

Characterization of Potato Peel Starch-based Bioplastic Reinforced with Banana Pseudostem Cellulose for Packaging Applications

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Abstract:- The development of environmentally friendly bioplastics is an interesting research area nowadays. Potato peel starch-based films reinforced with banana pseudostem cellulose (BPC) at different concentrations (0, 5, 10, 20, and 30% wt) on a dry basis were developed. Cellulose from dried banana pseudostem was obtained by alkali delignification and bleaching. The films were produced by casting and oven-drying the gelatinized mixture of potato peel starch, BPC, and glycerol (plasticizer) at constant weight in all the films. Physicochemical, mechanical, and thermal properties of the films were determined. The films were also characterized morphologically and structurally, including the soil burial method for biodegradability. An increase in BPC concentration improves the physicochemical, mechanical, and thermal properties of the films. The film with 10% BPC has the least moisture content of 18%, has the best mechanical properties (tensile strength of 9.20 MPa, modulus of 188.93 MPa, and elongation at break of 8.66%), and has maximum thermal stability (TGA 270–285 oC and DTA 377 oC). A film containing 30% BPC has the highest opacity and thickness, also with a maximum DTA of 377 oC. Surface morphology revealed a smoother surface of the films as the concentration of BPC increased, and functional groups identified showed good interaction among the components of the films. All the films were completely biodegraded within 12 days. This study has shown that incorporation of cellulose powder into starch-based bioplastics gives better bioplastic films as a substitute for petroleum-based plastics.

Keywords:- Pseudostem, Plasticizer, Delignification, Bioplastic.

I. INTRODUCTION

There has been substantial growth in the global production of fossil fuel plastics for many years. Plastics production grew from 0.5 million tonnes in 1950 to over 348 million tonnes in 2017 and packaging covers 39.6% of the total demand for the products, which has been recorded as the largest application of plastics [1]. Plastics are commonly used for packaging because of their distinctive properties such as lightness, cheapness, inertness to the environment, non-permeability, durability, stability, and availability [2] [3]. These properties make plastics stay in the environment for a long time and accumulate as solid waste [4]. The accumulation and persistence of plastics in the environment have become one of the major challenges in the environment because they degrade slowly and can stay in the

environment for hundreds or thousands of years [5]. It is now a serious threat to the environment, contributing to a major part of the land pollution that accounts for up to 25% of the total volume of landfills [6]. The oceans are not left out in the accumulation of plastic waste. Plastic waste's destruction of the marine ecosystem, inadequate waste management system, a low recycling proportion, toxic gas emissions from plastic incineration, plastic non-degradability, and the economic problem of rising fossil fuel prices are all drawbacks of plastics made from fossil fuel or coal tar [2]. Because of this setback, as well as the non-renewable nature of fossil fuels, the development of bioplastics as a significant alternative to reducing the use of synthetic or fossil fuel plastics has occurred.

Bioplastics are plastics materials produced from renewable biomass sources, such as vegetables, fats and oils, woodchips, starch, sugar, recycled food wastes, agricultural by-products, used plastic bottles [7] and other containers using microorganisms [8]. Bioplastics are considered biodegradable if they are naturally degraded into carbon dioxide and water by microorganisms. Bio-based plastics are obtained from renewable resources containing cellulose, starch, and protein. The most well-known bio-based plastic is Polylactic Acid (PLA). Currently, bioplastics cover close to one percent of the almost 300 million tonnes of plastic produced each year, and 50% of the bioplastics used commercially are prepared from starch [9].

Starch is a natural biopolymer consisting predominantly of two types of polysaccharides that are polymers of glucose, namely amylose and amylopectin. Amylose is essentially a linear polymer of glucose linked together by -1,4 bonds, while amylopectin is a branched polymer consisting of both -1,4 and -1,6, glycosidic linkages. The ratio of amylose to amylopectin in starch is so important and significantly affects its physicochemical properties, functionality, and applications [6]. Availability, biodegradability, renewability, low cost, and thermal stability are among the advantages of starch for plastic [10]. Starch dissolves easily in water as water serves as the primary plasticizer for starch. Naturally, it is difficult to transform starch into plastic because of its brittleness and low mechanical properties, which leads to poor film-forming capacity. These challenges can be addressed by plasticization and blending with other polymers such as cellulose, proteins, and lipids [11][7] [3]. All these conditions and peculiarities of starch for bioplastics are also applicable to the potato peel starch used in this study.

