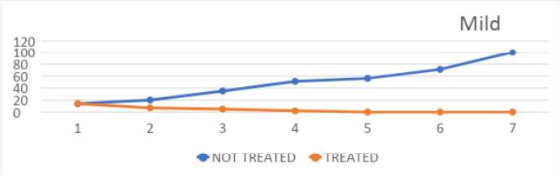


Fig. 6.2. Graph that shows the growth of aphid's infection in moderate case.

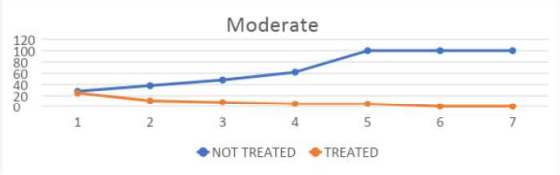


Fig. 6.3. Graph that shows the growth of aphid's infection in severe case.

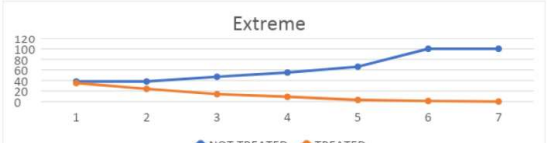


Table 2. Normal Distribution Data Table

	Mild					
	n	x̄	s	df	Computed T-value	Critical Value
NT	7	49.6	30.37			
T	7	4	5.19	6	3.92	1.94
	Moderate					
	n	x̄	s	df	Computed T-value	Critical Value
NT	7	1001.33	31.64			
T	7	73.9	8.60	6	4.87	1.94
	Extreme					
	n	x̄	s	df	Computed T-value	Critical Value
NT	7	459.3	21.43			
T	7	171.9	13.11	6	4.74	1.94

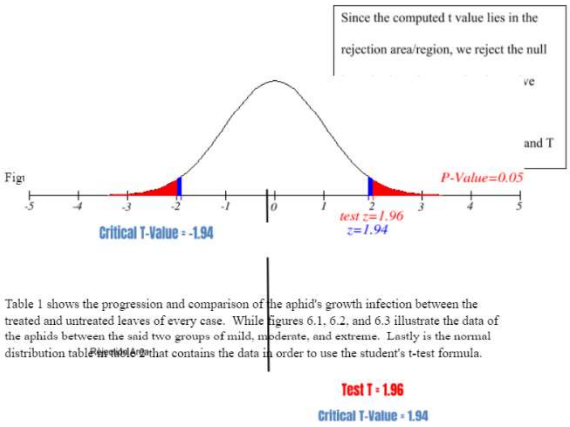


Table 1 shows the progression and comparison of the aphid's growth infection between the treated and untreated leaves of every case. While figures 6.1, 6.2, and 6.3 illustrate the data of the aphids between the said two groups of mild, moderate, and extreme. Lastly is the normal distribution table [illegible] that contains the data in order to use the student's t-test formula.

3.2. Is there a significant difference between the result in three cases (mild, moderate, and extreme)?

Table 3. Anova Single Factor Data Table

Anova Single Factor

Summary

Groups	Count	Sum	Average	Variance
T1	7	28	4	27
T2	7	54	7.714286	73.90476
T3	7	68	12.28571	171.9048

Anova

Source of Variation	SS	df	MS	F	P-Value	F-Crit
Between Groups	241.1429	2	120.5714	1.325886	0.290293	3.554557
Within Groups	1636.857	18	90.93651			
Total	1878	20				

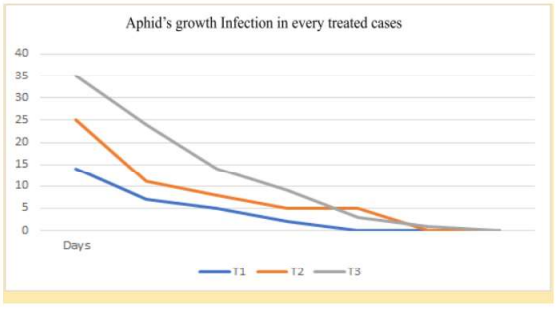


Fig. 7. Graph that shows the growth of aphid's infection in every treated case.

Table 3 shows the data computed using Microsoft Excel one way anova single factor and figure 7 shows the downfall of the growth of pest.

3.3 What is the effect of terpenes on the leaves?

Table 4.1. Effects of Terpenes on Leaves – Mild Case

Changes	Mild Day(s) 1	2	3	4	5	6	7
Green	+	+	+	+	+		
Light Green						+	+
Yellow							
Brown							
Dried Up							

Table 4.2. Effects of Terpenes on Leaves – Moderate Case

Changes	Moderate Day(s) 1	2	3	4	5	6	7
Green	+	+	+	+	+		
Light Green						+	+
Yellow							
Brown							
Dried Up							

Table 4.3. Effects of Terpenes on Leaves – Severe Case

Changes	Extreme Day(s) 1	2	3	4	5	6	7
Green							
Light Green	+						
Yellow		+	+	+	+	+	+
Brown							
Dried Up							

Tables 4.1, 4.2 and 4.3 indicate the changes on leaves using a heat map wherein color of leaves are being observed.

