Correlation between degradability of plastics and its tensile strength

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ABSTRACT

The use of plastics is ubiquitous in our current day and age for many different uses despite its well-known harmful effects, such as the consumption of microplastics in humans leading to a myriad of health issues. In this study, the correlation between degradability of plastics and its tensile strength is experimented by finding the maximum weight at which the respective plastic breaks: High-Density Polyethylene (HDPE), Polylactic Acid (PLA), Oxo-biodegradable and a plastic alternative, Telobag. Herein, it was found that there is an overall decrease in tensile strength of the plastics with an increase in degradability of plastics, while there is an outlier – Telobag – that can withstand more weight than oxo-biodegradable bag, that is less degradable than it.

INTRODUCTION

The use of plastic is highly prevalent in our modern society, such as being used for shopping, retailing, and parcelling because of its durability and low cost of fewer than 0.25 cents per piece. Plastic bags are less vulnerable to tearing and can protect its contents from rain or water more than paper or cloth bags [1]. Unsurprisingly, the world produces 381 million tonnes of plastic waste yearly, which is set to be doubled by 2034. Furthermore, a whopping 500 billion plastic bags are used annually, translating to 150 for each person on Earth [2]. Despite several collective efforts to reduce plastic bag usage and strive toward a zero-waste nation, such as implementing charges for plastic bag usage in countless supermarkets, raising awareness through campaigns and initiatives and introducing policies to reduce plastic consumption [3], its efforts still fall short. An excessive amount of plastic is used and wasted every single day.

While plastic can benefit us, there are harmful trade-offs to wildlife and human health. For instance, the entanglement of 334 species of marine turtles, seals, whales, seabirds, and other marine creatures has been reported and the ingestion of plastic in 233 marine species [4]. Additionally, we humans ingest microplastics through water, consumption of aquatic products which contain microplastics or inhale particles in the air. In fact, a study by the University of Newcastle reported that, on average, people could be ingesting approximately 5 grams of plastic every week, which is the equivalent weight of a credit card [5]. This could lead to a myriad of health consequences, including inflammation, genotoxicity, oxidative stress and more, which are linked to cancer, cardiovascular diseases, and more negative health outcomes [6]. Despite these harmful effects, the prevalence of plastic usage in society is still superfluous. These all beg the question, “How can we reduce plastic consumption in our society without changing the behaviour of our users?”

One solution to this issue of plastic pollution is to use biodegradable plastics. In general, biodegradable plastics are seen to have many benefits, such as reducing carbon emissions and consuming less energy as compared to non-biodegradable ones [7]. Additionally, a study by São Paulo state university (UNESP) found that a type of biodegradable plastic that is Gelatin based, has a higher tensile strength than petroleum-based plastic [8], making it an eco-friendly solution to plastic waste. However, a United Nations Environment Programme (UNEP) report finds that complete biodegradation of plastics occurs in conditions that are rarely met, with some polymers requiring industrial composters and prolonged temperatures above 50°C to disintegrate [9].

There are several main groups of biodegradable plastics, namely bio-based bioplastics, bioplastics-synthetic polymers, oxo-degradable plastics, photo-biodegradable plastics, hydro-biodegradable plastics, and compostable plastics [10]. Non-biodegradable plastics would then include polyethylene, polypropylene, polystyrene, poly (vinyl chloride) and poly (ethylene terephthalate) [11]. Lastly, a plant-based plastic alternative has wholly revolutionised the use of plastics by many companies. Telobag, made of cassava starch, is not only biodegradable but also leaves no residue of plastic [12]. How long do these plastics and plastic alternatives take to degrade then? High-Density Polyethylene (HDPE) plastic bags generally take just under 100 years to degrade in landfills fully [13], oxo-biodegradable bags take 2 years to fully degrade [14], Telobag takes only 180 days to biodegrade [12], and Polylactic acid (PLA) bags take about 80 years to degrade in natural conditions [15]. However, it is essential to note that these data were retrieved from different sources and were tested for their degradability in different conditions. However, all these data are in the conditions closest to natural conditions.

It is hypothesised that the degradability of plastic affects its strength; the more degradable the plastic, the less strong it is as the more degradable a plastic is, the more susceptible to decomposition and breaking down it is. This project aims to report the tensile strength of four types of plastics: non-biodegradable plastic, the HDPE bag, biodegradable plastics, oxo-biodegradable bags, PLA bags and a plastic alternative, Telobag, hence evaluating if the hypothesis is proven and subsequently weighing if a change in the type of plastic used in our everyday life should be changed.