Cellulose is an organic compound, the main component of plant cell walls. Wood, cotton, and banana pseudostem fibre are abundant in cellulose. The glucose units in cellulose are linked by glycosidic bonds. Hydrogen bonds present between contiguous glucose units, both within a chain and between adjacent chains, make cellulose a tougher fibre than glycogen or starch. This makes cellulose acts as a reinforcement material in bioplastics. [12][11] [13]

The cellulose used in this study was obtained from the pseudostem of a banana (*Musa acuminata*) plant. Banana pseudostem is the major banana plant waste that is cut off, left on the plantation, allowed to rot, or burned after the fruits must have been harvested. Banana pseudostem fibre is very rich in cellulose, having cellulose as one of the major constituents [14] but underutilized [12]. The average percentage content of cellulose in banana pseudostem is 49.33% [15]. Numerous research studies have reported the use of banana pseudostem fibre in the fabrication of polymer or fibre composites [16]. Starch-based bioplastics are reinforced with cellulose or cellulose derivatives to improve their mechanical properties, thermal stability, water and gas barriers to suit their purposes, especially for packaging. Also, significant improvement in the mechanical properties of cassava peel starch reinforced with microcrystalline cellulose and sorbitol as plasticizer was reported [11]. It was also reported that nanocellulose from banana pseudostem used in biopolymer enhances the stability of the polymer films from migrating to food simulants and improves tensile strength and contact angle [13]. It is also important to determine the percentage composition of cellulose in the starch matrix that will be best suited for packaging light goods. Therefore, this study investigated the impact of banana pseudostem cellulose powder of 0.2 mm at different percentages on potato peel starch-based bioplastics.

II. MATERIALS AND METHODS

A. Materials

Sweet potato (*Ipomoea batatas* L.) tubers were purchased from a local market in Ado Ekiti, Nigeria and banana (*Musa acuminata* C.) pseudostem was sourced from the farm of Federal Polytechnic, Ado Ekiti, Nigeria. Plasticiser (glycerol), sodium hydroxide, sulphuric acid, distilled water and sodium hypochlorite were obtained from the Chemistry Laboratory, The Federal University of Technology, Akure, Nigeria.

B. Methods: Sample Preparation of Starch from Potato Peel and Cellulose from Banana Pseudostem

Potato Peel starch was obtained as described by [2]. Potato tubers were washed thoroughly with running water and rinsed with distilled water. The cleaned potato tubers were peeled and the peels were granulated and centrifuged at 15000 rpm for 20 min. The supernatant was filtered and starch obtained was dried in the oven at 60 °C for 2 h. The dried starch was kept in an air-tight container until further use. Banana pseudostem (the whole trunk of banana tree) was cut into chips, air-dried and stored for analysis. A 50 g of the dried sample was boiled in sulphuric acid solution (2 g/L) for 2 h to remove pectin and sugar [14]. The pulp was washed thoroughly with excess water until neutral. The neutral pulp was also boiled in 20% NaOH solution for 3 h to remove lignin and other extractible. On cooling, the sample was washed until neutral and ground to obtain paste. The pulp was bleached with 200 ml of 3.5% w/v sodium hypochlorite (NaOCl) and allowed to stand for 12 h [16]. The cellulose obtained was washed with excess water until it becomes white and dried in oven at 102 °C for 2 h. The dried cellulose was ground to powder size and sifted with mesh size 0.2 mm to homogenise the particle size.



Fig. 1: A- Freshly cut banana pseudostem, B- Dried banana pseudostem, C- Delignified and bleached banana pseudostem and D- Banana pseudostem cellulose powder

C. Bioplastic Films Preparation

The cellulose powder was blended with potato peel starch powder at 0, 5, 10, 20 and 30% with 2 g of glycerol added to each blend. Each of the blends was made up to 100 g with distilled water and was placed on hot plate at 90 °C with consistence stirring for 20 min to gelatinise. The gelatinised starch was casted in a polypropylene plate and transferred into an oven at 50 °C for 12 h to dry. The dried films were carefully peeled from the plate and store in a desiccator prior characterisation.

D. Biofilms Characterisation

Moisture Content, Solubility in water and Thickness:

Moisture content, solubility in water and thickness of the biofilms were determined as reported by [17]

- **Density:** The density was calculated directly from the films weight and dimension (2 x 2 cm²) and it was taken in triplicate.

$$\text{Density} = \frac{M}{Ad}$$

Ad

M is the mass (g), A is the Area (cm²) and d is the thickness of the films

- **Opacity:** Opacity in percentage (%) of the bioplastic films was determined from the light transmittance by measuring transmittance (%) using a double beam Ultra Violet – Visible Spectrometer, Model 1800 manufactured in Japan at 600 nm. The film samples were cut into 4 x 1 cm² and attached to one side of the colorimetric cup while the empty colorimetric cup was used as control. The relative opacity of the films were measured in triplicate and calculated using the formula below:

$$\% \text{ Opacity} = \frac{A_{600\text{nm}}}{X}$$

X

Where A_{600nm} is the Absorbance at 600nm, X is the film thickness (nm)

