

COMPARISON OF DEGRADATION OF BIODEGRADABLE PLASTIC AND LDPE BAGS

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Abstract: The increasing awareness of environmental problems has resulted in many private and government initiatives that allow greater public participation. One of these is the shift in usage from plastic packaging materials to biodegradable forms. Many of the larger retail establishments prominently label their plastic bags as being biodegradable or oxobiodegradable. In this study we compared the mass losses, attenuated total reflectance infrared spectra, and thermomechanical properties of store-labeled biodegradable plastic shopping bags with ordinary low density polyethylene plastic bags under different conditions from 30 to 100 days to ascertain the claims on these biodegradable plastics.

Key Words: biodegradable plastics; thermomechanical analyzer

1. INTRODUCTION

Recent experiences with weather disturbances in the Manila area underscore the importance of an effective system of solid waste management in the country. The dumping of enough garbage to fill 30 dump trucks on the stretch of Roxas Boulevard from monsoon surge in the wake of typhoon Saola (Gener) in August of 2012 serves as further proof that frequent flooding in the metropolitan areas are in part due to the futility of government efforts to implement RA 9003 or the Ecological Solid Waste Management Act. Metro Manila produces some 8,400 tons of garbage daily, and as seen at Roxas Boulevard, the most visible of these are plastics in one form or another. Local governments have reacted to the extreme by passing measures banning the use of plastic bags. Included among these are Quezon City, Pasay City, Muntinlupa, Pasig, Marikina, Las Piñas and Manila.

Local establishments have also responded by turning to biodegradable or oxo-biodegradable plastics to help alleviate the problem. These are prominently labeled in shopping bags from department stores, bookstores, drugstores, fast food outlets and convenience stores. The term "oxo-biodegradable" is an appealing marketing term which however is very misleading because it cannot be verified due to the absence of a standard specification. In the U.S. the Federal Trade Commission has advised companies "that unqualified biodegradable claims are acceptable only if they have scientific evidence that their product will completely decompose within a reasonably short period of time under customary methods of disposal." Accordingly, the National Advertising Division in the USA recommends that advertisers discontinue claims such as "100% oxo-biodegradable" because such statements incorrectly suggest that a plastic will quickly or completely biodegrade.

In this paper we report preliminary findings on the comparison of mass loss, attenuated total reflectance and breakage temperature under constant load between "biodegradable/oxo-biodegradable" labeled plastic bags and ordinary low density polyethylene in the form of the market *sando* bag.

2. METHODOLOGY

Samples

The plastic samples (blue bags from a department store, red bags from a bookstore) were obtained as packaging from products bought from the respective stores around March of 2012. The non-biodegradable plastic (green, RJ brand) was bought as is in a pack. The samples were cut into 10×2 cm pieces and labeled according to the following test conditions: humid (H) and dry (D). These were further diversified into ambient room light and temperature, LRT; uv exposure for 1 hour or 4 hours, UV1 and UV2 respectively; dark, D; and elevated temperature (40 °C), ET. Thus a total of 10 conditions were observed.

Mass Losses

Three samples from each sample condition were weighed periodically up to 100 days. Due to the non-uniformity of samples, changes in masses are expressed as either percentage mass gain or mass loss.

FT-IR- spectroscopy

The samples were measured using a Nicolet 6700 FT-IR Spectrometer using Smart Multi-Bounce HATR made of ZnSe crystal. The infrared beam was at an angle of 45° relative to the crystal allowing it to be reflected 10 times between the crystal and the film resulting in a longer path length of about 10 μm.

Thermal Expansion

A Shimadzu thermomechanical analyzer (TMA-60) was used to analyze the mechanical properties of the plastic samples, most especially its elongation values when compared to an increase in temperature. The sample was placed between chucks at each vertical end and subject to a constant load of 5g while the temperature was increased gradually from room temperature to a final temperature 120 °C. Before each test, N₂ gas was pumped into the furnace to shield potentially reactive materials from contact with oxygen.