Observation Sheet (Aphid's Growth Infection)

The result of data shows that there is a significant difference between the treated and untreated cases which are mild, moderate and severe. As the experimentation goes by the aphid's growth infection in the treated cases are already gone while the untreated cases continue to increase the number of pests on its leaves.

Effects of Terpenes on leaves

The researchers observed discoloration on leaves as it lightens all throughout the experimentation process, factors such as the condition of plants, changes in temperature, breaking down of chlorophyll and such should be considered.

4. CONCLUSIONS

The study found out that the biopesticide prototype showed an enormous significant difference between the treated and untreated tomato leaves in every case. The outcome of the experiment revealed a huge decrease of the population of aphids as the day passed until it wiped out all the aphids in the treated leaves. In the same effect, data showed that between the three cases number of aphids it showed that there is no significant difference. This is only indicated that the biopesticide prototype is effective in whatever cases (mild, moderate, and extreme).

However, mild discoloration in leaves observed when the biopesticide prototype was applied. Out of all the results gathered the researchers concluded that the prototype terpenes properties as biopesticides has

potential to be a controlling agent for aphids in plants.

5. ACKNOWLEDGMENTS

The researchers recommend the following based on the result of the study:
A further research is needed wherein factors like aphid's growth infection, discoloration on leaves should be modified in order to increase the accuracy of the prototype. More efficient way of applying the prototype on the infected leaves by aphids.

The researchers would like to express their heartfelt thanks to the following people whose assistance, guidance and support contributed a lot in conducting and accomplishing this paper.

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6. REFERENCES

Aneja, K. R., S. A. Khan, and A. Aneja. "Biopesticides an eco-friendly pest management approach in agriculture: status and prospects." Kavaka 47 (2016): 145-154

Boncan, D. A. T., Tsang, S. S., Li, C., Lee, I. H., Lam, H. M., Chan, T. F., & Hui, J. H. (2020). Terpenes and Terpenoids in Plants: Interactions with Environment and Insects. International Journal of Molecular Sciences, 21(19), 7382.

Costa, Jorge Alberto Vieira, et al. "Potential of microalgae as biopesticides to contribute to sustainable agriculture and environmental development." Journal of Environmental Science and Health, Part B 54.5 (2019): 366-375.

de Matos, Sheila P., et al. "Essential oils and isolated terpenes in nanosystems designed for topical administration: A review." Biomolecules 9.4 (2019): 138.

Desai, Ketaki R., et al. "MITIGATION OF EARLY DELTAMETHRIN INDUCED HEPATOTOXICITY IN MALE MICE OF SWISS STRAIN BY ALLIUM SATIVUM." (2017).

Jayaraj, Ravindran, Pankajshan Megha, and Puthur Sreedev. "Organochlorine pesticides, their toxic effects on living organisms and their fate in the environment." Interdisciplinary toxicology 9.3-4 (2016): 90-100.

Maes, Chloë, Sandrine Bouquillon, and Marie-Laure Fauconnier. "Encapsulation of essential oils for the development of biosourced pesticides with controlled release: A review." Molecules 24.14 (2019): 2539.

Malini, Desak Made, M. Madihah, and Euis Julaeha. "Histological Structure of Mice (Mus Musculus L.) Liver after Administration of Ethanol Extract and Spinasterol from Senggugu (Clerodendron Serratum L) Leaves." (2015).

Martins, M. A. R. (2017). Studies for the development of new separation processes with terpenes and their environmental distribution (Doctoral dissertation, Universidade de Aveiro (Portugal).

Nnamonu, Lami A., and Amana Onekutu. "Green pesticides in Nigeria: an overview."Journal of Biology, Agriculture and healthcare 5.9 (2015): 48-62.

Srijita, Dutta. "Biopesticides: An ecofriendly approach for pest control." World Journal of Pharmacy and Pharmaceutical Sciences (WJPPS) 4.6 (2015): 250-265.

