Production of Bioplastics Using Yam and Plantain Peels and Their Biodegradability Potentials

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ABSTRACT: Plastics offers a variety of benefits, in a variety of shapes, such as sheets, panels, film which can all be flexible as the application requires. However, use of too many plastics results in massive harmful effects. It takes longer time to degrade which is estimated about 500 years to degrade and will become toxic after decomposed. With the ever-increasing demand of plastics in the world and their consequent disastrous effects on environment, a suitable environmentally friendly substitute like biodegradable plastics is presently in need. This study centers on the production of a variety of bioplastic samples from plantain and yam peels with varying amount of the filler and plasticizers. Glycerol and sorbitol have been utilized separately as the plasticizers to increase its flexibility. A total of 5 samples of each of the bio plastics were made using multiple amounts and combinations of the plasticizers, to test the differences in the physical and chemical characteristics (moisture content, absorption of water, biodegradation in soil, tensile strength) of the produced samples due to their different compositions. The differences in the properties of the bioplastic samples produced make them suitable for usage in many different applications. All 10 of the samples produced were synthesized using natural and environmentally safe raw material and showed biodegradation, thus proving to be a good alternative to the conventional plastics.

Keywords—bioplastics, waste management, Biomaterial

I. INTRODUCTION

Bioplastics are plastic materials produced from renewable biomass sources, such as vegetable fats and oils, corn starch, straw, woodchips, sawdust, recycled food waste etc. [8] Bio plastics are made by converting the sugar present in plants into plastics. This fact makes bioplastics renewable and better for the environment than conventional plastics.[3]. Bioplastics are used for disposable items, such as packaging, crockery, cutlery, pots, bowls and straws [6].

The biologically mediated decrease in chemical compounds complexity is known as biodegradation. It is the process by which microbial organisms break down organic molecules into smaller ones. Present day packaging options for bioplastics include composting bags, packaging for hygiene and food products, as well as industrial packaging. It is anticipated that these materials biodegradability may lessen greenhouse effects [9].

II. MATERIALS AND METHODS

A. Extraction of Starch from Yam and Plantain Peels

Dried yam peels were blended with $100cm^3$ to make a paste and sieved using muslin cloth, and the liquid mixture collected in a beaker, leaving the chaff in the mortar. Overnight, the filtrate was allowed to settle in the beaker. The water was poured out of the beaker, leaving behind the white starch that had accumulated at the bottom. After adding 100cm3 of distilled water to the starch, the mixture was gently agitated and allowed to settle before decanting the water and collecting the starch. The plantain peels were processed similarly to the yam peels to obtain the paste [1,2]

B. Bioplastic Production from Yam and plantain Peels

The basic constituents were aqueous acetic acid (5%) solution, vinegar of 5% concentration, plasticizers and water. To produce a variety of various samples, the number of main substances such as plasticizer content (glycerol, sorbitol) and plantain peels powder filler (PP1-PP10, YP1-YP10) content were varied ranging from 1%, 3%, 5%, 7% and 10% of both the plasticizers (sorbitol and glycerol). The extracted starch was either dried for 3 hours in an airtight environment at 50C or left to dry for 24 hours. After the starch had dried, 13.5 grams were weighed and combined with 135 milliliters of purified water, 16.2 milliliters of vinegar, and 10.8 milliliters of glycerin. On a hot plate, the mixture was heated to 100C and held there for 20 minutes, allowed to air dry for 48 hours, generating a completed bio plastic pellet [1]. Similarly, to produce plantain bioplastic, a beaker was filled with the needed amount of plantain peel paste (13.5 grams), 5ml aqueous acetic acid (5%) solution, 5ml/5g plasticizer, and the required amount of reinforcing filler, all of which were completely mixed. Additionally, 5M HCL, 5ML of NaOH, and vinegar of 5% concentration were added. For the hydrolysis of amylopectin, HCl was used and NaOH was added to neutralize the mixture's acidity. The mixture was heated on a hot plate at 300 C for 15 minutes while continually stirred. The heated mixture was spread into a petri dish lined with aluminum foil and left to dry at room temperature for 24 hours [5]. All production was in triplicates.

C. Biodegradation Process and Isolation of Bacteria from Degraded Bioplastic

The produced samples of both the yam and plantain bio plastics were buried at a depth of 5cm and 10cm at the botanical garden of Nile university, Abuja. This step was triplicated. After 2 weeks, the soil sample was collected in a petri dish and transferred to the Biotechnology Lab of Nile University for conventional and molecular identification of the microorganisms responsible for its biodegradation following the manufacturer's instructions.

D. Soil Burial Test

The following formulae were used to compute the percentage of weight loss and the rate of biodegradation of each sample [4].

