Utilization of White Yam *(Dioscorea rotunda)* in Bioplastic Production

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This research aimed to utilize white yam starch in the production of bioplastic. In bioplastic production, the two main ingredients are starch and glycerin. This study aims to determine the amount or proportion of glycerin that would yield the best bioplastic prototype. In addition, some properties of the produced bioplastics, such as water absorption, tensile strength, and biodegradability, were analyzed. The research method used was experimental, which consisted of five treatments with three replications: Treatment A - With 5 ml glycerin; Treatment B - With 10 ml glycerin; Treatment C - With 15 ml glycerin; Treatment D - With 20 ml glycerin; and Treatment E - With 25 ml glycerin. The water absorption of the bioplastic from white yams was measured using the water absorption test to determine how much the bioplastic absorbs water. The tensile strength of the bioplastic was measured to determine how much longitudinal stress it can bear without tearing apart. The biodegradability of the bioplastic was investigated in a controlled environment, and was carried out using the soil burial test method. The best bioplastic prototype produced is using the 10 ml glycerin added to 15 grams of white yam starch.

Keywords: Water Absorption, Tensile Strength, Biodegradability

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ISSN 1908-2843 Print

Introduction

Plastics are more practical than metals, paper, and other materials due to their durability, affordability, and lightweight. As a result, they are employed in practically all industrial domains. Over 300 million tons of plastic were used globally in 2015 (Mekonnen, 2013). Plastic garbage fills the oceans and the entire planet. Furthermore, the plastics business has several drawbacks that are associated with environmental and economic issues (Zarate-Ramirez et al., 2014).

The first environmental drawback is that landfill capacity is decreasing as a result of the growing volume of plastic trash in landfill locations (Philp et al., 2013). Due to strict laws and growing expenses, landfills are experiencing a crisis as a result of an increase in plastic trash. However, there is also a lot of plastic debris in the oceans. The second drawback is harm to the marine environment. The insufficiency of waste management solutions is the third drawback. Plastic recycling rates are extremely low. On the other hand, burning plastic produces harmful emissions, including carbon dioxide and methane. Global climate change is adversely impacted by these greenhouse gases (GHGs) (Barker, 2010). The fourth drawback of plastic is its durability and lack of biodegradability.

It has long been known that plastics can persist in the environment for hundreds of years and are not biodegradable (El-Kadi, 2010). Furthermore, it is anticipated that the cost of fossil fuels will rise, and their supply will become more unstable. The rising cost of fossil fuels is an economic issue. Green materials, such as bioplastics, have emerged in recent years due to these social and environmental issues (Peelman et al., 2013). Since they may lessen reliance on fossil fuels and other environmental issues, bioplastics are now considered a possible substitute for plastics.

Although there are many definitions, "bioplastics" are usually understood to be polymers manufactured by a variety of microorganisms and derived from renewable resources such corn, sugar, potatoes, and so forth (Karana, 2012) (Luengo et al., 2003). Bioplastics can be classified as photodegradable, compostable, bio- based, or biodegradable. Because of the additives, photodegradable bioplastics are light-sensitive, and ultraviolet light can break down their polymeric structure. They cannot, however, break down in the absence of sunlight. According to Alvarez- Chavez et al. (2012), bio-based bioplastics are made from renewable materials that include cellulose, protein, and starch.

One of the most recognized bio-based plastics is Polylactic Acid (PLA). Compostable bioplastics are classified as those that undergo biological decomposition during the composting process, and as per the standards of the American Society for Testing and Materials (ASTM) D6400, the plant material should remain intact after composting. Biodegradable bioplastics are entirely broken down by microorganisms through biological processes. The term "biodegradable" refers to substances that can naturally disintegrate or decompose into carbon dioxide and water when exposed to a microbial environment and moisture (El-Kadi, 2010).

Bioplastic is primarily utilized in numerous industrial sectors in many nations as packing materials, diapers, cutlery, etc. Global production of bioplastics is expected to reach 7.8 million tons in 2019 (Schulze et al., 2017). Consequently, it is believed that bioplastics have a bright future. However, the price of bioplastic made from microbial resources is still more than that made from renewable resources (Anjum et al., 2016). Because of this, most bioplastic producers have concentrated on using renewable resources in their production.