Agaricales Production: A Systematic Review on its Representative Species' Cultivation Process and Substrate Influence

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Abstract: Mushroom cultivation has long been of economic importance, specifically in Asian nations where most mushrooms are grown and sold. The globally popular Pleurotus ostreatus and a mushroom with similar composition profiles to it, Calocybe indica, are gaining recognition among farmers in urban areas due to their low-cost production and ability to grow on diversified substrates. Assessing the cultivation of both C. indica and P. ostreatus with selected substrates has been unexplored by researchers, most especially systematic reviews that focus on the cultivation of mushrooms in the Philippines. This paper sought to find the effectiveness of wheat straw, paddy straw, and sugarcane bagasse substrates in increasing specific growth parameters of C. indica and P. ostreatus. A systematic review with a narrative synthesis approach was performed to determine the effects of the chosen substrates on growth and yield parameters. The study utilized the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) as a basis for reporting the results and the Cochrane risk-of-bias tool to appraise the studies included in the review critically. Results show that wheat straw had increased the rate of spawn run and pinhead formation of both mushrooms, while paddy straw obtained high yield parameters. Though there was a lack of substantiation of a leading substrate among the three, paddy and wheat straw are substrates that might have the potential in increasing the mushroom's yield and quality in the Philippines.

Key Words: mushroom cultivation; Pleurotus ostreatus; Calocybe indica; lignocellulosic substrates; systematic review

1. INTRODUCTION

Mushrooms are a group of macro-fungi unable to perform the process of photosynthesis. Therefore, they feed on the nutrients of organic matter by releasing enzymes that decompose their organic material. These fruiting bodies belong to the kingdom Fungi under Phylum Basidiomycota and Ascomycota. However, most edible and commercially cultivated fungi belong to Basidiomycota under the order of Agaricales (Rahi & Malik, 2016). One species under Agaricales would be the Pleurotus ostreatus, otherwise known as Oyster mushrooms. They are low in maintenance, easy to cultivate, and can tolerate and thrive in a wide range of temperatures and climatic conditions (Sbhatu et al., 2019; Bellettini et al., 2019). According to the National Horticulture Board (n.d.), P. ostreatus thrives in an environment with a temperature of 20°C to 30°C and humidity of 55% to 70%. They productively grow on various lignocellulosic wastes, making them simple to produce. One mushroom that is also capable of thriving over a selection of lignocellulosic wastes is Calocybe indica. This fungus is cultivated in South India and other South Asian countries and is most suitable for tropical regions. This mushroom's cultivation is low-cost and can be grown throughout a year (Samonte, 2014). C. indica has a high fruit yield of 100% to 800% (Spowart, 2017) and is also less perishable than other fungi whose shelf life is only a week at room temperature. Though C. indica possesses properties similar to the P. ostreatus, no research that focused on assessing both C. indica and P. ostreatus with selected substrates as their focused subject was found.

Additionally, no systematic review focuses on the potent mushroom cultivation that concentrates on the Philippines. Thus, a systematic review is needed to analyze both mushrooms' substrate efficacy. This study aims to critically assess all relevant investigations related to Agaricales production in answering research questions that address the effectiveness of various lignocellulosic substrates in increasing specific growth and yield parameters of C. indica and P. ostreatus.

This review was confined to literature situated in Asia and had used wheat straw, paddy straw, and sugarcane bagasse as their substrates.

These agro-wastes are frequently used in a plethora of studies involving P. ostreatus and C. indica cultivation. While it was stated that this paper was limited to the three mentioned substrates, at least one of the three is required in a study due to the limited research conducted on the topic. Different growth and yield parameters were used to evaluate each substrate's influence, namely, spawn run, pinhead formation, total yield, and biological efficiency.

Spawn run and pinhead formation were the first two steps for mycelial growth that primarily focus on its substrate colonization duration. On the other hand, the total yield and biological efficiency exhibited the substrates' effect on the fruiting bodies' overall growth.

This study's findings will be beneficial to Filipino mushroom farmers, for a thorough analysis of the strategies and substrates in increasing mushroom production will be imparted to them. It offers an opportunity for milky mushrooms to be introduced to the Philippine mushroom industry. It also encourages rice and sugarcane farmers to invest in mushroom production since it is an environment-friendly alternative to managing their wastes. Additionally, future researchers may use these findings as evidence of the selected substrates' influence towards both mushrooms' growth parameters.

2. METHODOLOGY

2.1. Research Design

A systematic review was conducted to provide evidence of the substrate efficacy in the cultivation parameters of both C. indica and P. ostreatus. Studies were gathered and critically assessed in different criteria and biases to ensure the quality of the review's findings. A narrative synthesis, accompanied by graphical data presentations, was used in analyzing the results from the eligible literature.

2.2. Search Strategy

Due to physical limitations, purely electronic databases accessible through the University Library were used for gathering literature to review. These databases include the following: SciFinder, ScienceDirect, and AnimoSearch. Keywords were formed from the research questions combined with truncation symbols. Table 1 includes the keywords used with the respective database.

