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EXPERIMENTAL ARTICLE

The usage of hen eggshell and water hyacinth (*Eichhornia crassipes*) as biodegradable plastic

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Conventional plastics are deemed to be harmful to the health of the people, wildlife, and environment. Therefore, developing biodegradable plastics is needed because it is a better alternative to conventional plastics since they can be broken down through natural processes. This study investigates the effectiveness of eggshells and water hyacinth as one of the main components of biodegradable plastic. Three variations of biodegradable plastic were made in this study, one with 70% eggshell and 30% water hyacinth; the second one has 30% eggshell and 70% water hyacinth; and finally, 50% eggshell and 50% water hyacinth was recommended due to its poor plastic property. Low-density polyethylene (LDPE) was used for comparison. Experiments were conducted to test each of the biodegradable plastics' durability, elasticity, ductility, and solubility. After analyzing the results, it suggests that there is a significant difference in durability, elasticity, and solubility but no significant difference in ductility. The results of this study also suggest that the biodegradable plastic with 30% eggshell and 70% water hyacinth has higher durability and elasticity while decreasing its solubility in water. In contrast, bioplastic with 70% eggshell and 30% water hyacinth has lower durability, elasticity, and higher ductility and solubility. Finally, the bioplastic with 50% eggshell and 50% water hyacinth has the least durability and moderate elasticity, ductility, and solubility.

Keywords: biodegradable plastic, water hyacinth, eggshell, durability, elasticity

Introduction

Plastics are widely used in the community because of their versatility and unique properties—it is flexible, durable, and lightweight. In addition, plastic can be molded into various shapes, and it is cheaper to manufacture than any other material that also possesses these characteristics. These led to numerous applications of plastics. To serve as an example, it has been used in producing packaging materials, containers, utensils, building materials, and electronic machinery. However, the widespread usage of plastics also has its downsides. Most conventional plastics that are being used today are made up of non-biodegradable polymers. This means that plastics are almost impossible to decompose because it is an inorganic material; they would take a very long time to be broken down (1). This implies that most of the plastics that were produced many years ago are still lingering in the environment. If not properly disposed of, the accumulation of plastics harms the environment in many ways. For instance, plastics can be ingested by marine animals, poisoning them as a result. If the plastics are disposed of by incineration, it can lead to air pollution.

Meanwhile, other means of plastic disposal such as deep landfills can cause the plastics to seep their harmful chemicals into the soil, which could spread to groundwater (2). Considering that groundwater is the main source of drinking water, this is detrimental to people's health.

Taking the disadvantages of using plastics into account, this is an environmental problem that needs to be resolved lest the people's health and wildlife be at a state of risk. Moreover, the amount of plastics that are being mass produced would only increase as time goes by; therefore, the relevance of this issue would persist until the problem is solved. Even so, the issue with plastics proved to be problematic which is why the solution for this problem seems to be non-existent. The convenience that plastics provided to the people while being cost-efficient is difficult to replace; therefore, stopping the mass production of plastics is not an option. This implies that the problem should be approached in a different way. To address this problem, biodegradable plastics were developed. Since biodegradable plastics are made up of organic materials such as starch, they can be broken down relatively quicker than conventional plastics. In general, biodegradable plastics are also compostable, and they can decay without spreading harmful chemicals in the soil (3). Replacing conventional plastics with biodegradable plastics in the market can be the solution to the crisis brought by plastic waste. Besides, biodegradable plastic almost has the same properties as conventional plastics; therefore, it can provide consumers with a better substitute for non-biodegradable plastics.

The purpose of this study was to substantiate the effectiveness of eggshells and water hyacinth as reinforcing material in a biodegradable plastic made from cassava starch. Furthermore, the researchers aim to create bioplastic with higher quality with the help of several low-cost materials that are naturally found in the environment. Likewise, the findings of this research would be assistance for the development of biodegradable plastic. This would aid in creating a bioplastic that can compete with conventional plastics.