Among renewable resources, starch represents a promising material for bioplastics due to its affordability and wide accessibility (Ma et al., 2008). It has found applications across various industries, including paper products, corrugated cartons, biofuels (Naik et al., 2010), pharmaceuticals, textiles (Tupa et al., 2013), and particularly within the food sector. Furthermore, numerous companies have started utilizing starch for bioplastic manufacturing. Despite its plentiful availability, low cost, and natural sources, there remain significant concerns regarding the use of this renewable resource for production.

Additionally, numerous researchers argue that renewable resources like starch should not be allocated for non-food purposes when global hunger persists. Moreover, the bioplastic sector may reduce the land available for food cultivation or, to create more arable land, could incentivize deforestation. The current trend is to utilize waste to address potential competition for agricultural resources meant for food and to provide new raw material sources (Lagaron & Lopez-Rubio, 2011).

This study aims to explore the use of white yams (*Dioscorea rotundata*) for creating bioplastics. The process of producing bioplastics from white yams was examined to meet this goal. The two primary components in bioplastic production are starch and glycerin. This study intends to identify the optimal glycerin ratio that will result in the best bioplastic prototype. Additionally, various attributes of the generated bioplastics were analyzed, including water absorption, tensile strength, and biodegradability.

Objectives

This study aimed to utilize white yam (Dioscorea rotundata) for bioplastic production.

Specifically, it sought to achieve the following objectives:

1. Determine the water absorption, tensile strength, and biodegradability of

   bioplastic derived from white yam (Dioscorea rotundata) in five different treatments:

a. Treatment A - With 5 ml glycerin

b. Treatment B - With 10 ml glycerin

c. Treatment C - With 15 ml glycerin

d. Treatment D - With 20 ml glycerin

e. Treatment E - With 25 ml glycerin

Materials and Methods

Materials

Quantity	Description
100 g	white yam starch
15 g	sodium bicarbonate
80 ml	glycerin
80 ml	vinegar
800 ml	distilled water

White yam and vinegar were obtained from the public market. Sodium bicarbonate and glycerin were ordered in Shopee. Distilled water was bought from a drugstore.

Tools and Equipment

1	saucepan
1	sieve
1	weighing scale
1	molding materials

Research Methods

The research method used was experimental, which consisted of five treatments with replications:

Treatment A- with 5ml glycerin

Treatment B- with 10ml glycerin

Treatment C- with 15ml glycerin

Treatment D- with 20 ml glycerin

Treatment E- with 25ml glycerin

Preparation of White Yam Starch

White yam obtained from a local market was washed with clean water before being peeled and shredded into small pieces. The shredded white yam was later placed in a mixing blender and soaked in water for about 100 ml. After the mixing process, the starch slurry was filtered and later placed in a tank for settling, which took at least 30 minutes. Starch sediment was separated from the slurry and then washed again with distilled water. After the second settling, starch sediment was dried using an oven at a temperature of 70 C for the removal of free water. Starch was sieved with a strainer 100 mesh/inch for better homogeneous size.

Fabrication of Bioplastic Sheets for Treatment A

1. In a saucepan, add 135 ml of water, 15 g of white yam starch, 2.5 g of sodium bicarbonate, and 10 ml of vinegar.
2. Add 5 ml of glycerin,
3. Mix together and stir until combined.
4. Cook the solution over medium-low heat or approximately 1300 °C.
5. Stir continuously as the mixture heats until it becomes thick and almost transparent (10 min)
6. Spread the mixture in a mold into bioplastic sheets.
7. Place the sheets in the oven set at 750 °C for 2 hours to dry.
8. For final drying, take the bioplastics sheets out of the oven and let them dry in a room temperature for 24 hours.