- **Structural and Morphological Analysis:** Biofilms functional groups were evaluated using Fourier-Transform Infrared (FTIR) spectrophotometer (Perkin Elmer TGA 4000). The scanning electron microscopy (SEM) analysis was performed to examine the surface morphology of the biofilm samples using SEM model PhenomProX, by phenomWorldEindhoven, Netherlands.
- **Thermal Stability Analysis:** Thermal stability of the films was determined using thermo-gravimetric analyser (Perkin-Elmer TGA 4000) at the temperature range of 30 °C and 950 °C
- **Biodegradability of the Bioplastics:** Soil burial method was used for the determination of biodegradability of the five samples as reported by [18]. Each sample with size 2 x 2 cm² was weighed (W₁) and buried in the soil of 10 cm

deep. This test was carried out at room temperature (26-28°C) and 80-85% humidity for 12 days. The samples were taken out from the soil, cleaned, dried at room temperature (26-28 °C) for 24 h and weighed (W₂) at interval of 3 days. The reduction percentage of bioplastic was determined with equation below:

$$\% \text{ Weight loss} = \frac{W_1 - W_2}{W_1} \times 100$$

W₁

Where; W₁ is the original weight of samples; W₂ is the weight of samples after the degradation time

- **Mechanical Properties:** The mechanical properties were determined using Universal Testing Machine (Instron Machine-Serie 3369) in accordance with ASTM D 88-02 (2002) method. Films were cut into 25 mm wide strips and at least 10 cm long, the instron series load capacity was 50 KN equipped with long-travel extensometer and 0 to 550 nm extensometer. The loading was continuously measured by a load transducer (load cell) mounted between the specimen and the crosshead. The parameters determined were: tensile stress (MPa), elongation at break (%) and Young's modulus (MPa). The test was done in triplicate.
- **Statistical Analysis:** All the data of the analyses obtained were investigated and the standard deviation of all measurements was calculated and subjected to statistical analysis using Statistical Package for Social Sciences (SPSS) software 23 for ANOVA method. Significant differences (p<0.05) between the means were also determined.

III. RESULTS AND DISCUSSIONS

A. Physicochemical Properties of Bioplastic films Prepared

The results of the physicochemical properties of the bioplastic films prepared are presented in Table 2.

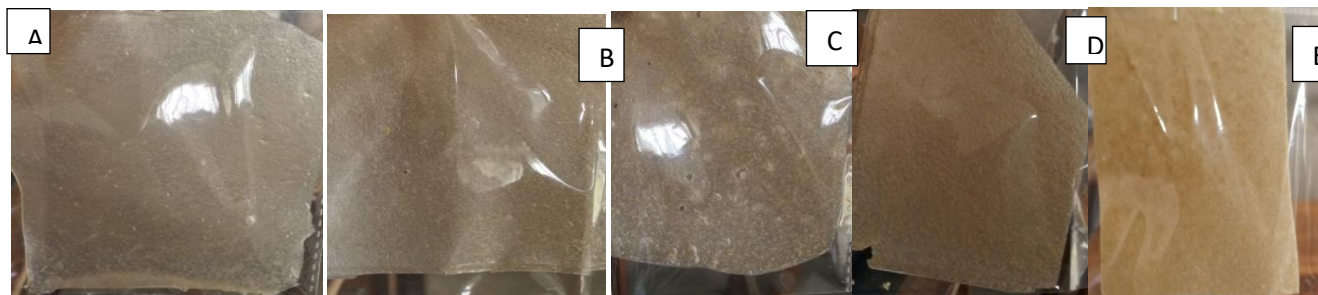


Fig. 2: Potato peel starch-based biofilms, A-with 0% BPC, B- with 5% BPC, C- with 10% BPC, D- with 20% BPC and E- with 30% BPC

Film (% BPC)	Moisture %	Opacity %	Water solubility %	Thickness Mm	Density g/cm ³
A 0%	30.24±0.05 ^a	0.33±0.25 ^d	54.07±0.03	0.23±0.03	0.27±0.02
B 5%	22.64±0.12 ^c	0.66±0.01 ^c	27.09±0.02	0.24±0.02	0.24±0.04
C 10%	18.34±0.05 ^e	0.86±0.04 ^b	25.82±0.03	0.25±0.02	0.22±0.03
D 20%	20.05±0.05 ^d	1.06±0.02 ^a	25.02±0.08	0.31±0.02	0.19±0.02
E 30%	25.04±0.05 ^b	1.09±0.25 ^a	28.17±0.03	0.34±0.02	0.19±0.03

Table 1: Physicochemical properties of the prepared films

The moisture content of bioplastics is an important characteristic of concern. As bioplastic is aimed at serving as an alternative to conventional plastic, its moisture barrier properties should be improved. As shown in Table 1, the moisture content of the biofilms produced decreases with an increase in the concentration of banana pseudostem cellulose (BPC). Film A, the control sample with 0% BPC, has the highest moisture content of 30%, while film C, with 10% BPC, has the least moisture content of 18%. The decrease is due to the hydrogen bonding of the cellulose network with starch [19]. The decrease may also be attributed to the hydrophobic properties exhibited by highly crystalline cellulose fibres in contrast to the hydrophilic nature of starch-glycerol. This hinders the passage of moisture within the films [20]. The least value observed in film C implies a longer life span of the film and would serve as a good packaging material. This applies to water solubility; films with low water solubility are preferred for packaging purposes [21]. There is a significant decrease in the solubility of the films prepared. As shown in Table 1, water solubility decreases as the concentration of the cellulose in the films increases. Cellulose exhibits its hydrophobicity in the films, thereby shielding the solubility of the biofilms in water. Reference [22] backs up this claim. It was stated that the introduction of sugar palm fibre particles, which contain 43% cellulose, into sago starch lowers the water solubility and absorption of the films produced. A report from [23] also stated that upon the addition of fillers into starch-based biofilms, the biofilms' water solubility decreases. This is because banana pseudostem cellulose is slightly soluble or insoluble in water.

