Development of Biodegradable Facial Masks Using Banana Pseudo-Stem Fiber Filters: Assessing Its Air Permeability, Water Absorbency and Water Repellency

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Abstract: The efficiency of facial masks is crucial in crises that can cause damage to the health of individuals who have no method to resolve such issues through healthcare. This paper explores the traits necessary for a facial mask to be efficient at preventing transmission through the airborne and droplet vectors and explores how using different, unconventional materials in the construction of said facial masks affects that efficiency. This study focused on determining whether facial masks are made using materials, such as banana pseudo-stem fiber, polypropylene, thread and elastic, are feasible for use and biodegradable by extracting fibers from banana plant pseudo-stems and using these fibers to form sheets of fabric to be used in constructing two distinct sets of facial masks with different amounts of filter layers. Air permeability tests were conducted to determine the rate of particle penetration through the airborne vector, and water repellency and absorbency tests were used to determine the rate of particle penetration through the droplet vector. Results show that using banana fiber layers as filters demonstrated a low rate of particle penetration in the water repellency but a high rate in water absorbency; in terms of breathability, air permeability showed higher compared to the baseline, making it efficient.

Key Words: facial mask; banana fiber; air permeability; water repellency; water absorbency

1. INTRODUCTION

The risk of airborne ash, air pollution and airborne and droplet-based diseases are among the plethora of hazards that severely increase due to generally poor housing conditions available to those in extreme poverty. Given the socioeconomic ability of these people, the preferred solution would be to prevent rather than incur the need for expensive and inaccessible medical care. Facial masks are used for protection against various bacteria and viruses. Facial masks are made with normally 3 layers, an inner and outer barrier layer which uses polypropylene and a filter layer. These are tested through pressure differential tests, breaking force strength and more. The study focuses on air permeability, water absorbency and water repellency since these focus on bacterial penetration and breathability. There are different ways to make a facial mask, it could be made in a factory or handmade, most facial masks are sewn together (Davies et al. 2013).

Amongst the large pool of related literature, studies were incomplete in that none could determine the quantitative efficacy of facial masks as protection (Cummings et al. 2016), none examined the possibility of facial masks composed of unconventional materials (Davies et al. 2013), and the setup of certain experiments were flawed for a lack of control variables that ensured less of the experiment would be affected beyond the tested variables (MacIntyre et al. 2015). Therefore, the purpose of the study is to develop facial masks constructed out of alternative, readily available, and cost-effective materials that are on-par, if not better, at filtering particle penetration on the airborne and droplet vectors, making them effective as a form of protection against respiratory illnesses.

Manufacturing Biodegradable Materials

Different studies have manufactured biodegradable materials to benefit their research. In a study of Chia-Yuan et al. (2016), electrospinning was utilized to make fibrous material out of lignin solution, similar to using naturally occurring fibers in plants for weaving. Findings have shown that the filtration efficiency tests conducted revealed the material was inadequate, and that the consistency factor suggested that due to high penetration values, the filters would not meet the requisite quality requirements. The procedures of these related methods on facial mask creation was incorporated into the methodology for the banana fiber facial mask. A study by Chowdhury et al. (2020), made filters that use *Glycyrrhiza glabra.* It was made a solution to undergo electrospinning. It was found that the electrospinning process was shown to enhance the fabric's breathability, indicated by high air permeability. These will be utilized in the study by applying the same tests that their samples went through. The procedures that will be applicable to the creation of the banana fiber facial mask would be following the general guidelines of a facial mask, 3-layer structure which is aligned with the surgical mask structure.