MATERIALS AND METHODS

Figure 1: Example of testing sample and setup of a piece of a plastic bag clamped on a retort stand with weights hung on it to derive the tensile strength of the plastic bag

Each piece of plastic bag sample (manually cut by a paper cutter) is 15 cm in length, and 1 cm in width, and folded into half, with reference to <Force Measurement IMADA> [16]. Before testing the sample, measure the thickness of the folded plastic using a micrometre. Thereafter, the thickness of each plastic is obtained by dividing the thickness of the folded plastic by two. Repeat the measurement of the thickness of the plastic testing sample of each type of plastic bag thrice and obtain the average of the three readings.

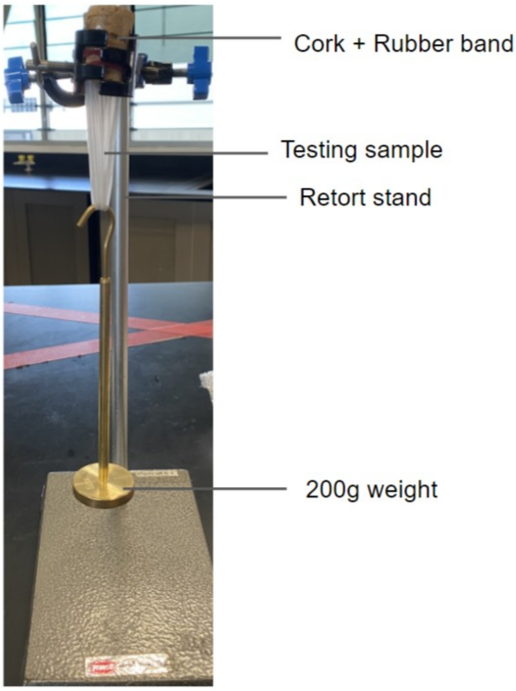

Figure 2: Setup of a piece of plastic bag clamped on a retort stand with weights hung on it to derive the tensile strength of the plastic bag

As shown in Figure 2, the plastic bag is placed between two-half pieces of cork and secured tightly with a rubber band before being clamped on a retort stand. The two-half pieces of cork, with the plastic bag must be tightly secured with a rubber band to increase the friction, holding the testing sample in place, preventing the testing sample from slipping out from the cork when weights are loaded onto them.

Then, start the experiment to test the tensile strength of the plastic bag testing sample. Hang a 200g weight on the plastic bag and continue to add weights in increments until the testing sample breaks. Record the weight at which the plastic bag breaks, repeating the experiment thrice and obtain the average of the three results.

RESULTS

Type of material	Made of	Average thickness of bag / mm
Telobag	Cassava starch	0.04
Oxo-biodegradable	Petroleum	0.01
PLA	Corn starch	0.03
HDPE	Polyethylene	0.02

Table 1: The thickness of the different bags tested and its main constituent ([11], [16]-[18] respectively)

As seen in Table 1, the average thickness of the different types of plastic bags are inconsistent. Hence, for the results to allow fair comparison, the results of the maximum weight of each type of plastic bag are measured per 0.01mm. The main component of each plastic bags was found from several other research papers [11], [16]-[18] for consideration.

	Degradability / year	**Experiment 1**	**Experiment 2**	**Experiment 3**	**Average**
Type of material		**Maximum weight it can withstand per 0.01mm / g**			
Telobag	0.5	436.6	411.6	386.7	411.6
Oxo-biodegradable	2	249.2	249.2	299.2	265.9
PLA	80	449.6	516.3	499.6	488.5
HDPE	100	548.9	498.9	548.9	532.2

Table 2: Results of the maximum weight each type of plastic bag can withstand per 0.01mm with comparison to its degradability in terms of years