Opacity is a measure of the impenetrability of electromagnetic radiation (especially visible light) of the films. Film E, with the highest concentration of banana pseudostem cellulose (BPC) at 30%, has the highest opacity (1.09%), which implies the least transparency among other films. The film with 0% banana pseudostem cellulose (BPC), which serves as the control, has the lowest opacity, which indicates the highest transparency. The increase in opacity with the increase in the addition of BPC could be as a result of the blockage of pores in the films as more cellulose is added. The presence of cellulose causes the

films to be heavier and probably reduces the passage of ultraviolet and visible light. This is very important because passage of radiation into the packaging material may expose the content to ultraviolet and visible light, and if the content is food, there is a possibility of loss of nutrients and flavour [24]. This result also agrees with [21], who reported that the addition of cellulose from sugar bagasse to corn starch increases the cloudiness of the starch-based films. Likewise, the film thickness as presented in Table 1 increases as the concentration of cellulose in each film increases, the thickness also increases. It was established that thicker films have higher elongation due to the high density of the polymer matrix and high inter and intramolecular interactions [25]. The thickness of the developed films was found within the range of 0.26 mm and 0.34 mm, which is higher than what was reported by [26], who found that the thickness of several starch films made up of potato, rice, wheat, gelatin, and sorghum was 53 to 63 microns, which was much lower than the result of this study. The result of this study is almost in the same range with the report of [9], whose average thickness of the bioplastic developed was 0.25mm, which was claimed as good for packaging as it was far above the minimum of 50 microns recommended by the government of India for packaging films. Reference [27] stated that in packaging materials, the thicker the materials, the lower the permeation to environmental pressure. In this study, density is subject to the dimension and thickness of the prepared films. From Table 1, the density of the control sample is higher than other samples reinforced with BPC. The density decreases as the concentration of the BPC increases. This is in agreement with the report of [11], who reported that the addition of microcrystalline cellulose to cassava peel starch decreases the density of the films developed. [28] also reported that the addition of polylactic acid (PLA) into starch-based bioplastic films decreases the density of the films.

B. Mechanical Properties:

Mechanical properties of the films were determined to know the value of important parameters such as tensile strength, young modulus and percentage elongation at break. The results of the mechanical properties of the five samples (films) are presented in Figure 3a, 3b and 3c respectively.