Effects of material composition to biodegradable materials

The material composition of a product is defined as the quantity of a material used in the production of one unit of a product during a year (Roberts, 2002). In a recent study (Heaven, 2018), they measured the effectiveness of facial masks when in a polluted area. They also tested each facial mask by having three different dummies with three different rates of air intake and measuring the amount of penetrations per facial mask. Other studies dealt with bacterial penetration through the droplet vector by demonstrating superior clinical efficacy of the continuous use of N95 respirator (also known as "airborne precautions") against infections presumed to be spread by the droplet mode, including influenza (MacIntyre et al. 2017). Observing material composition is a practice done in other studies, such as when a study (Chia-Yuan et al. 2016) examined how banana fiber is used to form as a filter for the facial mask due to the characteristics of lignin-based nanoscale fibers that improved the filtration efficiency of facial masks by substantially decreasing the pressure drop inside the filters. In the conducted by (Sen et al. 2020), banana stem fiber was extracted from banana peel and was utilized for the development of a newly researched facial masks. It was concluded that the bio facial mask would be competitive in the market and can benefit frontliners and civilians from the transmission of the virus.

Conceptual Framework

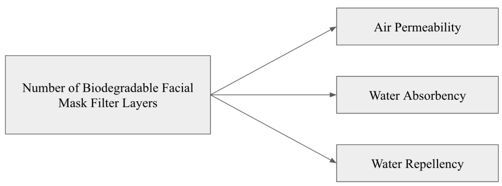

Figure 1. Conceptual Framework

Research Questions

1. What is the air permeability, water repellency, and water absorbency of the biodegradable facial masks using three and four filter layers of banana fiber filters?
2. Is there a significant difference in the air permeability, water repellency, and water absorbency of three-layer and four-layer facial masks?

2. METHODOLOGY

2.1 Research Design

This study utilized experimental research design where the experimental setup was divided into two. Each setup consisted of facial masks that differed in the amount of the banana fiber layers (3 layers and 4 layers) present between the internal and external layers of nonwoven polypropylene. Each setup had 10 facial masks and it was reused for each test; the control was the standard given by the Department of Health. Each setup was tested through the Philippine Textile Research Institute tests. Particle penetration was tested through the air permeability and water repellency through the water absorbency tests. After which, the results were analyzed using Mann-Whitney U test with the aid of IBM SPSS Version 24 software.

2.2 Data Gathering Procedures

The necessary materials, banana pseudostems and polypropylene, was gathered by the target community based on its general environment having an abundance of banana trees. However, polypropylene fabrics were purchased, rather than gathered, due to its inexpensive nature. Through the use of the hand-stripping method, the fibers of the banana plant can be extracted from its pseudostems. After the materials have been collected, the polypropylene and banana fibers were woven together into one fabric with a different number of banana fabric layers between the inner and outer polypropylene. After the sample facial masks have been prepared, each setup was tested for bacterial penetration and the data was compiled.

3. RESULTS AND DISCUSSION

3.1. Mann-Whitney U Test for Air Permeability, Water Repellency, and Water Absorbency

Table 1. Descriptive

Dependent Variable	Group	N	Mean	Std. Error	Mask Shape	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Air Permeability cm^3/s/cm^2	3-Layer BFM	10	44.90	1.137	Flat	42.511	47.289
	4-Layer BFM	10	37.07	1.137	Flat	34.681	39.459
Water Repellency rate	3-Layer BFM	10	95.00	.000	Flat	95.000	95.000
	4-Layer BFM	10	95.00	.000	Flat	95.000	95.000
Water Absorbency seconds	3-Layer BFM	10	60+ s	.000	Flat	60.000	60.000
	4-Layer BFM	10	60+ s	.000	Flat	60.000	60.000

Baseline: Air Permeability (0.5614 cm^3/s/cm^2); Water repellency (70 rate); Water Absorbency (seconds), Mark Shape (Flat/Curved/Folded)

Table 1 shows that the air permeability of the three-layer biodegradable facial mask (BFM) is higher (M = 44.90, SD = 1.137) compared to the baseline for air permeability which is 0.5614 $cm^3/s/cm^2$. The four-layer biodegradable face mask is also higher (M = 37.07, SD = 1.137) than the baseline for air permeability. Since the layers are higher than the baseline for air permeability, then using the banana fiber filters with three and four layers will be able to provide comfort in terms of the breathability.

