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Comparative Mechanical Properties of Cassava (*Manihot Esculenta)* and Potato (*Ipomoea Batatas*) Peel Starch Biodegradable Plastics in Food Packaging

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ABSTRACT

This study aimed to compare the mechanical properties of cassava (*Manihot esculenta*) and potato (*Ipomoea batatas*) peel bioplastics as a food packaging materials to synthetic plastics. These findings highlight the potential of cassava and potato peel bioplastics as a viable alternative to traditional plastic packaging materials, with the added benefit of being biodegradable and environmentally friendly. The results showed that bioplastics from cassava and potato peels have mechanical properties comparable to conventional plastics a packaging material. The tensile strength, toughness, and breaking force increased with increasing glycerol concentration from 2 to 5%, while the water absorption and elongation at break decreased. Results showed that the cassava peel bioplastics with a plasticizer concentration of 5% had the highest tensile strength and elongation at break. On the other hand, the potato peel bioplastics with a plasticizer concentration of 3% had the highest tensile strength. The shear strength and thickness remained relatively constant across all concentrations and it gives futuristic insights on studies can be conducted to optimize the concentration of glycerol and other additives to improve the mechanical properties of the bioplastic. Overall, this research contributes to the development of bioplastics and promotes the utilization of agricultural waste as a valuable resource in the production of sustainable materials.

Keywords: *Bioplastic, Mechanical Properties, agricultural waste, Cassava, Potato*

INTRODUCTION

Materials frequently referred to as 'bioplastics' have been proposed to minimize the strain on both the petroleum resource base and the environment, while the preferable phrase is 'bio-based polymers', to underline that they are generated from renewable/sustainable biological resources. Ideally, these are also 'biodegradable polymers,' which means they can be degraded in the environment by microorganisms. Decomposition may be aided by the same abiotic chemical events that are involved in the disintegration of conventional plastics, such as photodegradation, oxidation, and hydrolysis. (Luckachan and Pillai, 2011). It has been concluded that, taken as part of a combined strategy of 'reduce, reuse, recycle', the implementation of biodegradable polymers could usefully help to reduce the quantity of plastic pollution in the environment; however, any significant substitution of conventional plastics by them will require further advances in Research and Development most significant proposing is hybrid plastics and reinforced bioplastic with wool and fibers. Uwanta *et al* (2023) showed that several *Pseudomonas spp* isolates present a in 60-day vermiculture produced from sludge gotten from a plastic manufacturing site possess the capacity for synthetic plastic (polyvinyl alcohol and polyvinyl chloride) degradation. Some researchers have reported polyvinyl alcohol and polyvinyl chloride degradation by various *Pseudomonas* spp and posited that they have the capacity to not just degrade plastics but also play a key role in xenobiotics and reclaiming many habitats polluted with microplastics and nanoplastics. It has also been concluded that, when combined with a 'reduce, reuse, recycle' strategy, the use of biodegradable polymers could help to reduce the amount of plastic pollution in the environment; however, any significant substitution of conventional plastics by them will necessitate further advances in Research and Development; the most significant proposal is hybrid plastics and reinforced bioplastic with wool and fibers. Some biodegradable polymers are naturally formed by plants, animals, or microorganisms, while others are synthesized. Polylactide (also known as polylactic acid) (PLA), polyglycolide (PGA), polycaprolactone (PCL), polyhydroxyalkanoates (PHA), poly(butylene succinate) (PBS), and poly(butylene adipate-co-terephthalate) (PBAT) are the most frequently seen. (Luckachan and Pillai, 2011)- of the above-mentioned materials, PLA is seen to be the most promising because it is made from lactic acid, which can be obtained sustainably from corn and other crops. (Elvers *et al*., 2016; Luckachan and Pillai, 2011). PLA has been used successfully for biomedical applications and packaging due to its mechanical strength and low toxicity (Luckachan and Pillai, 2011), and it can be used to fabricate medical implants such as anchors, screws, plates, pins, rods, and meshes because it breaks down within the body over a period of 6 months to 2 years to form lactic acid as a harmless product. (Auras *et al*., 2010).