Table 1. *Electronic databases utilized in the systematic review*

Database	Search Strategy
SciFinder (15,367 results)	(Calocybe indica OR Pleurotus ostreatus) AND (~yield OR ~morphological properties OR ~Agronomic OR ~cultivation)OR(~paddy straw OR ~wheat straw OR~ sugarcane)OR (Lyophyllaceae OR Pleurotoceae)
ScienceDirect (35,387 results)	(Calocybe indica OR Pleurotus ostreatus) AND (yield OR morphological properties OR Agronomic OR cultivation)OR(paddy straw OR wheat straw OR sugarcane)OR (Lyophyllaceae OR Pleurotoceae) Year: 2013 to 2020
Animosearch (5,153 results)	(Calocybe indica OR Pleurotus ostreatus) AND (yield~ OR morphological* OR Agronomic~ OR cultivation*~)OR(paddy straw~ OR wheat straw~ OR sugarcane ~)OR (Lyophyllaceae* OR Pleurotoceae*)

2.3. Inclusion and Exclusion Criteria

To secure the eligible articles' quality, the researchers screened the studies through the inclusion and exclusion criteria. A study was included for the following reasons:

It included at least one of the three target substrates.
It investigated the substrates' effects using the following parameters: spawn run, pinhead formation, total yield, and biological efficiency.
It focused on the cultivation of the C. indica or P. ostreatus.
It has an experimental research design with at least two replications of the experiment.
Its methodology was conducted in vitro and within an Asian country.

On the other hand, a study was excluded for the following reasons:

It addressed another concept aside from cultivation.
Its full-text cannot be accessed due to premium publication restrictions.
It was written in a language aside from English.
Its publication date exceeded seven years from the present time.
It was not a peer-reviewed article.

2.4. Study Selection

Researchers followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Flowchart for eligible articles' screening process. Titles and abstracts were first screened concerning the topic. Afterward, the inclusion and exclusion criteria were applied to the screened articles with their full text, followed by the critical assessment review. The remaining articles were considered eligible studies for the review. Data were then extracted, including the study design and characteristics, the substrate used, and the outcome parameters.

2.5. Risk of Bias Assessment

Risk of bias assessment was conducted following the Cochrane risk of bias tool to ensure validity and objectivity from the eligible articles. The following criteria were used in the assessment: (1) performance bias, (2) detection bias, (3) attrition bias, and (4) reporting bias. Assessments were rated as uncertain, high, or low. Results were presented in a table showing the included study and the degree of bias present based on the researchers' individual and group assessments.

3. RESULTS AND DISCUSSION

3.1 Study Selection

This systematic review included ten studies. A flow chart of the identification and inclusion of studies is presented in Figure 1.

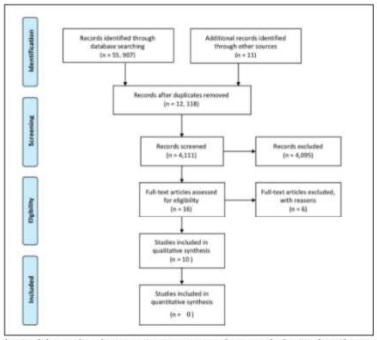

Figure 1. *Flow chart of the study selection process in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement*

3.2 Risk of Bias Assessment

The final ten journals chosen reached an overall judgment of Risk of Bias Assessment (RoB) of 75-100% of low risk and less than 25% rating of "some concerns," most information across the journals were sufficiently low-risk bias. Despite some incomplete information, it is unlikely that this would affect the synthesized results.

Figure 2. *Traffic Light plot and summary plot of the risk of bias assessment.*

3.3 Spawn Run

Subbiah and Balan (2015) states that C. indica's spawn run usually appears at 15 to 20 days while P. ostreatus' 2 to 3 weeks (Buah et al., 2010). In Table 2, it was observed that the reviewed journals followed these values with slightly larger ranges (C. indica - 15.00 to 23.20 days, P. ostreatus - 13.81 to 29 days).

Two substrates are tied as a preferred substrate for C. indica: paddy and wheat straw. Patel and Trivedi (2016) and Shrikhandia and Sumbali (2019) had paddy straw as their best substrate, while for Singh et al. (2019) and Vijaykumar et al. (2013), it was wheat straw. Similarly, wheat straw was also a suitable performing substrate for P. ostreatus, followed by sugarcane bagasse. Spawn run was significantly higher than other substrates in two studies (Abid et al., 2020; Yang et al., 2013).