Fabrication of Bioplastic Sheets for Treatment B

1. Repeat Step 1 in Treatment A
2. Add 10 ml of glycerin,
3. Repeat steps 2 - 8.

Fabrication of Bioplastic Sheets for Treatment C

1. Repeat Step 1 in Treatment A
2. Add 15 ml of glycerin,
3. Repeat steps 2 - 8

Fabrication of Bioplastic Sheets for Treatment D

1. Repeat Step 1 in Treatment A
2. Add 20 ml of glycerin,
3. Repeat steps 2 - 8.

Fabrication of Bioplastic Sheets for Treatment E

1. Repeat Step 1 in Treatment A
2. Add 25 ml of glycerin,
3. Repeat steps 2 – 8

Bioplastic Characterizations

The water absorption of the bioplastic from white yam was measured using the water absorption test to determine how much the bioplastic absorbs water. White yam bioplastic prototypes of the same initial weight (4g) were submerged in 180ml of water for 24 hours. At the end of 24 hours, samples were weighed again, and the water absorption of the samples was calculated. The final weight after minus the initial weight is defined as the total absorbed water. All water absorption measurements were performed in three replications. Water absorption was calculated by the following equation:

$$\mathbf{WA(\%)} = \frac{\mathbf{(W - Wo)}}{\mathbf{W}} \times \mathbf{100}$$

W0 and W are the initial and final weights of bioplastic samples, respectively. Also, WA refers to Water Absorption. The tensile strength of the white yam bioplastic was measured to determine how much longitudinal stress it could bear without tearing apart. The ultimate tensile strength of a material is the force per unit area at which it breaks into two. The bioplastic samples from white yams were cut into rectangular strips of the same dimensions (3.5in x 1.5in) and tested using a tensile tester, measured in Newton.

The biodegradability of white yam bioplastic was investigated in a controlled environment. After weighing, three different white yam bioplastic samples were buried under 50g of moist soil. Bioplastic samples, whose initial masses are known, were weighed after burying weekly. Biodegradation refers to the breakdown of materials due to biological processes, particularly through the action of enzymes, resulting in notable alterations to the chemical structure of the substance. Additionally, measuring weight loss is a common method used to assess the biodegradation of polymers.. The amount of biodegradation was calculated by the following equation:

$$\mathbf{WA(\%)} = \frac{\mathbf{(W - Wo)}}{\mathbf{W}} \times \mathbf{100}$$

W0 and W are the initial and final weights of bioplastic samples, respectively. Also, WL refers to Weight Loss.

Results and Discussions

Results of the Water Absorption

Measurements

The results of the water absorption experiments in Table 1 showed that Treatment E (with 25 ml glycerin) has the greatest amount of water absorbed, followed by Treatment D, Treatment C, Treatment B, and Treatment A. It can be shown that as the amount of glycerin added increased, the amount of water absorbed after 24 hours also increased.

Table 1. Water absorption of white yam bioplastic in the five treatments

Prototype	Initial Weight	Final Weight* R1	Final Weight* R2	Final Weight* R3	Average WA (%)
Treatment A	4g	11.23 g	12.14 g	11.46 g	65.55
Treatment B	4g	10.88 g	12.22 g	12. 18 g	65.99
Treatmeant C	4g	12.62 g	10.94 g	12.12 g	66.37
Treatment D	4g	13.02 g	11.28 g	11.44 g	66.42
Treatment E	4g	12.65 g	11.84 g	11.92 g	67.04

Prototype	Initial Weight	Final Weight* R1	Final Weight* R2	Final Weight* R3	Average WA (%)
Treatmeant A	4g	11.23 g	12.14 g	11.46 g	65.55
Treatmeant B	4g	10.88 g	12.22 g	12. 18 g	65.99
Treatmeant C	4g	12.62 g	10.94 g	12.12 g	66.37
Treatmeant D	4g	13.02 g	11.28 g	11.44 g	66.42
Treatmeant E	4g	12.65 g	11.84 g	11.92 g	67.04

** After 24 hours in 180 ml of water*

Results of the Tensile Strength Measurements

The results of the tensile strength experiments in Table 2 showed that Treatment B (with 10 ml glycerin) had the highest tensile strength of 3.88 N, followed by Treatment C, Treatment A, Treatment D, and Treatment E.