%Reduction of weight =

$$(w2 - w1)/_{w1\ X\ 100} \quad (1)$$

Rate of biodegradation = (W2-W1)/maximum time of degradation (w)

E. Moisture Content

Bio plastic sample of 1.5cm2 were weighed to measure the initial weight (W1). The samples were dried in an oven at 85C for 24 hours. The samples were weighed once more to measure the final weight (W2). The moisture content was then determined. The moisture content was then determined using the following formula [7].

$$\text{Moisture Content (\%)} = (w1 - w2)/_{w1\ X\ 100} \quad (2)$$

F. Tensile Strength

A small piece of bioplastic was cut into 2cm X 6cm squares, and the thickness were measured with micrometer screw gauze, while the length was measured with the assistance of scale. At the same time, the samples weight was recorded by electronic balance. A spring balance was hooked onto the middle of the bioplastic and load was added until the sample broke apart.

The strength was calculated by using the formula [4].

Tensile Strength = $Fmax/_{Ao}$ (3)

G. Absorptivity Test

Bio plastic samples with size 15cm2 were first dried in oven at 85c for 24 hours to allow measuring its dry weight, W1. It was then placed in the beaker at 50ml distilled water at room temperature for 24 hours. After 24 hours, the bio plastic was obtained by filtering the water, and weighted to get the final weight, W2.

Water absorptivity test = $(w2 - w1)/_{w1\ X\ 100}$ (4)

III. RESULTS

The gelatinous mixture formed by the different samples of both the plantain and yam bio plastics were observed. The gelatinous mixture solidified after 48 hours, yielding a light brown bioplastic with a smooth surface area. The bio plastics also had high water retention capacity due to its non-porous nature (Table 1). In Table 2, 6 probably bacterial species were isolated and identified, however the most abundant species was Bacillus sp. appearing in all degraded samples hence, the nucleotide sequence from the bioplastic buried at 10cm and 5cm depth had the accession number which is MT415972.1 *Bacillus wiedmanni* Strain JCM 2152 of 16S ribosomal RNA of partial sequence. Fig. 1 shows the colony count of each bacterium isolates in both the 5cm and 10cm depth completely biodegraded bioplastic. The highest colony count of 1.2 x 10^6 CFU/2g was recorded in the 5cm deep completely degraded bioplastic. The lowest count was observed to be 1.0 x 10^6 CFU/2g for 10cm completely degraded bioplastic.

Table 1. Selected Characteristics of produced Bioplastic from Yam and Plantain Peels

Parameters	**Observation from yam**	**Observation from plantain**
Color	Light brown	Black
Formation	Solid	Solid
Surface	Smooth	Smooth
Water retention	High	High
Porosity	Non-porous	Non-porous

Table. 2 Morphological Identification of probably Bacterial Isolates from Biodegraded Bio-Plastics.

Strain	**Coagulase**	**Catalase**	**Indole**	**Citrate**	**Sugar Fermentation**
Bacillus sp.	-	+	-	+	+
Shigella	+	+	-	-	-
Staphylococcus sp.	+	+	-	-	+

Micrococci	-	+	+	+	+
Streptococci sp.	-	-	+	+	+
Enterobacteraerogen	-	+	+	+	+

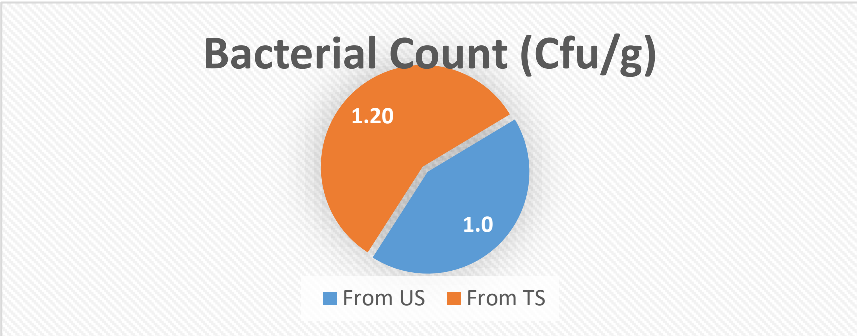

Fig. 1: Total bacterial count from degraded plastic collected from the soil.
Key: Cfu/g = colony forming unit per gram; U.S = under soil 10cm deep; T.S = under soil 5cm deep

The table below shows result for burial test carried out on the samples.

Table 3: **Soil Burial test for Different Samples of Yam and Plantain Bio-plastics**

Bioplastic sample	**Depth**	**% Reduction of weight**	**Rate of Biodegradation**
Yam Sample	5cm	-63	-0.7
Yam Sample	10cm	-75	-0.8
Plantain Glycerol	5cm	-48	-0.9
Plantain Glycerol	10cm	-66	-1.2
Plantain Sorbitol	5cm	-90	-0.9
Plantain Sorbitol	10cm	-67	-1.3