Table 2. *Mean spawn run (days) of C. indica across different studies*

Substrate	Patel & Trivedi (2016)	Singh et al. (2019)	Vijaykumar et al. (2014)	Navathe et al. (2014)	Shrikhandia and Sumbali (2019)
Paddy straw	18.4	-	17.67	17	15.00
Wheat straw	20.2	18.44	15.67	-	15.93
Sugarcane bagasse	21.4	23.20	19.00	-	-

Table 3. *Mean spawn run (days) of P. ostreatus across different studies*

Substrate	Abid et al. (2020)	Zakil et al. (2020)	Zakil et al. (2019)	Sitaula et al. (2018)	Yang et al. (2013)
Paddy straw	25.83	-	-	18.25	-
Wheat straw	19.50	-	-	-	13.81
Sugarcane bagasse	-	29	26	20.00	-

3.4 Pinhead formation

The first growth milestone to a fruiting body, pinhead formation, signifies a mushroom's health (Ibrahim et al., 2017). For C. indica, it takes 10 to 28.67 days to form (Subbiah & Balan, 2015; Kumar et al., 2017). Similarly, P. ostreatus takes 16 to 27 days to develop pinheads (Buah et al., 2010).

Figure 3. *Spawn Run (a), Pinhead Formation (b), and Pinhead Formation to Maturation (c) of P. ostreatus from Tesfay et al. (2020)*

Figure 4. *Spawn Run (a), Pinhead Formation (b), and Cropping Stage (c) of P. ostreatus from Kora (2020)*

In Table 4, Shrikhandia and Sumbali (2019) and Navathe et al. (2014) had the paddy straw develop the fastest pinheads. Contrariwise, Singh et al. (2019) and Vijaykumar et al. (2014) had wheat straw as the best substrate. Note that in Singh et al. (2019), paddy straw was not able to cultivate mushrooms.

P. ostreatus' best substrate for pinhead formation was identical to its spawn run: wheat straw. Occurring in two literature works (Yang et al., 2013; Abid et al., 2020), it was the fastest pinhead formation across journals. Following these values was sugarcane bagasse for C. indica and paddy straw for P. ostreatus. It is evident among both mushrooms that wheat straw is the most efficient for pinhead formation.

Table 4
Pinhead formation(days) of C. indica across different studies

Substrate	Patel & Trivedi (2016)	Singh et al. (2019)	Vijaykumar et al. (2014)	Navathe et al. (2014)	Shrikhandia and Sumbali (2019)
Paddy straw	18.66	-	-	21.75	-
Wheat straw	16.50	-	-	-	6.00
Sugarcane bagasse	-	30	28	23.25	-

Table 5. *Pinhead formation(days) of P. ostreatus across different studies*

Substrate	Abid et al. (2020)	Zakil et al. (2020)	Zakil et al. (2019)	Sitaula et al. (2018)	Yang et al. (2013)
Paddy straw	145.33	-	-	528.45	287.2
Wheat straw	160.5	-	-	-	287.43
Sugarcane bagasse	-	41.35	273.3	527.8	-

3.5 *Total yield*

Despite the incomplete information, paddy straw was revealed to be a dominant substrate in terms of the average yield in the C. indica. Three out of five studies concluded this with wheat straw as the second-best substrate. Consequently, Vijaykumar et al. (2014) and Singh et al. (2019) had wheat as their preferred substrate with paddy straw following these values.

Studies on P. ostreatus show that wheat straw has a more significant influence than paddy straw in the mushroom's growth. This was supported by Abid et al. (2019) and Yang et al. (2013), with their total yield was highest on paddy straw. This was closely followed by paddy straw. Although sugarcane bagasse had a significantly high value in Sitaula et al.'s (2018) work, overall, it still had relatively lower values.

Table 6. *Total yield (grams) of C. indica across different studies*

Substrate	Patel & Trivedi (2016)	Singh et al. (2019)	Vijaykumar et al. (2014)	Navathe et al. (2014)	Shrikhandia and Sumbali (2019)
Paddy straw	405	-	1324	810.5	399.03
Wheat straw	298	320.04	1463	-	388.61
Sugarcane bagasse	255	221.8	515.7	-	-

Table 7. *Total yield (grams) of P. ostreatus across different studies*

Substrate	Abid et al. (2020)	Zakil et al. (2020)	Zakil et al. (2019)	Sitaula et al. (2018)	Yang et al. (2013)
Paddy straw	145.33	-	-	528.45	287.2
Wheat straw	160.5	-	-	-	287.43
Sugarcane bagasse	-	41.35	273.3	527.8	-

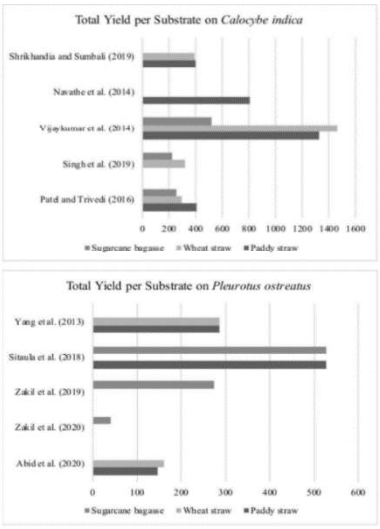

Figure 5. *Total yield (grams) of C. indica (top) and P. ostreatus (bottom) across various studies*