The study looks at Comparative Mechanical Properties of Cassava (*Manihot esculenta)* and Potato (*Ipomoea batatas*) Peel Bioplastics in Food Packaging.

MATERIALS AND METHODS

BIOPLASTIC SYNTHESIS FROM CASSAVA AND POTATO PEEL SEARCH

90ml of glycerol at concentrations of 2, 3, and 5% (v/v) was stirred for 5 minutes on a magnetic stirrer at 900 rpm, 5ml of vinegar was added to the mixture. The solution was heated on a magnetic stirrer at 80°C for 45 minutes while being stirred at 900 rpm with cassava/potato peel starch at a concentration of 5.0% (b/v). The bioplastic solution was put into the proper mold, dried in a 50°C oven for 24 hours, and then stored in a desiccator (Wahyuningtiyas and Suryanto, 2017).

MECHANICAL PROPERTY TESTS ON BIOPLASTICS

a. **Tensile Test (ASTM D638-14, 2015)**:

Tensile test is a measure of the magnitude of axial force required to separate a rigidly fixed body over a unit area of that given material/body. To carry out the test, **THE UNIVERSAL MONSANTO TENSOMETER MACHINE** was used. This machine as the name applies was used to carry out many mechanical properties of certain materials by choosing the rightful accessory for the specific test. In carrying out tensile test, ASTM standard for bio-plastics specifies the dimension of the sample as (100x19) mm. that is, the length x breadth of the sample with the bio-plastic thickness. The cut out specimen was inserted into the tensile accessory of the testing machine and locked up appropriately. The axial load was applied gradually by manual means and the effect of the loading was recorded on the machine graph. The machine graph draws load/extension relationship of the material. The test was controlled by a working fluid (mercury in glass) which indicates when the material has been separated apart. At the point of separation of the sample into two, the test was stopped and the material removed. The machine graph is interpreted into tabular form from where the tensile strength of the specimen will be determined as shown below:

Tensile Strength: $\frac{\text{Maximum applied load}}{\text{Cross-sectional area of the specimen.}}$

(Cross-sectional area calculation is given as: breadth x thickness)

b. Water Absorption Percentage

All the bioplastic films will be cut into 2 cm × 4 cm dimension and was dried at 60 °C in hot air oven. Initial mass of the films was noted. The films was immersed in the water for 24 h. The mass after immersion was measured.

$$\text{Water absorption \%} = \frac{M_1 - M_0}{M_0} \times 100$$

Where, M_0, M_1 = mass of the sample before and after immersion of the sample, respectively

c. Material Toughness (ASTM D638-14, 2015)

Material Toughness is defined as the ability of the material to absorb energy and physically deform without fracturing. In carrying the test, we measured the weight volume of the specimen first using the Venier caliper. The energy of the sample was determined after the sample have been subjected to compressive force at elastic point. **That is, Energy: maximum deformation x applied compressive load.** So the toughness was therefore be calculated using the equation.

Toughness: $\frac{\text{Energy}}{\text{Weight volume.}}$

d. **Elongation at Brake (ASTM D638-14, 2015)**:

Elongation is a measure of ductility of a material. By ductility we mean the magnitude of extension over a given amount of load. To determine elongation, we carried out the tensile test. We measured the initial length of the sample as L_O and after rupture, the materials final length L_1 is also measured.

The elongation at brake was defined by L_1-L_O and it is measured in (mm).

e. **Shear Strength (ASTM D638-14, 2015)**:

Shear strength is a measure of a materials ability to withstand tearing effect when exposed to shear forces. To carry the test out, the Monsanto Tensometer was used. The shear spindle was attached to the shear chamber of the machine. The diameter of the spindle was measured and recorded. The sample is fixed in the machine. Once the spindle pieces through the sample, the piecing force was recorded on the machine graph.