Research elaborations

Every minute, two million plastic bags are being used worldwide. This adds to a ginormous amount of between 500 billion to 1 trillion plastic bags every year (4). This is alarming considering that conventional plastics are primarily petroleum-based; specifically, it is made up of polyethylene terephthalate. These kinds of plastics are inorganic materials which are why microorganisms are not able to break down these materials into simpler compounds. To solve this issue, multiple studies have been conducted to develop biodegradable plastics. Unlike conventional plastics, biodegradable plastics are essentially made up of organic materials to make it possible for microorganisms to break the plastics down naturally. Ironically, bioplastics were the first to be invented rather than conventional plastics. In fact, the first known biodegradable plastic was invented by Maurice Lemoigne. This bioplastic is referred to as polyhydroxy butyrate (PHB), which was derived by utilizing the bacterium Bacillus megaterium. However, his discovery was overshadowed by the rise of petroleum-based plastics, which are generally cheaper and abundant during his time (5). Nevertheless, when the harms of plastics were recognized, the interest in biodegradable plastics came back as researchers seek for an alternative to petroleum based plastics.

In accordance with the findings of Samadhan (6), biodegradable plastics can be made from polylactide acid (PLA), which can be made by using starches from cassava, corn, and potato. This can potentially replace petroleum based polymers in creating plastics because it has high mechanical strength, transparency, and low toxicity. This knowledge can be utilized in formulating various kinds of bioplastics.

Although biodegradable plastics have come a long way, researchers are still finding a way to create high-quality bioplastic that can completely replace conventional plastics. Various types of starches are tested in their effectiveness as the main component of biodegradable plastic. For instance, it was found that cassava starch has higher tensile strength and dissolubility compared with corn starch (7), which is why the researchers in this study chose cassava starch in creating starch-based bioplastic. It was also found that adding reinforcing materials or fillers in biodegradable plastics increase its tensile strength even further (8). Materials such as eggshells and cellulose of water hyacinth are great examples of fillers that can be used in strengthening biodegradable plastics. Thus, the researchers intend to test the effectiveness of these fillers in enhancing starch-based biodegradable plastic.

Considering the history and the findings regarding biodegradable plastics, the researchers used cassava starch, eggshell, and water hyacinth as the main components of biodegradable plastics. Furthermore, the compatibility between these raw materials was tested in this study, and the optimal amount of fillers for bioplastics would be determined. The findings of this study would provide insights into the constant pursuit of sustainable bioplastics that can potentially replace conventional plastics.

This study aimed to determine how the amount of eggshell and water hyacinth present in the cassava starch based biodegradable plastics affects its several properties.

Specifically, this study aimed to answer the following questions:

1. What are the properties of biodegradable plastic with 70% (42 g) eggshell and 30% (18 g) water hyacinth in terms of the following:

   1.1 Durability

   1.2 Elasticity

1.3 Ductility
1.4 Solubility

2. What are the properties of biodegradable plastic with 30% (18 g) eggshell and 70% (42 g) water hyacinth in terms of the following:

    2.1 Durability
    2.2 Elasticity
    2.3 Ductility
    2.4 Solubility

3. What are the properties of biodegradable plastic with 50% (30 g) eggshell and 50% (30 g) water hyacinth in terms of the following:

    3.1 Durability
    3.2 Elasticity
    3.3 Ductility
    3.4 Solubility

4. Is there a significant difference between biodegradable plastic with 70% eggshell (42 g) and 30% water hyacinth (18 g); 30% eggshell (18 g) and 70% water hyacinth (42 g); and 50% eggshell (30 g) and 50% water hyacinth (30 g) in terms of the following:

    4.1 Durability
    4.2 Elasticity
    4.3 Ductility
    4.4 Solubility

The research design should be determined for it is crucial in providing answers for the statement of the problem. To have the most efficient way of gathering data and insights in accomplishing the objectives of this study, the researchers used the experimental method of quantitative research design since this study deals with how the amount of eggshells and water hyacinth affect several properties of biodegradable plastic. The amount of eggshell and water hyacinth will be the independent variable for it affects the dependent variable, the durability, elasticity, ductility, and solubility.