Table 2. Tensile strength of white yam bioplastic in the five treatments

Prototype	Tensile Strength R1	Tensile Strength R2	Tensile Strength R3	Average Tensile Strength
Treatment A	3.74 N	3.88 N	3.70 N	3.77 N
Treatment B	3.92 N	3.84 N	3.88 N	3.88 N
Treatment C	3.76 N	3.82 N	3.82 N	3.80 N
Treatment D	3.75 N	3.72 N	3.78 N	3.75 N
Treament E	3.71 N	3.74 N	3.72 N	3.72 N

Results of the Biodegradability Measurements

The results of the biodegradability experiments showed that Treatment C (with 15 ml glycerin) is the most biodegradable as almost 82.92% of its weight was lost after being buried for two weeks in moist soil, followed by Treatment D, Treatment A, Treatment E, and Treatment B.

Table 3. Biodegradability of white yam bioplastic in the five treatments

Prototype	Initial Weight	Final Weight* R1	Final Weight* R2	Final Weight* R3	Weight Loss (%)
Treatmeant A	4 g	.64	.75	.82	81.58%
Treatmeant B	4 g	.84	.72	.70	81.17%
Treatmeant C	4 g	.45	.82	.78	82.92%
Treatmeant D	4 g	.72	.73	.74	81.75%
Treatmeant E	4 g	.68	.80	.74	81.50%

* buried for 2 weeks under 50g of moist soil

Prototype	Initial Weight	Final Weight* R1	Final Weight* R2	Final Weight* R3	Weight Loss (%)
Treatmeant A	4 g	.64	.75	.82	81.58%
Treatmeant B	4 g	.84	.72	.70	81.17%
Treatmeant C	4 g	.45	.82	.78	82.92%
Treatmeant D	4 g	.72	.73	.74	81.75%
Treatmeant E	4 g	.68	.80	.74	81.50%

Difference in the Water Absorption among the Five Treatments

Table 4 shows no significant difference in the water absorption of white yam bioplastic in the five treatments. This means that the amount of glycerin added in every treatment did not significantly affect the amount of water absorbed for every treatment.

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Table 4. ANOVA results on the difference in the water absorption of the five treatments

Source of Variance	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.000	4	.000	.195	.935
Within Groups	.004	10	.000		
Total	.005	14			

Source of Variance	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.000	4	.000	.195	.935
Within Groups	.004	10	.000		
Total	.005	14			

Difference in the Tensile Strength among the Five Treatments

Table 5 shows a significant difference in the tensile strength of white yam bioplastic in the five treatments in favor of Treatment B (with 10 ml glycerin). This means that the tensile strength of Treatment B is significantly better compared to the other treatments.

Source of Variance	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.043	4	.011	4.201	.030
Within Groups	.026	10	.003		
Total	.069	14			

Source of Variance	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.043	4	.011	4.201	.030
Within Groups	.026	10	.003		
Total	.069	14			

Difference in the Biodegradability among the Five Treatments

Table 6 shows no significant difference in the biodegradability of white yam bioplastic in the five treatments. This means that the amount of glycerin added in every treatment did not significantly affect the biodegradability for every treatment.

Table 6. ANOVA results on the difference in the biodegradability of the five treatments

Source of Variance	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.001	4	.000	.182	.943
Within Groups	.007	10	.001		
Total	.008	14			

Source of Variance	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.001	4	.000	.182	.943
Within Groups	.007	10	.001		

Conclusions and Recommendations

Conclusions

This study shows that white yam starch could be utilized in bioplastic production. The white yam bioplastic with 25 ml glycerin (Treatment E) has the greatest amount of water absorbed, while the white yam bioplastic with 10 ml glycerin (Treatment B) has the highest tensile strength, and the white yam bioplastic with 15 ml glycerin (Treatment C) is the most biodegradable. No significant difference was found in the water absorption and biodegradability of the white yam bioplastic in the five treatments. However, there was a significant difference in the tensile strength of the white yam bioplastic in the five treatments. Results show that Treatment B (white yam bioplastic with 10 ml glycerin added) has the best proportion of glycerin to be added to white yam starch in the preparation of white yam bioplastic, as this produced the highest tensile strength.

Recommendations

When making bioplastic using white yam starch, use 10 ml glycerin for every 15 grams of white yam starch. Further research may be conducted to reduce the high-water absorption rate and improve the tensile strength of white yam bioplastic. White yam bioplastics can be used in the packaging industry, but the development of mechanical properties should be investigated for its utilization in different industrial areas.

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