3.6 *Biological Efficiency*

Biological efficiency is the amount of yield per kilogram of substrate. Similar to the yield, paddy straw outperforms other substrates on the biological efficiency of C. indica. With a range of 77.6% to 134.86%, paddy straw is the best substrate in three out of four journals, excluding the studies that did not assess it. Having more divided views, among P. ostreatus studies, paddy has the overall highest biological efficiency in Sitaula et al. (2018) and Yang et al. (2013). In contrast, wheat straw was favored in Singh et al. (2019), followed by paddy straw. It can be said that paddy and wheat straw have a slightly similar performance.

Table 8. *Biological Efficiency (Percentage) of C. indica across different studies*

Substrate	Abid et al. (2020)	Zakil et al. (2020)	Zakil et al. (2019)	Sitaula et al. (2018)	Yang et al. (2013)
Paddy straw	24.38	-	-	78.33	78.73
Wheat straw	22.6	-	-	-	78.35
Sugarcane bagasse	-	44.95	68.33	71.91	-

Table 9. *Biological Efficiency (Percentage) of P. ostreatus across different studies*

Substrate	Patel & Trivedi (2016)	Singh et al. (2019)	Vijaykumar et al. (2014)	Navathe et al. (2014)	Shrikhandia and Sumbali (2019)
Paddy straw	134.86	-	132.4	81.05	79.8
Wheat straw	85.07	64	146.3	-	77.6
Sugarcane bagasse	85.02	44.36	51.57	-	-

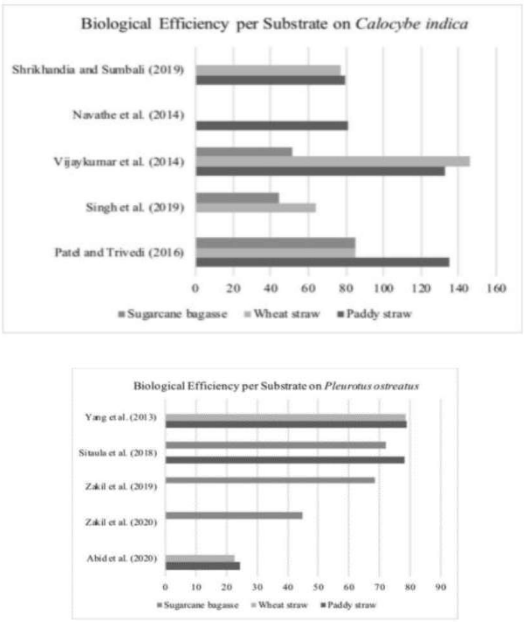

Figure 6. *Biological Efficiency (Percentage) of C. indica (top) and P. ostreatus (bottom) across different studies*

3.7 Effect of the composition of substrates

It is speculated that the composition of the substrates affected the growth and yield of the mushroom. Ahmed et al. (2009) and Elahe et al. (2016) reported that the right amount of hemicellulose, cellulose, lignin, and the carbon-nitrogen (C/N) ratio is accountable for quick spawn run. Hoa et al. (2015) also stated that an adequate amount of C/N ratio is desired for mycelium growth. However, a lower ratio is better for the creation of primordia that develop into fruiting bodies. Wheat straw has the lowest C/N ratio out of all the chosen substrates as seen in Table 10. Hence, the contents of wheat straw fulfill the nutritional demand of both mushrooms, which results in early primordial formation.

Additionally, Amin et al. (2010) expressed that cellulose-rich substrates are also responsible for higher yield. With a relatively higher cellulose content than sugarcane bagasse, wheat and paddy straw initiated high yield performance in P. ostreatus and C. indica. Lastly, paddy straw has the second-highest C/N ratio and highest cellulose content. It outperformed the other two substrates in yield parameters but had equal performance in growth parameters to wheat straw. This could be due to the abundance of both the C/N ratio and cellulose content.