For the water repellency, both the three-layer biodegradable facial mask (BFM) and four-layer biodegradable mask (BFM) are alike to each other (M = 95.00; SD = .00). Comparing it to the baseline which has a rating of 70, both the three-layer and the four-layer biodegradable facial mask (BFM) are repellent to water droplets. Similarly, for the water absorbency, the three-layer and the four-layer biodegradable facial mask (BFM) are also alike to each other (M = 60s; SD = .00). Comparing it to the baseline for the water absorbency which is ≤ 5 seconds, then both groups take up to 60s before absorbing water fluids. The tested biodegradable facial mask contains a flat shape which are included in the facial masks shape requirements of the laboratory (Flat/Curved/Folded).

3.2. Mean difference in water repellency and water absorbency

Since the standard error of the collected data for water repellency and water absorbency are both zero (0.00), this means that all the collected data for these variables are equal. Thus, there is no need to perform statistical tests to determine if there is a mean difference in the water repellency and water absorbency between the two groups.

As demonstrated in Table 1, the mean for both the three-layer and four-layer of the biodegradable facial mask (BFM) are the same for water repellency (95.00 rate for both filter layers) and water absorbency (60+ seconds for both filter layers). From the same reference, there is no significant difference in the water repellency and water absorbency between the biodegradable facial masks (BFM) with three-layers and four-layers of banana fibers.

The effectiveness of using a three-layers or four-layer can be determined by the water repellency and water absorbency tests. In terms of water repellency, the biodegradable facial mask has a rate of 95 out of 100, while the baseline has a rate of 70 out of 100. With regard to water absorbency, the biodegradable facial mask (BFM) resulted with 60 seconds whereas the baseline was less than 5 seconds. Due to this, we can observe that the biodegradable facial mask (BFM) has exceeded the baseline in both water absorbency and water repellency.

3.3. Normality Test for Air Permeability

Table 2. Shapiro-Wilk Test

	Statistic	df	Sig.
Air Permeability	.865	20	.009

The Shapiro-Wilk test result in Table 2 showed that data for air permeability obtained from the two groups do not follow a normal distribution, $p < 0.05$, which means that the data is not distributed normally. Thus, Independent Samples Mann-Whitney U Test will be used to determine the mean difference of air permeability between the three (3) and four (4) filter layers of the biodegradable facial mask.

3.4. Mean difference between the air permeability

Table 3. Hypothesis Test Summary

Null Hypothesis	Test	Sig.	Decision
The distribution of Air Permeability is the same across categories of groups.	Independent Samples Mann-Whitney U Test	.001[1]	Reject the null hypothesis

Asymptotic significance is displayed. The significance level is .05.
Exact significance is displayed for this test.

As shown in Table 3, the p-value of the air permeability test for both the three-filter layer and four-filter layer of the biodegradable facial mask, is significant at 0.001. Thus, since it is smaller than the significance level, which is 0.05, there is a significant difference between the air permeability in the 3 and 4 layers of the biodegradable filter mask.