3. RESULTS AND DISCUSSION

Gross examination of the plastic bag samples over time under the different experimental conditions generally show higher loss of flexibility/elasticity for the biodegradable types than LDPE. The store films were perceived to be coarser and more brittle than the *sando* bag samples.

Mass Losses

Changes in masses are taken to indicate reactions occurring on the plastics. Generally, both positive and negative changes in masses were observed with larger changes usually observed within the first 50 days before changes decreased to minimal and masses essentially remained constant towards the end of the observation period for some samples. However some trends were observed across the samples. The first is that humid conditions, whether at room temperature or elevated, dark or in ambient light or exposed to uv radiation, resulted in greater percentage changes compared with dry conditions. Moisture contact with polymers can lead to a number of effects such as dimensional changes, reduction in the glass transition

temperature of the resin and degradation in mechanical and physical properties like stiffness hardness and strength. In contrast, the chosen room temperature and 40 °C conditions do not affect the changes observed. All samples showed very similar patterns of changes at both temperatures. Thermal degradation is similar to photodegradation and also involves initiation, propagation and termination. Increasing temperatures can hasten the degradation process of polymers such as oxidation and mechanical creep. However, the 40 °C temperature may not have been high enough for the effect to be observed.

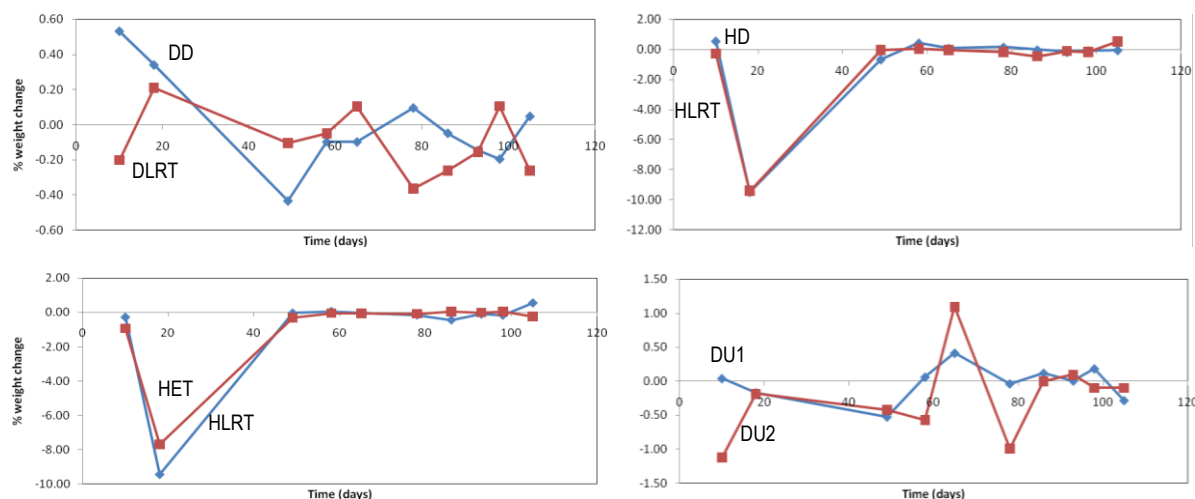


Figure 1. Percentage mass changes with time for department store sample. DD – dry dark, DLRT – dry ambient light room temperature, HD humid dark, HLRT humid ambient room light and temperature, HET humid elevated room temperature, DU1 – dry 1-hour uv, DU2 – dry 4-hour uv .