Table 10. *Composition of substrates (Ahmed et al., 2011; Bakker et al. 2013; Ferreira et al., 2016; Lindsley et al., 2017; Sakdaronnarong et al., 2012; Sharma et al., 2014)*

Substrate	C/N ratio	Cellulose (%)	Hemicellulose
Paddy straw	90:1	37.5	30
Wheat straw	80:1	33.5	25
Sugarcane bagasse	100:1	33	24

4. CONCLUSIONS

The studies reviewed sufficiently provided detailed information that indicated wheat straw seemed to outdo the other substrates on spawn run and pinhead formation for both C. indica and P. ostreatus. Simultaneously, paddy straw excelled on total yield and biological efficiency for both mushrooms. To some extent, this suggests that both wheat straw and paddy straw as substrates may be acceptable for use in specific parameters by farmers and producers, depending on the targeted parameter that needs concentration. No evidence supported which substrate outdid all other substrates alone, considering both parameters and mushrooms. Instead, the results from studies situated in Asian countries similar to the Philippines' climate suggested that the application of wheat straw and paddy straw substrates is worth investing in to attain more efficient production. Results provided limited coverage of the influences the substrates have from various set-ups and environmental effects. This emitted implications on the validity of mushroom cultivation evaluations.

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6. REFERENCES

Abid, A., Hamid, A., Naz, R., Shah, S., Anjum, S., Khan, M., & Ilyas, M. (2020). Impact of different lignocellulose substrates on growth and yield of oyster mushroom (Pleurotus ostreatus). Pure and Applied Biology. 9(1). 768-775. https://doi.org/19045/bspab.2020.90083

Ahmed, I., Zia, M. A., Iftikhar, T., & Iqbal, H. M. (2011). Characterization and detergent compatibility of purified protease produced from Aspergillus niger by utilizing agro wastes. BioResources, 6(4), 4505-4522.

Ahmed S.A., Kadam, J.A., Mane, V.P., & Baig M.M. (2009). Biological efficiency and Nutritional contents of Pleurotus florida cultivated in different agro Wastes. Nat. Sci, 7(1), 45-48.

Amin, R., Khair, A., Alam, N., & Lee, T. S. (2010). Effect of Different Substrates and Casing Materials on the Growth and Yield of Calocybe indica. Mycobiology, 38(2), 97–101. https://doi.org/10.4489/MYCO.2010.38.2.097

Bakker, R. R. C., Elbersen, H. W., Poppens, R. P., & Lesschen, J. P. (2013). Rice straw and wheat straw-potential feedstocks for the biobased economy. NL Agency.https://english.rvo.nl/sites/default/files/2013/12/Straw%20report%20AgNL%20June%202013.pdf

Bellettini, M., Fiorda, F., Maieves, H.,Teixeira, G., Ávila, S., Hornung, P., Júnior, A., & Ribani, R. (2019). Factors affecting mushroom Pleurotus spp. Saudi Journal of Biological Sciences, 26(4), 633-646. https://doi.org/10.1016/j.sjbs.2016.12.005

Buah, J. N., Van der Puije, G. C., Bediako, E. A., Abole, E. A., & Showemimo, F. (2010). The growth and yield performance of oyster mushroom (Pleurotus ostreatus) on different substrates. Biotechnology, 9(3), 338-342. https://doi.org/10.3923/biotech.2010.338.342

Elahe K.J., Mehrdad, J., & Shahin, E. (2016). King oyster mushroom production using various sources of agricultural wastes in Iran. International J Rec Org Waste Agr, 5, 17-24. https://doi.org/ 10.1007/s40093-015-0113-3

Ferreira, D. A., Franco, H. C., Otto, R., Vitti, A. C., Fortes, C., Faroni, C. E., ... & Trivelin, P. C. (2016). Contribution of N from green harvest residues for sugarcane nutrition in Brazil. Gcb Bioenergy, 8(5), 859-866. https://doi.org/10.1111/gcbb.12292

Hoa, H. T., Wang, C. L., & Wang, C. H. (2015). The Effects of Different Substrates on the Growth, Yield, and Nutritional Composition of Two Oyster Mushrooms (Pleurotus ostreatus and Pleurotus cystidiosus). Mycobiology, 43(4), 423–434. https://doi.org/10.5941/MYCO.2015.43.4.423

Ibrahim, R., Jamil, A. A. I. M., Hasan, S. M. Z., Arshad, A. M., & Zakaria, Z. (2017). Enhancing Growth and Yield of Grey Oyster Mushroom (Plearotussajorcaju) Using Different Acoustic Sound Treatments. MATEC Web of Conferences, 97, 1054. https://doi.org/10.1051/matecconf/20179701054

Kora, A. J. (2020). Nutritional and antioxidant significance of selenium-enriched mushrooms. Bulletin of the National Research Centre, 44(1), 1-9. https://doi.org/10.1186/s42269-020-00289-w

Kumar, R., Singh, G. , Mishra, P. , & Singh, R. (2012). Effect of different organic supplements and casing mixtures on yield of two strains of milky mushroom (Calocybe indica). Indian Phytopathol, 65, 399-403.