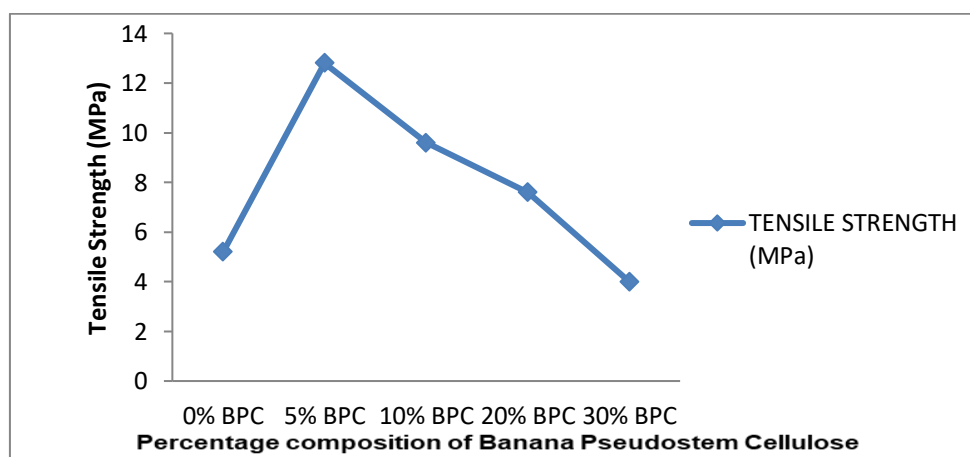


Fig. 3: Tensile Strength of the prepared films

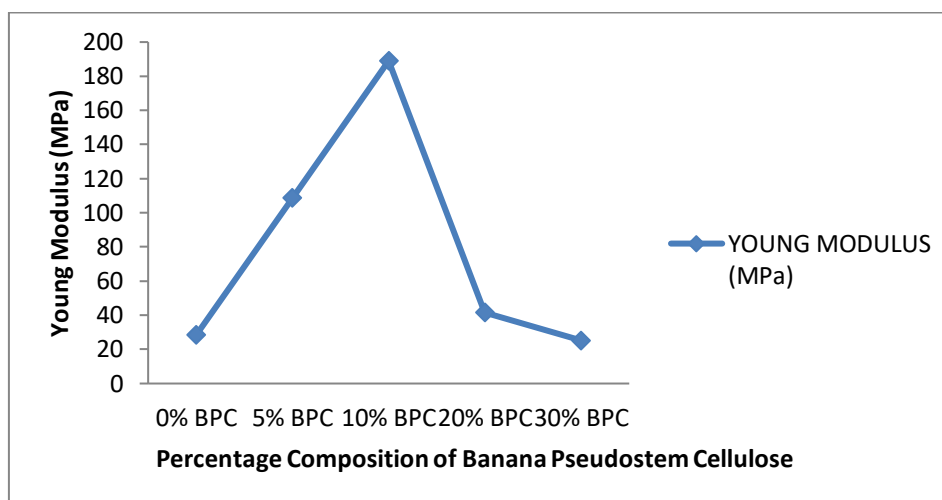


Fig. 4: Young Modulus of the prepared films

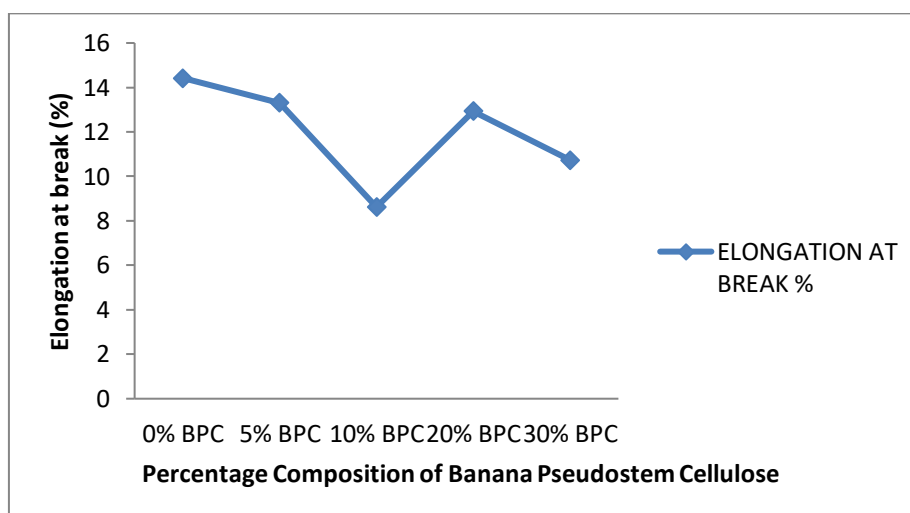


Fig. 5: Elongation at break for the prepared films

The tensile strength of the five films does not have a regular pattern, but an increase with a gradual decrease was noticed starting from the film with 5% BPC to the film with 30% BPC, which is the least value of 4 MPa, lower than the 5 MPa of the control film containing 0% BPC. This pattern of results was found in the reports of [19] and [11]. The increase in tensile strength observed in films containing 5%, 10%, and 20% BPC is an improvement in the strength of bioplastic films which could be attributed to good dispersion and strong molecular interaction formed between the hydrogen bond of the starch matrix and the banana pseudostem cellulose (BPC). [19] [11]. Film with 5% BPC has the highest value of tensile strength with 12.80 MPa and the least value of 4 MPa found in film containing 30% BPC could be due to the higher content of BPC, responsible for weak intermolecular interaction between starch matrix and BPC, leading to a heterogeneous film structure. [12] [29]. In the case of young modulus, a similar case to tensile strength was also noticed. There was an increase in young modulus in films containing 5% BPC with a value of 108.84 MPa, 10% BPC with a value of 188.98 MPa and a drastic decrease in films containing 20% BPC and 30% BPC with a value of

41.56 MPa and 25.24 MPa, respectively. The highest value noticed in a sample was 10% BPC, which indicates the sample having the highest stiffness, followed by samples with 5% BPC and 20% BPC. This increase could be attributed to the degree of dispersion and percentage of BPC in the starch matrix. Low young modulus in a sample containing 30% BPC could be attributed to poor BPC dispersion within the starch matrix [19]. The higher value of young modulus indicated vulnerability to brittleness [12]. Contrary to tensile strength and young modulus values, the increase in BPC content of the films decreases the elongation at break. Percentage elongation at break decreases from 14.42% in the control sample to 10.72% in the least sample with 30% BPC. According to [12] and [11], a decrease in the value is possible due to molecular interaction between the hydroxyl group (O-H) of the starch and the hydroxyl and carboxylic (COOH) groups of the cellulose, which led to high tensile strength and low elongation at break for the films. The decrease in elongation at break was evidence of the brittleness of the film, and such film is suitable for food packaging [30].

C. Fourier Transformed Infrared (FTIR) Analysis:

Bioplastic films developed were examined to identify the functional groups present using FT-IR analysis. The films were investigated for functional groups in the range of 500–4000 cm^{-1} wavelength with their spectra superimposed in Figure 4. The FTIR spectra of the biofilms developed with different concentrations of banana pseudostem cellulose (BPC) reveal the presence of a large number of peaks. A similar pattern of FTIR spectra exhibited by all the samples

indicated similar chemical compositions before and after the addition of BPC [20]. As shown in the spectra, the strong and broad band at 3268.9 cm^{-1} across the five spectra can be assigned to the stretching vibration of the OH group with a broad peak. This indicates hydrogen bonds of starch molecules and also confirms the presence of water (H_2O). Also, strong bands ranging from 2937.1 cm^{-1} to 2929.7 cm^{-1} for the five spectra can be attributed to the C-H stretching vibration of the alkane group or methylene group [20].