Data gathering procedure

After creating the biodegradable plastic with their respective amount of eggshell and water hyacinth, the researchers will conduct four tests on every bioplastic created—each test has three trials, measuring the durability, elasticity, ductility, and solubility. An object's durability is measured by its ability to withstand pressure. Therefore, the biodegradable plastic's durability will be tested by determining the maximum weight that it can carry before tearing it apart. The measurement of the biodegradable plastic for this test will be 10 × 10 cm. Moving on, the elasticity of a material is measured by its ability to return to its original shape when the applied stress is removed. In testing the elasticity, a 3 × 8 cm bioplastic will be stretched out. Later, the researchers will determine what percent of the initial length was retained when it is released from being stretched out. To further illustrate, the mathematical formula for this is shown below:

$$Length\ of\ Elongation = L_{Final} - L_{Inital}$$

Where $L_{Initial}$ is the length of the biodegradable plastic before it is stretched, while LFinal is its length when released from being stretched. The quotient of the two multiplied by 100 will represent how much of the initial length of the bioplastic was preserved—this will serve as the measure of elasticity.

TABLE 1 | List of materials.

	Materials	Quantity and Measurements	Description
1	Cassava starch	55 g	A carbohydrate product that has an excellent binding property
2	Eggshells	30% = 18 g 50% = 30 g 70% = 42 g	A shell that is made up of calcium carbonate
3	Water hyacinth	30% = 18 g 50% = 30 g 70% = 42 g	A floating aquatic plant characterized as an invasive plant species.
4	Sodium hydroxide	5 g per 200 mL of water	It is a corrosive white crystalline solid that readily absorbs moisture until it dissolves
5	Sodium hypochlorite	200 mL per batch of water hyacinth	It is a type of compound made from reacting chlorine with a sodium hydroxide solution commonly found in disinfecting agents such as bleach.
6	Metal trays	Six	A flat and shallow container where the bioplastic is placed to dry.
7	Glycerin	15 mL per batch	It is a colorless or pale-yellow liquid: sweet and warm taste.
8	Water	210 mL per batch	It is a substance composed of the chemical elements' oxygen and hydrogen and exists in gaseous, liquid, and solid states.
9	Vinegar	9 mL per batch	It is a sour liquid that is made up of fermenting substances that contain sugar, such as fruit and wine.

The next test is to measure biodegradable plastic ductility. In testing the biodegradable plastic's ductility, a 3 × 8 cm biodegradable plastic will be stretched out until it completely tears apart. The length of the bioplastic's elongation before it tears will serve as the measure of ductility. To demonstrate, the equation below will be used in measuring the bioplastic's ductility.

$$Length\ of\ Elongation = L_{Final} - L_{Inital}$$

where $L_{Initial}$ is the bioplastic's length before being stretched; L_{Final} is the length of the bioplastic before tearing apart due to stretching. The difference between the two will be the length of elongation, which will also serve as the measurement of its ductility.

In terms of the solubility test, the 3 × 10 cm bioplastic will be submerged in water, and then an object with a weight of 42 g will be placed on top of it. Then, the time it takes for the bioplastic to dissolve and make the object fall will be measured. These tests will be repeated in every biodegradable plastic with varying amounts of eggshell and water hyacinth cellulose. The first biodegradable plastic has 70% eggshell (42 g) and 30% water hyacinth (18 g). The second has 30% eggshell (18 g) and 70% water hyacinth (42 g), while the last biodegradable plastic has 50% eggshell (30 g) and 50% water hyacinth (30 g).

After conducting the tests, the data and results gathered will be analyzed and interpreted by the researchers using a suitable statistical treatment for this study.

Results and findings

The durability, elasticity, ductility, and solubility of biodegradable plastic with 70% eggshell and 30% water hyacinth

Table 2 shows the results of the four tests conducted on the bioplastic with 70% eggshell and 30% water hyacinth; each test is provided with three trials. In terms of durability, the bioplastic can carry 440 g on the first trial; 467 on the second trial; and 529 on the third trial. Given the results of the three trials, the bioplastic can carry an average weight of 478.67 g. For the elasticity test, the bioplastic retained 97.6% of its original length after being stretched on the first trial, while 96.4% on the second and third trials. The bioplastic has an average of 96.8% on the elasticity test. In the ductility test, the bioplastic can stretch for 3 cm before tearing apart in the first and second trials. In the third trial, the bioplastic can stretch for 2.9 cm before completely tearing apart. Therefore, the bioplastic has an average of 2.97 cm in the ductility test. For the solubility, the object resting on the bioplastic fell after 248 s on the first trial; 292 s on the second trial; and 193 s on the third trial. Recognizing the results of the three trials, the bioplastic has an average of 244.33 s in the solubility test.