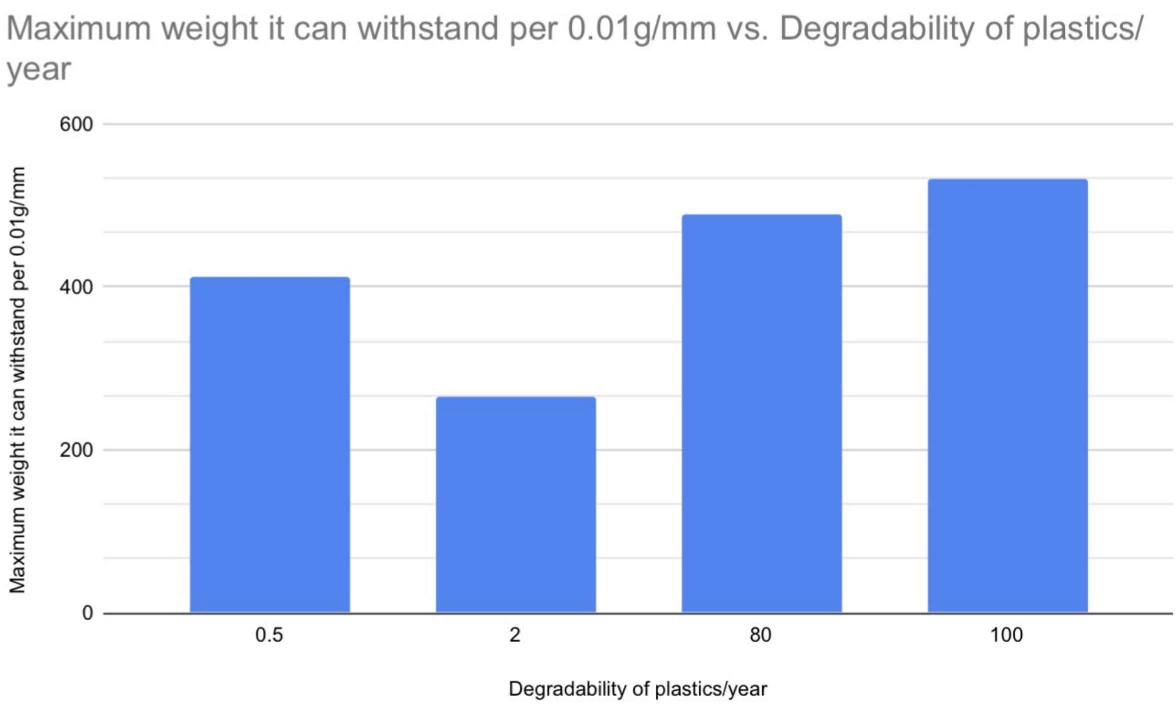

Figure 3: Maximum weight each plastic can withstand per 0.01 g-degradability of plastic of the data presented in Table 2

DISCUSSION

As in Table 2, the tensile strength of the respective plastics was tested thrice, and the averages were calculated. As seen from the results, HDPE can withstand the most weight, which validates the initial hypothesis. However, oxo-biodegradable bag could withstand only half (50.0%) the weight that HDPE could. Instead, Telobag, which is more degradable (i.e., fewer years required to fully degrade), could withstand around 77.3% of the weight of the HDPE bag. Hence, this may not validate the hypothesis.

When tabulated into a bar chart as seen from Figure 3, there is an overall increasing trend of tensile strength of plastics with increasing degradability, from Telobag to HDPE. As mentioned, there is a decrease in tensile strength of the oxo-biodegradable bag, but the tensile strength of the other plastics continued to increase by decreasing degradability. The strength of Telobag is almost comparable to PLA and HDPE, and this might be due to its different constituent – cassava starch – from the other plastics. Other than cassava starch, Telobag is made of glycerine and polyvinyl alcohol [12] which may play a part in its tensile strength. Additionally, the molecular structure of the materials and other factors may affect its degradability.

However, the limitations of the experiment must be considered. As stated, the degradability of the plastics was measured in different conditions and may not be a fair comparison. Furthermore, only four types of materials were tested, hence the correlation between the type of material and its tensile strength may not be fully accurate.

CONCLUSION

In conclusion, the initial hypothesis, “the more degradable the plastic, the less strong it is.” may only be true to a small extent. While there was an overall increase in the strength of plastics with a decrease in degradability of plastics, there were inconsistencies in the trend due to Telobag being stronger than the oxo-biodegradable bag.

Through this experiment, it was found that Telobag, a fully biodegradable (100% biodegradable) plastic alternative has comparable strength to HDPE, a non-biodegradable (0% biodegradable) bag. Therefore, the switch to cassava-based bags should be heavily considered for use to slow down the harmful effects of the use of plastic bags that are detrimental to the health of our environment, other living things, and ourselves.

For future experiments, more testing of other types of plastics must be carried out in order to fully validate the hypothesis. The testing of the degradability of plastics can also be carried out in the same conditions to ensure that the degradability of plastics can be compared more precisely, and factors such as molecular structure should be considered.

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