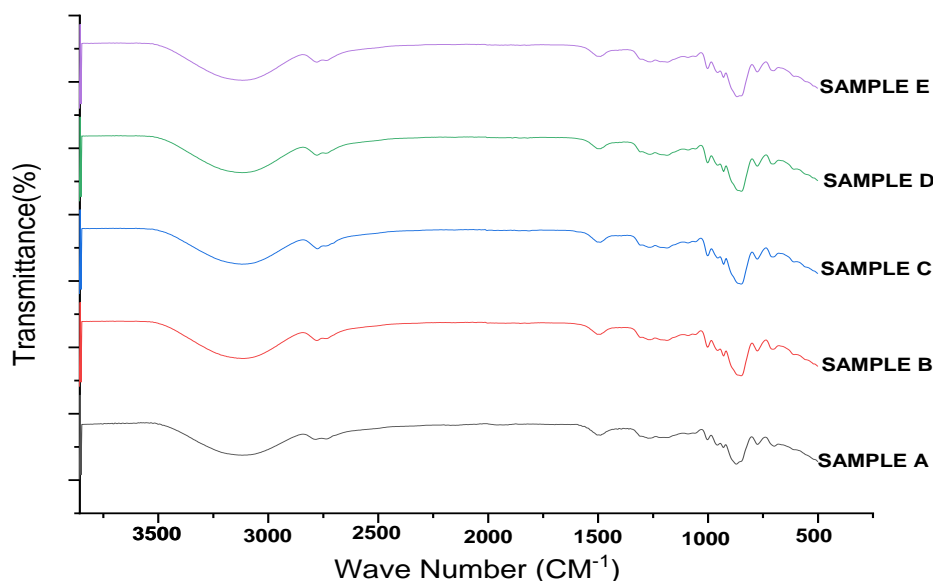


Fig. 6: FT-IR Spectra of Sample B (5% BPC)

Characteristics peak at 2109.7 cm^{-1} for only sample A and B indicates $\text{C}\equiv\text{C}$ stretching of alkynes group. Strong band at 1640 cm^{-1} can be attributed to $\text{C}=\text{C}$ stretching vibration of alkene or active $\text{C}=\text{O}$ group from ring-carbonyl carbons. It was also reported that a close band at 1639 cm^{-1} was attributed to O-H deformation due to loss of water [19] and also shows a carbonyl glucose from the starch [31]. A band at 1237.5 cm^{-1} represents C-O stretching of C-O-H group [32]. Peak observed at $1420.1 - 1408.9 \text{ cm}^{-1}$ maybe due to aromatic $\text{C}=\text{C}$ functional group or C-H deformation of cellulose and bending vibration of methylene group [31]. 1338.4 to 1338.1 cm^{-1} may represents C-H asymmetric deformation of cellulose and hemicellulose [19]. The peaks at 1100 to 1151.7 cm^{-1} may be assigned to C-O stretching vibration of alcohol and the ones at about 849.8 to 853.6 cm^{-1} including bands at 998.9 cm^{-1} of all the five spectra may be attributed to C-H bending vibration of alkenes while bands at $1017.6 - 1080.9$ indicate C-O stretching from C-O-H groups [18]. All the spectra exhibited peaks at the same band range which indicates the same functional groups in all except the absence of peak at 2109.7 cm^{-1} and 1237.5 cm^{-1} in the spectra of films containing 10%, 20% and 30% BPC respectively. The peak at 2109.7 cm^{-1} in the spectra of films

with 0% and 5% BPC with medium intensity disappeared in the remaining three spectra of samples with 10%, 20% and 30% BPC respectively. This indicates no exist peak at the triple bond region of the spectra which could be due to increase in concentration of banana pseudostem cellulose (BPC) added and as a result of good compatibility of starch and cellulose used [33]. Also disappearance of peak at 1237.5 cm^{-1} may be due loss of C-O stretching of starch molecule as a result of increase in concentration of BPC in the films. This is the only functional group added with addition of cellulose. Absence of peak at 1500 cm^{-1} in the spectra indicates complete removal of lignin from banana pseudostem cellulose.

D. Thermal Behaviour:

Thermogravimetry and Differential Thermal Analysis (TG-DTA) were carried out to investigate the thermal behaviour of films. Both thermal analyses were performed simultaneously at temperature range of $30 - 950 \text{ }^\circ\text{C}$ and the results are presented in Figures 5a, 5b, 5c, 5d and 5e for 0% BPC, 5% BPC, 10% BPC, 20% BPC and 30% BPC respectively.