Lindsley, L., & Lentz, E. (2017). Nutrient value of wheat straw. Ohio State University Extension. https://agcrops.osu.edu/newsletter/corn-newsletter/nutrient-value-wheat-straw#:~:text=The%20USDA%20reports%20a%20C,mineralization%20will%20be%20much%20slower

National Horticulture Board. (n.d.). OYSTER MUSHROOM http://nhb.gov.in/report_files/oyster_mushroom/oyster%20mushroom.htm.

Navathe, S., Borkar, P., & Kadam, J.J. (2014). Cultivation of Calocybe indica (P & C) in Konkan Region of Maharashtra, India. World Journal of Agricultural Research, 2, 187-191.

Rahi, D., & Malik, D. (2016). Diversity of Mushrooms and Their Metabolites of Nutraceutical and Therapeutic Significance. Journal of Mycology, 2016. https://doi.org/10.1155/2016/7654123

Sakdaronnarong, C., & Jonglertjunya, W. (2012). Rice straw and sugarcane bagasse degradation mimicking lignocellulose decay in nature: An alternative approach to biorefinery. ScienceAsia, 38(4), 364-372. https://doi.org/10.2306/scienceasia1513-1874.2012.38.364

Samonte, P. (2014). Milky mushroom now produced commercially. Monthly Agriculture. https://www.agriculture.com.ph/2018/03/22/milky-mushroom-now-produced-commercially/

Sbhatu, D., Abraha, H., & Fisseha, H. (2019). Grey Oyster Mushroom Biofarm for Small-Scale Entrepreneurship. Advances in Agriculture, 2019. https://doi.org/10.1155/2019/6853627

Sharma, A., Sharma, R., Arora, A., Shah, R., Singh, A., Pranaw, K., & Nain, L. (2014). Insights into rapid composting of paddy straw augmented with efficient microorganism consortium. International Journal of Recycling of Organic Waste in Agriculture, 3(2), 54.

Singh, V., Baghel, D., Shukla, C.S., and Singh, H.K. (2019). Role of Different Substrates and Organic Supplements on Growth and Yield of Different Strains of Calocybe indica. International Journal of Current Microbiology and Applied Sciences, 8(11), 2263-2269. https://doi.org/10.20546/ijcmas.2019.811.263

Sitaula, H. P., Dhakal, R., Geetesh, D., & Kalauni, D. (2018). Effect of Various Substrates on Growth and Yield Performance of Oyster Mushroom (Pleurotus ostreatus) in Chitwan, Nepal. International Journal of Applied Sciences and Biotechnology, 6, 215. https://doi.org/10.3126/ijasbt.v6i3.20859

Spowart, R. (2017). The story of milky mushroom. Monthly Agriculture. https://www.agriculture.com.ph/2017/10/09/the-story-of-milky-mushroom/

Subbaiah, K., & Balan, V. (2015). A Comprehensive Review of Tropical Milky White Mushroom (Calocybe indica P & C). Mycobiology, 43(3), 184-194. https://doi.org/10.5941/MYCO.2015.43.3.184

Sumbali, G., & Shrikhandia, P. (2019). Studies on the evaluation of some strains of Calocybe indica P&C for cultivation in Jammu. International Journal of Research in Pharmaceutical Sciences, 10(3), 2457-2465. https://doi.org/10.26452/ijrps.v10i3.1494

Tesfay, T., Godifey, T., Mesfin, R., & Kalayu, G. (2020). Evaluation of waste paper for cultivation of oyster mushroom (Pleurotus ostreatus) with some added supplementary materials. AMB Express, 10(1), 1-8. https://doi.org/10.1186/s13568-020-0945-8

Trivedi, R., & Patel, P. (2016). Yield Performance of Calocybe indica on Different Agricultural Subatrate. International Research Journal of Engineering, IT and Scientific Research, 2, 105-111.

Vijaykumar, G., John, P., & Ganesh, K. (2014). Selection of different substrates for the cultivation of milky mushroom (Calocybe indica P & C). Indian Journal of Traditional Knowledge, 13, 434-436.

Yang, W., Guo, F., & Wan, Z. (2013). Yield and size of oyster mushroom grown on rice/wheat straw basal substrate supplemented with cotton seed hull. Saudi journal of biological sciences, 204, 333-338. https://doi.org/10.1016/j.sjbs.2013.02.006

Zakil, F., Hassan, K., Mohd, S., Mohd, S., & Isha, R. (2020). Growth and yield of Pleurotus ostreatus using sugarcane bagasse as an alternative substrate in Malaysia. IOP Conference Series: Materials Science and Engineering. 736. 022021. https://doi.org/10.1088/1757-899X/736/2/022021

Zakil, F.A., Sueb, M.S., & Isha, R. (2019). Growth and yield performance of Pleurotus ostreatus on various agro-industrial wastes in Malaysia. AIP Conference Proceedings, 2155(1). https://doi.org/10.1063/1.5125559