Shear strength is defined as: $\frac{\text{Shear force}}{\text{Area of the spindle.}}$

f. **Braking Force (ASTM D638-14, 2015):**

Braking force is defined as the axial pull that can cause a sample to be pulled apart when exposed to tension. It will be calculated from the machine plotted graph and it will be measured in Newton (N).

g. **Hardness Determination (ASTM D638-14, 2015):**

The hardness of a material signifies how resistant it is to abrasion, indentation, scratching, and plastic deformation under compressive load. Material hardness can be determined through Brinell hardness test. In carrying out the test, sample of the specimen was inserted into the indentation chambers of the testing machine (monsantor tensometer). The size of the indenter popularly called the Brinell bulb was measured and recorded. The material will therefore be subjected to a constant axial load. The depth of indentation was measured on the machine graph which was later interpreted and recorded as follows:

$$BHN: \quad \frac{2P}{\pi D\sqrt{(D-\sqrt{D2-d2})}}$$

Where

BHN = Brinell Hardness Number (kgf/mm^2)

P= Applied Load in Kilogram-Force (kgf)

D= Diameter of indenter (mm)

D= diameter of indentation (mm)

h. **Thickness Measurement (ASTM D638-14, 2015)**:

Thickness is a definition of how thick or light the material. It measured using the digital Venier caliper calibrated in millimeter (mm).

RESULTS AND DISCUSSIONS

Table 1: Table showing the Mechanical Properties of Cassava and Potato Peel Bioplastics

	Tensile strength (Nmm^2)	**Water absorption (%)**	**Toughness**	**Shear strength**	**Breaking force (N)**	**Hardness**	**Thickness (mm)**	**Elongation at break (mm)**
C95	**3.74 ± 0.11**	**19.42 ± 0.82**	**2.95 ± 0.55**	**8.74 ± 1.51**	**6.04 ± 0.34**	**1.66 ± 1.34**	**0.15 ± 0.13**	**6.30 ± 2.01**
P95	**2.25 ± 0.15**	**23.88 ± 1.04**	**1.83 ± 0.09**	**5.94 ± 0.75**	**4.98 ± 1.37**	**1.27 ± 1.67**	**0.13 ± 0.06**	**11.33 ± 3.51**
C97	**3.80 ± 0.03**	**23.77 ± 1.11**	**3.37 ± 0.14**	**6.48 ± 2.64**	**9.15 ± 1.23**	**1.68 ± 1.33**	**0.17 ± 0.11**	**6.83 ± 1.45**
P97	**2.87 ± 0.03**	**28.96 ± 3.26**	**2.68 ± 0.12**	**7.49 ± 1.60**	**9.49 ± 2.47**	**0.89 ± 0.47**	**0.13 ± 0.05**	**9.67 ± 1.52**
C98	**3.68 ± 0.03**	**34.8 ± 3.61**	**4.24 ± 0.21**	**7.65 ± 1.14**	**9.55 ± 3.74**	**1.48 ± 0.60**	**0.08 ± 0.02**	**7.23 ± 1.25**
P98	**2.06 ± 0.71**	**33.41 ± 1.45**	**3.15 ± 0.21**	**5.62 ± 2.07**	**8.19 ± 1.67**	**0.61 ± 0.71**	**0.17 ± 0.05**	**10.1 ± 0.98**
***p* value**	**0.001**	**0.001**	**0.002**	**0.662**	**0.165**	**0.936**	**0.976**	**0.248**

Key:

C: Cassava based bioplastics

P: Potato based bioplastics

DISCUSSION

The study result in Table 1 shows that the mechanical properties of cassava and potato peel bioplastics as follows**.** The Tensile Strength of the Cassava peel bioplastics showed a range of values from 3.68 - 3.80 Nmm^2 and have a slightly higher tensile strength than potato peel bioplastics (2.06 - 2.87 Nmm^2), indicating their better resistance to pulling forces exerted on the varying glycerol-starch based synthesis. Harunsyah *et al* (2017) illustrate the tensile strength properties that indicates the concentration addition tendency of glycerol as plasticizer could increase elongation percentage and reduce tensile strength. The maximum tensile strength obtained was 22.30 kgf/mm^2 (218.673 Nmm^2) on addition of zinc oxide by 0.6 percent and plasticizer by 25%. This values slights exceeds the value obtained due to the addition of zinc oxide served as strong antimicrobial agent and reinforcement of the starch-

based plastic increasing the tensile strength. The Toughness of the Cassava bioplastics (2.95 - 4.24 Nmm) generally exhibit higher toughness than potato bioplastics (1.83 - 3.15 Nmm), meaning they can absorb more energy before breaking. Notably, C98 (3% glycerol) shows the highest overall toughness. Breaking Force While C98 (cassava) has the highest breaking force (9.55 N), P97 (potato) closely follows (9.49 N). Both seem superior to other samples, indicating better resistance to breaking under applied force. The Elongation at Break Potato bioplastics (9.67 - 11.33 mm) demonstrate significantly higher elongation at break than cassava bioplastics (6.30 - 7.23 mm). This indicates greater flexibility in potato-based materials. The results shows symmetry with the Elongation (E %) determined by (Muhammed, *et al* 2020) helps to determine the flexibility and stretch-ability of films. The greater the elongation, the greater will be the flexibility. Mean elongation of starch films for different treatments (Non treated, HTTS and AATS) and varying plasticizers (glycerol and sorbitol) concentration (35%, 45% and 55%) varied from 2.5% for ATTS film (55% sorbitol) to 11.5% for HTTS film (35% glycerol). Plasticizers concentration and modifications showed significant effect ($P<0.05$) in elongation of films. HTTS film with low concentration of the glycerol addition increased the elongation of the films. Glycerol having less molecular weight produced more plasticization might have caused more elongation. Thickness Both cassava and potato bioplastics have similar thicknesses (0.08 - 0.17 mm), suggesting comparable applicability in thin-film applications. Hardness Cassava bioplastics (1.48 - 1.68 Shore D) have slightly higher hardness than potato bioplastics (0.61 - 0.89 Shore D), suggesting better scratch resistance. Water absorption shows an inverse variation significantly between the two types of starch-based plastic (as the concentration of glycerol increased the water absorption pattern of the plastic decreased), with potato peel bioplastics showing higher values. This might influence their suitability for different applications. This results varies greatly with the work of Olugbenga *et al* (2021) that shows water absorption can be reduced or prevented by adding additives or by using a chemical modifed starch matrix during the preparation of the bioplastic. Bioplastic flm prepared with dialdehyde starch solution had a water uptake of 75.73% for $film_{di}60$, 60. 57% for $film_{di}80$, 58.10% for filmd100, and their corresponding bioplastic produced with added silica solution had 78.40% for $film_{si}60$, 74.57% for $film_{si}80$, and 69. 93% for $film_{di}100$. The results revealed a reduction in water uptake as the amount of added dialdehyde starch and silica solutions increased. The Shear strength shows a slight insignificant variation across the potato and cassava based bioplastic.

CONCLUSION

This study further looked at the importance of an alternative style plastic using agrobased waste materials putting into perspectives the threats associated with food security- the agrobabsed plastics materials showed great futuristic prospects from assay carried out to determine both the mechanical and physical properties. The research shows that it is important to consider the intended application when choosing between these bioplastics. For instance, if flexibility is crucial, potato-based have showed great prospects. If strength and hardness are priorities, cassava-based options could be better suited- the comparative analysis throws more light on decisions based on the specific mechanical properties required for the production and application of bioplastics.

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