To determine if facial masks constructed using banana fibers as material for the filter layers functioned on-par with baseline standards for facial masks, it was necessary to compare the masks in terms of air permeability, water repellency, and water absorbency which are the tests given by PTRI. Air permeability is crucial for facial masks, given that if air cannot permeate through the masks, the wearer may find it difficult or be entirely unable to breath. The study found that air permeability in both the three-layer and four-layer setups were significantly higher than the baseline standard, indicating that in terms of breathability the material encountered little to no issues functioning. Another key factor for facial mask efficacy is water repellency (Davies et al. 2013), a measure used to decide how effective a mask is at guarding against droplet-based transmission vectors, which are common in most respiratory illnesses such as COVID-19. Water repellency is important in testing a facial mask because it is used to determine if the facial mask is capable in preventing the spread of the disease through droplet-based transmission (Davies et al. 2013). The study found, however, that both the three-layer and four-layer setups had the same rating of water repellency, which was significantly higher than the baseline standard for this variable. In this it can conclude that the banana fiber facial masks are better than standard facial masks at repelling these particle penetrations from the droplet vector. In relation to the findings the study had regarding air permeability, this set of results speaks to the efficacy of the material selected, large enough to allow ease of use but capable of repelling aspects of droplet-based transmission vectors that indicate this facial mask is efficient at reducing potential transmissions. Finally, the study found that both the three-layer and four-layer setups' water absorbency, measured in wetting time in seconds, was significantly longer than the baseline standard of five seconds. This study concludes that the filter layers themselves are less effective than the standard mask at filtration, which is the mask's second line of defense. In this instance it can be said that while the biodegradable facial masks are usable, they are failed by their lack of efficacy in terms of absorbency. The biodegradable facial masks that have a lack of efficacy in terms of absorbency would mean that the breath and the water droplets that are made by the wearer would be trapped in the mask for a long time due to the data showing that the water is being absorbed for sixty (60)+ seconds, this results to the wearer feeling uncomfortable (Sato et al. 2019).

More than just the material composition, the number of filter layers present was also expected to affect the air permeability, water repellency, and water absorbency of the biodegradable facial masks, with one aim of the study being to determine which amount of filter layers resulted in the best possible mask for use. Adding a layer essentially increases the density of the woven fabric, and this increase in density should result in a decrease in air permeability, and therefore, water permeability as well (Ogulata, 2006). Due to the nature of the findings, it cannot make a meaningful comparison in terms of both water repellency and water absorbency between these two groups because they share similar data sets. Therefore, the only remaining criteria is air permeability. In terms of that variable, the expected result did occur, wherein the three-layer setup measured higher than the four-layer setup. It can be seen that the only significant difference between the setups is that the three-layer facial masks are more easily used due to their higher air permeability and may be the better option because of that higher air permeability, its similar abilities with regards to water repellency and absorbency, and that the construction of a three-layer mask will be less resource-intensive than the alternative. The reason why a three-layer facial mask is better is because the average standard of a facial mask is that it typically has three (3) layers, a barrier layer which repels droplets from entering the mask, a filter layer which prevents large particles to enter the mask and an inner layer which is absorbent of the water droplets that come from the wearer's mouth (Chua, et al. 2020).

4. CONCLUSIONS

The study was able to identify a biodegradable alternative with which to construct facial masks. This material, banana fiber sheets, was found to have high air permeability and water repellency, key aspects of mask efficacy, but as a material suffered in that it was unable to have short water absorbency times, reducing its efficacy as a filter material. Given that the findings with regards to water repellency is most likely a result of the barrier layers being constructed out of nonwoven polypropylene, at this time no firm conclusion can be reached on the efficacy of these biodegradable facial masks compared to standard facial masks, other than that they are useable and easily constructed. It is, however, possible to conclude that of the two distinct setups, those masks with three filter layers rated higher in air permeability and are therefore better for use than four-layer masks. In the future, it would be recommended for studies to focus on airborne particle penetration testing, in addition to the droplet vector, to test mask efficiency against aerosols. Moreover, this study was conducted with a relatively small sample size and was done using only one alternative material. It is recommended, if possible, that future inquiries compare other local, biodegradable materials, to these banana fiber sheets, and that these studies utilize a larger sample size. Finally, due to time constraints, the banana fiber sheets here were pre- constructed rather than extracted from pseudo-stems, and the study was thus unable to control for the efficacy of masks as constructed by a community rather than by professionals. To model results in the situation this study addresses, on the local community level that has little access to healthcare, these considerations must be taken to ensure the accuracy of the data. This study found that for these communities, while a trade-off between accessibility and better water absorbency could occur, biodegradable facial masks are a safe and acceptable alternative for community healthcare.

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