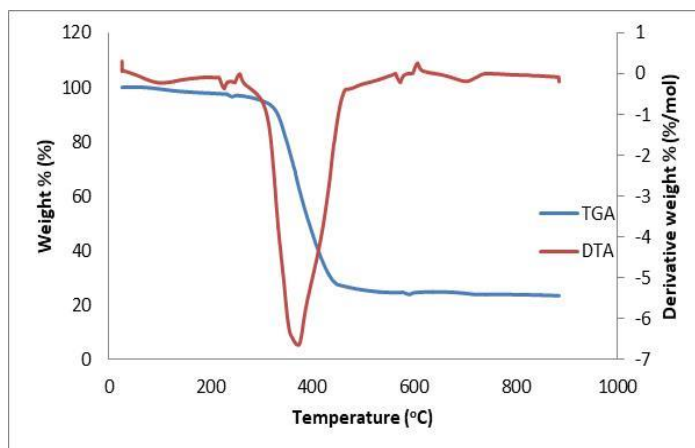


Fig. 7: TGA/DTG curves for sample A (0% BPC)

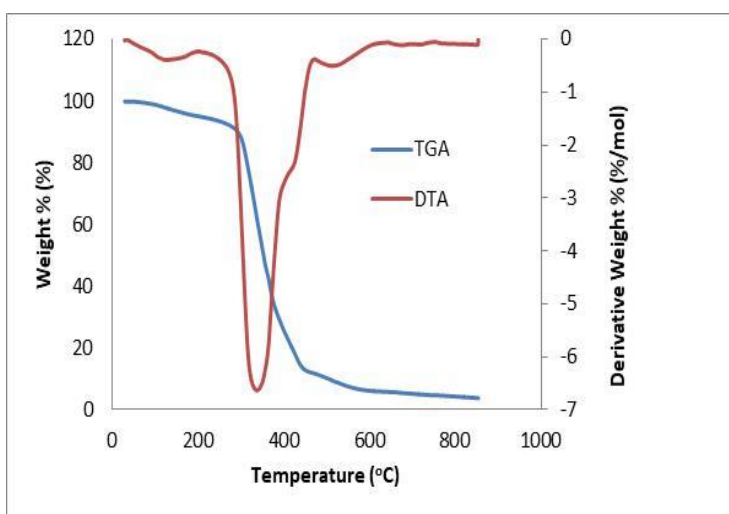


Fig. 8: TGA/DTG curves for sample B (5% BPC)

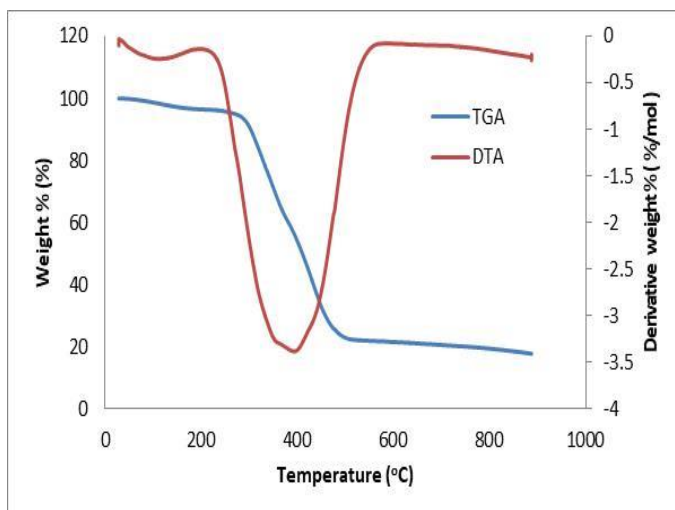


Fig. 9: TGA/DTG curves for sample C (10% BPC)

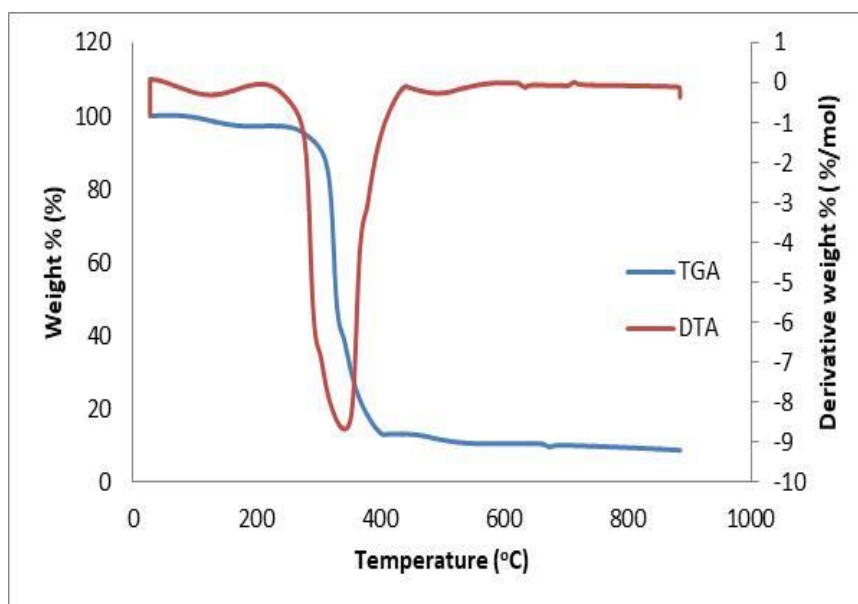


Fig. 10: TGA/DTG curves for sample D (20% BPC)