Interestingly uv exposure seems to have affected the plastics more inconsistently under dry conditions than humid. Photodegradation is an auto-oxidation process that proceeds via free radical chain reaction. Exposure to UV initiates this by breaking the chemical bonds in the main polymer chain. The relative changes in masses were generally larger at 4 hours than 1. The changes under humid conditions were more parallel for both 1 and 4 hours as contrasted with dry conditions, which showed more fluctuations. This could be due to UV producing a variety of free radicals from water that can maintain the degradation process consistently. The role of uv light is also suggested by the similarities of the changes in the samples whether in the dark or ambient room light. As to the difference between “biodegradable” and LDPE, the ordinary plastic bags gave more variable changes in mass. Under dry and room conditions, the department store and bookstore bags almost maintained constant weights. Results do not necessarily show more reactions on the biodegradable bags, on the contrary bigger changes though inconsistent were sometimes observed on the LDPE. The film thickness might also be a factor, as consistency was displayed more by the department store samples. This was generallyly noted to be thicker and more uniform than the bookstore or *sando* bags. However, the positive effects of both humidity and uv were observed for the biodegradable bags.

Biodegradable plastics are not an altogether different type of polymer. They are still composed of the same polymers but with and oxo-biodegradable additive mixed with it. The additives serve as catalysts that cause fragmentation first, and then degradation after.

Transition metals such as manganese, iron, and cobalt are responsible for the fragmentation process. Research studies have concluded that polyethylene films with oxo-biodegradable additives lose its mechanical properties eventually after a certain time period. The loss can be catalyzed by exposure to sunlight.

FT-IR- spectroscopy

IR spectroscopy did not reveal much difference between the biodegradable samples and the LDPE. This suggests that the materials are basically polyethylene. Additives however do not show on the spectra suggesting non-bonded incorporation in the polymer. During the later weeks of the analysis, OH peaks were detected in the samples kept in humid conditions. The largest -OH peak was detected on the elevated temperature department store sample. This could indicate that this particular biodegradable film is absorbent to moisture which is a positive factor for its degradability.

Thermal Expansion

Due to instrument breakdown and time limitations, only the ambient room temperature, elevated temperature and 4-hour uv exposure samples at humid conditions were subjected to TMA analysis. Measurements were spread across a 31-day period. Samples expanded to ~20% with no remarkable difference among conditions nor observable trends over time. With the exception of the first measurement at day 3 for the LDPE at ambient room conditions, all other samples started to elongate from 110.72° to 117.59°C which are above the 110°C melt transition, T_m of LDPE. This is reasonable as the melt transition is the temperature at which the polymer loses its crystalline structure and starts melting. As the polymer therefore starts to melt, the constant load pulling on it begins to stretch the polymer. The department store sample is notable in showing higher initial temperatures for both the uv-exposed (117°) and elevated temperature (118°) films than the room temperature sample (114.8). This was not observed for either the LDPE or the bookstore bags. Ordinary LDPE showed almost no variation, while the bookstore difference with uv exposure or elevated temperatures from room conditions was unclear. Direct comparisons across the three samples are not completely reliable due to differences in film thicknesses, but the increase in melt transition for the department store samples imply higher sensitivity to uv radiation and higher temperatures as compared with the other two. This is complemented by the differences in the breaking temperatures. Once more the department store films exposed to uv or elevated temperatures broke at temperatures 3-9°C higher than room condition samples while the bookstore samples clustered within a 2°C temperature range (122-124°C).

4. CONCLUSIONS

Mass losses, IR spectra, and thermomechanical comparison of two store-labeled oxo/biodegradable plastic bags with LDPE indicate inconsistent behavior expected from biodegradable polymers. The department store samples seem to be more sensitive to uv and higher temperatures, and by extrapolation, may break down faster when exposed to the elements as waste material. The book store samples seem to be only very slightly different from ordinary LDPE. We are continuing our investigations into oxobiodegradability claims by examining results of expected disposal methods. In the mean time it may be necessary to institute regulations on biodegradability claims if not call on the retail industry to present scientific evidence for their claims to avoid the risk of being labeled as environmental bandwagoners as a marketing ploy.

5. REFERENCES

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