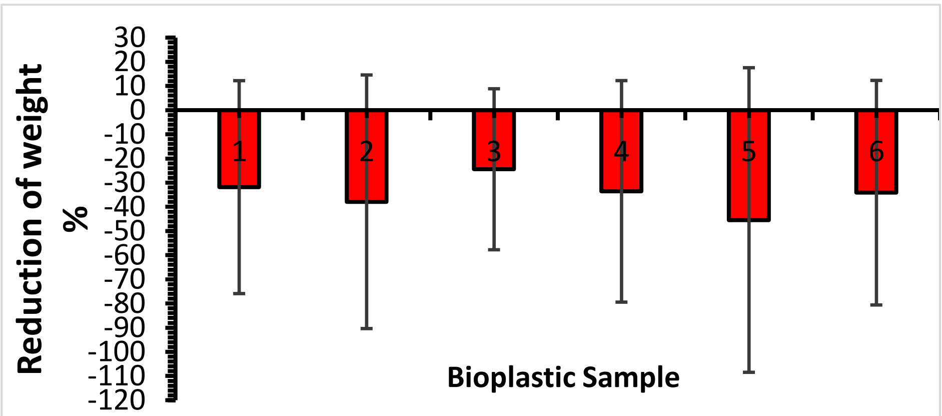

Fig. 2: Soil Burial test for Different Samples of Yam and Plantain Bio-Plastics

In Fig.3, the result for some properties of the Bio-plastics are indicated

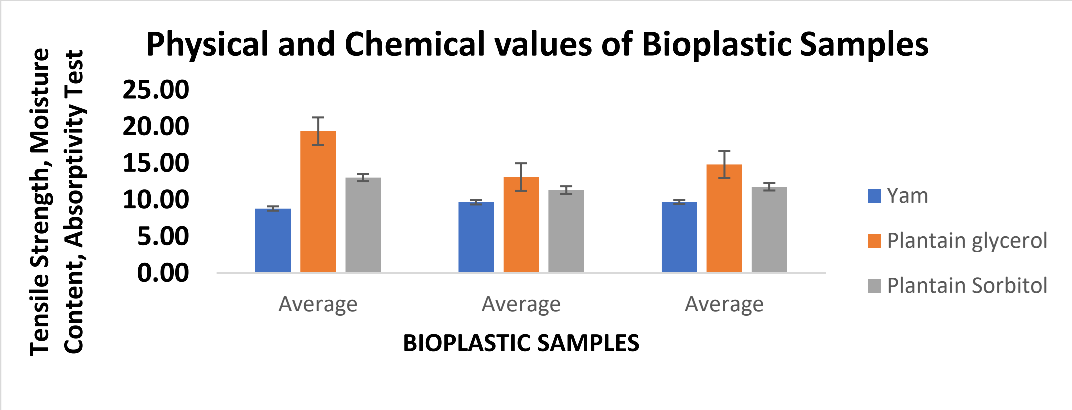

Figure 3: Selected Characteristics of produced Bio plastics from both Plantain and Yam peels

IV. DISCUSSION AND CONCLUSION

This research shows the comparative studies on production of Bioplastics using 2 bio waste, yam and plantain and their biodegradable potentials. The produced bioplastic shares the same characteristics to the work conducted by (Ezgi *et al.*, 2019). It shows that the produced bioplastic was non-porous and had a high-water retaining capacity. Some other notable characteristics were the light brown color of the bioplastic, its solid formation and smooth surface area.

Various quantities and mixtures of plasticizers and fillers were used to create samples of each starch-based bioplastic. For all samples, the acetic acid concentration was maintained constant.

The values for the moisture content for both plantain glycerol and sorbitol were noted to be greater than yam bioplastic. Bioplastic samples with sorbitol had the highest values of moisture content, then that of glycerol. This is due to the fact that the addition of plasticizer decreases absorption of water.

The control samples of both plantain pees had the highest absorption rates of water. The reason for this could be that the hydroxyl group in starch has an affinity for water molecules and the gelatinization also breaks up starch granules which lets water diffuse in. however, the inclusion of plasticizers reduces water absorption. The samples that had been plasticized with sorbitol had the greatest rate of water absorption because it has a higher attraction to water molecules compared to glycerol. Therefore, the higher the water absorption, the lower its plasticizing strength and the lower the water absorptivity, the higher its plasticizing strength.

Studying the mechanical properties of bio plastics is essential to find their usability. Samples of glycerol had the lowest values for tensile strength and sorbitol had the highest value.

The highest colony count of 1.2 x 10^6 CFU/2g was recorded in the 5cm deep completely degraded bioplastic. The lowest count was observed to be 1.0 x 10^6 CFU/2g for 10cm completely degraded bioplastic. Of the 6 bacterial isolates, 4 (75%) were *E. coli.*, 4 (75%) were *Enterobacteraerogen*, and 4 (75%) *Micrococci* which makes both the most dominant bacterial isolates in each burial site while Bacillus sp. was present in all of the sample's burial sites.

Conclusion

In this work, bioplastic using glycerol, sorbitol, and filler were successfully synthesized from yam and banana peels successfully. It can also be concluded that variations in the concentration of sorbitol and glycerol plasticizers affect the mechanical properties of bio plastics namely tensile strength, absorptivity test and moisture content. And according to result obtained, sorbitol was a better plasticizer than glycerol. The difference in these concentrations allows bio plastics to be suitable for varying applications. All the bio plastics produced were biodegradable and environment friendly, thus a good substitute for petroleum-based plastics, and an efficient way to alleviate the problem of pollution.

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