The durability, elasticity, ductility, and solubility of biodegradable plastic with 30% eggshell and 70% water hyacinth

Table 3 presents the results of the tests for the bioplastic with 30% eggshell and 70% water hyacinth. In the durability test, the bioplastic carried 550 g before tearing apart on the first trial; 548 on the second trial; and 614 on the third trial. Therefore, the bioplastic can carry an average weight of 570.67 g. In terms of elasticity, the bioplastic retained 98.8% of its initial length after being stretched in the first and second trials, while 97.6% in the third trial. This shows that the bioplastic has an average of 98.4% on the elasticity test. In the ductility test, the bioplastic can stretch for 2 cm before tearing apart on the first trial; 2.6 cm on the second trial; and 2.2 cm on the third trial. Therefore, the bioplastic has an average of 2.27 cm in the ductility test. For the solubility, the object resting on the bioplastic fell after 831 s on the first trial; 556 s on the second trial; and 500 s on the third trial. Thus, the bioplastic has an average of 629 s in the solubility test.

The durability, elasticity, ductility, and solubility of biodegradable plastic with 50% eggshell and 50% water hyacinth

Table 4 shows the results of the tests for the bioplastic with 50% eggshell and 50% water hyacinth. In testing the durability, the bioplastic carried 506 g on the first trial 418

TABLE 2 | Results of the tests conducted on the biodegradable plastic with 70% eggshell and 30% water hyacinth.

Percentage of Eggshell and Water Hyacinth	Durability (Weight in Grams it can Carry)			Elasticity (Percentage of Initial Length Retained After Stretching)			Ductility (Length of Elongation in cm Before Tearing Apart)			Solubility (Amount of Time in Seconds to Dissolve)		
70% Eggshell and 30% Water Hyacinth	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
	440	467	529	97.6	96.4	96.4	3	3	2.9	248	292	193
Average		478.67			96.8			2.97		244.33		

TABLE 3 | Results of the tests conducted on the biodegradable plastic with 30% eggshell and 70% water hyacinth.

Percentage of Eggshell and Water Hyacinth	Durability (Weight in Grams it can Carry)			Elasticity (Percentage of Initial Length Retained After Stretching)			Ductility (Length of Elongation in cm Before Tearing Apart)			Solubility (Amount of Time in Seconds to Dissolve)		
70% Eggshell and 30% Water Hyacinth	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**
30% Eggshell and 70% Water Hyacinth	550	548	614	98.8	98.8	97.6	2	2.6	2.2	831	556	500
Average		570.67			98.4			2.27			629	

TABLE 4 | Results of the tests conducted on the biodegradable plastic with 50% eggshell and 50% water hyacinth.

Percentage of Eggshell and Water Hyacinth	Durability (Weight in Grams it can Carry)			Elasticity (Percentage of Initial Length Retained After Stretching)			Ductility (Length of Elongation in cm Before Tearing Apart)			Solubility (Amount of Time in Seconds to Dissolve)		
70% Eggshell and 30% Water Hyacinth	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**
50% Eggshell and 50% Water Hyacinth	506	418	446	98.2	97.6	97.6	3.3	2.6	2.6	515	232	220
Average			456.67			97.8			2.83			322.33

on the second trial; and 446 on the third trial. The bioplastic can carry an average weight of 456.67 g. In terms of elasticity, the bioplastic retained 98.2% of its original length after being stretched in the first trial and 97.6% in the second and third trials. Therefore, the bioplastic has an average of 97.8% on the elasticity test. In the ductility test the bioplastic can stretch for 3.3 cm on the first trial; 2.6 cm on the second and third trials. Therefore, the bioplastic has an average of 2.83 cm in the ductility test. For the solubility the object resting on the bioplastic fell after 515 s on the first trial; 232 s on the second trial; and 220 s on the third trial. Thus, the bioplastic has an average of 322.33 s in the solubility test.

The significant difference in durability, elasticity ductility, and solubility of the biodegradable plastics

In **Table 5**, the p-value of < 0.05 is used in calculating the significant difference in the durability of the three bioplastics with varying amounts of eggshell and water hyacinth. After employing one-way ANOVA, the p-value is 0.037, which is less than 0.05. This means that there is a significant difference in durability. It is also shown that the F-statistic (5.97) is greater than the F-critical value (5.14), which means that the test is significant.

In contrast, **Table 6** shows the significant difference in the elasticity of the three bioplastics. It is indicated that the p-value is 0.045, which is also less than 0.05. Therefore, the hypothesis that there is no significant difference in elasticity is rejected. In contrast, the F-statistic is 5.44, which is more than the F-critical value of 5.14, showing that the test is significant.

Meanwhile, **Table 7** shows the significant difference in ductility of the three bioplastics. It is indicated that the p-value is 0.057, which is greater than the p-value of

TABLE 5 | Significant difference in durability.

	***p*-value**	***F***	**F-critical Value**	**Description**
Difference in Durability	0.037	5.97	5.14	Significant

TABLE 6 | Significant difference in elasticity.

	***p*-value**	***F***	**F-critical Value**	**Description**
Difference in Elasticity	0.045	5.44	5.14	Significant

TABLE 7 | Significant difference in ductility.

	***p*-value**	***F***	**F-critical Value**	**Description**
Difference in Ductility	0.057	4.78	5.14	Not statistically significant

TABLE 8 | Significant difference in solubility.

	***p*-value**	***F***	**F-critical Value**	**Significant**
Difference in Description	0.037	6.03	5.14	Solubility

0.05. Therefore, the hypothesis that there is no significant difference in ductility is accepted. It is also indicated in the results of one-way ANOVA that the F-statistic (4.78) is less than the F-critical value (5.14), showing that the test is not statistically significant.

In contrast, Table 8 presents the significant difference in solubility of the three bioplastics with varying eggshells and water hyacinth. Recognizing the results, the hypothesis that there is no significant difference in solubility is rejected because the p-value (0.037) is less than 0.05. In addition, the F-statistic is 6.03, which is more than the F- critical value of 5.14, suggesting that the test is significant.

Conclusion and recommendation

Conclusion

The findings of this study provided crucial information that is needed to answer the research question and in testing the hypothesis. Taking the findings of this study into consideration, the hypothesis that there is no significant difference in durability, elasticity, and solubility is rejected. However, the data gathered from this study suggest that there is in fact no significant difference in ductility; therefore, the hypothesis corresponding to the ductility is accepted.

In contrast, the durability, elasticity, ductility, and solubility of the three bioplastics with varying amounts of eggshell and water hyacinth have been determined. Recognizing the results of this study, the amount of eggshell and water hyacinth has a direct impact on the durability, elasticity, and solubility of the bioplastic. Increasing the amount of water hyacinth will lead to much higher durability, elasticity, and solubility, but the bioplastic will be less ductile. In contrast, a greater amount of eggshell led to lesser durability, lesser elasticity, and higher solubility in water. However, it has relatively higher ductility. Finally, when the eggshell and water hyacinth are in equal amounts, the bioplastic is much less durable but has moderate elasticity, ductility, and solubility. The conclusions drawn in this study will provide insights that can be applied in manufacturing biodegradable plastics out of eggshell and water hyacinth. One can create bioplastic out of these two accessible materials, and they will be able to know the optimal amount of eggshell and water hyacinth; whether they need a durable bioplastic or a much ductile one.

Recommendation

This study has fulfilled its objectives, and the research questions have been answered. However, there are improvements that can be made for more accurate findings and to further expand the scope of this study as follows:

1. The researchers suggest using better tools and equipment in producing the bioplastics.
2. Other plasticizers aside from glycerin should be used to determine if the results will be the same.
3. Future researchers can utilize the findings of this study to develop plastic wares or utensils out of eggshell and water hyacinth.

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