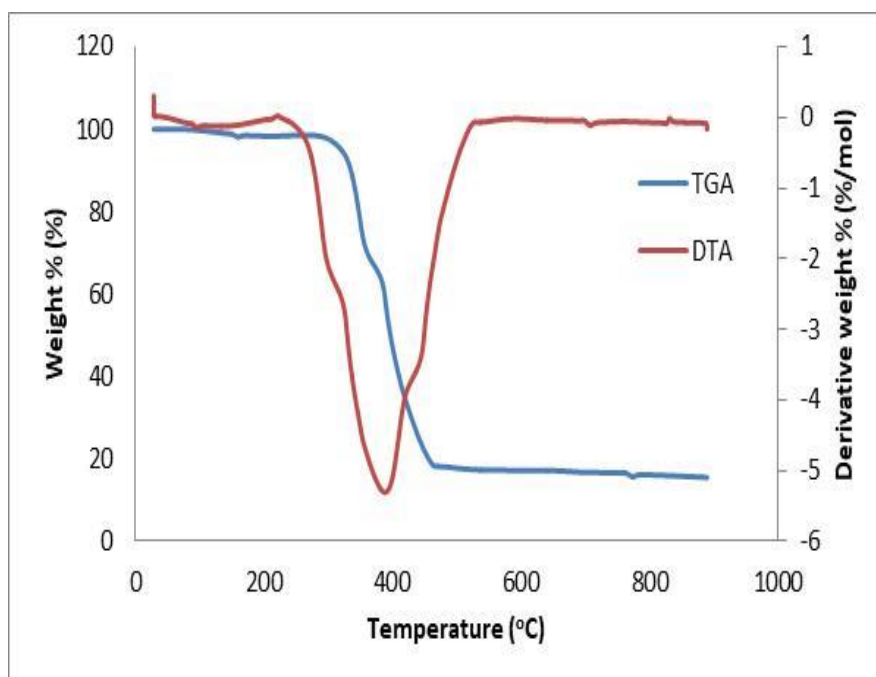


Fig. 11: TGA/DTG curves for sample E (30% BPC)

The thermal behaviour of all the five films gives similar pattern with mass loss in steps as presented in the TGA curves. Gradual loss of weight of the films at around 80-120 °C in the first step can be attributed to evaporation of water and volatile materials in the biofilms. The major weight loss which is the second step at around 295-437 °C, 288-435 °C, 270-485 °C, 270-390 °C and 278-455 °C for film A (0% BPC), B (5% BPC), C(10% BPC), D (20% BPC) and E (30% BPC) respectively were due to pyrolysis of the films and any loss of weight beyond 500 °C can be as a result of decomposition of remaining carbonaceous materials [19]. Reference [17] reported that starch sample for TGA usually gives mass stability at around 180-250 °C which was observed in the TGA curves of all the samples

(films). Also, in DTG curves, one significant peak at 361 °C, 324 °C, 377 °C, 336 °C and 377 °C for film A (0% BPC), B (5% BPC), C(10% BPC), D (20% BPC) and E (30% BPC) respectively shows the temperature of maximum decomposition of all the films. Comparing TGA and DTG curves of the five biofilm samples examined at a temperature range of 25 – 900 °C, the temperature at maximum rate of decomposition (DTG) and thermal stability based on weight loss (TGA) does not have a uniform pattern as it increases with increase in BPC concentration but the highest value at 377 °C for DTG and values for TGA at 270-485 °C and 278-455 °C were observed in sample C (10% BPC) and E (30% BPC), similar result was reported by Agustin *et al.*, (2014). It can be

deduced that sample C (10% BPC) and E (30% BPC) with highest TGA and DTG are more thermally stable than the control (film A with 0% BPC) and other films.

Scanning Electron Microscope (SEM): SEM micrographs of the surface of the bioplastic films developed at varying concentration of BPC with magnification of 500X are shown in Figure 12.

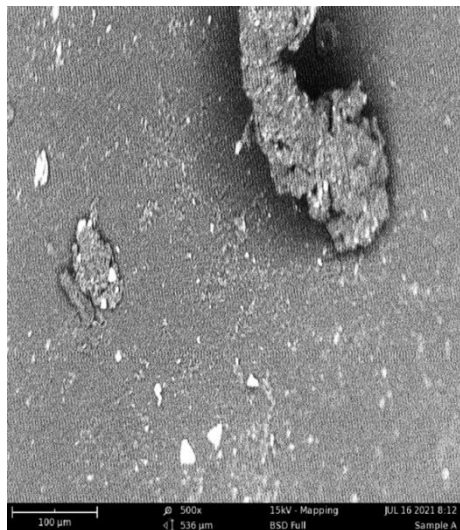


Fig. 12 a: Film A (0 % BPC)

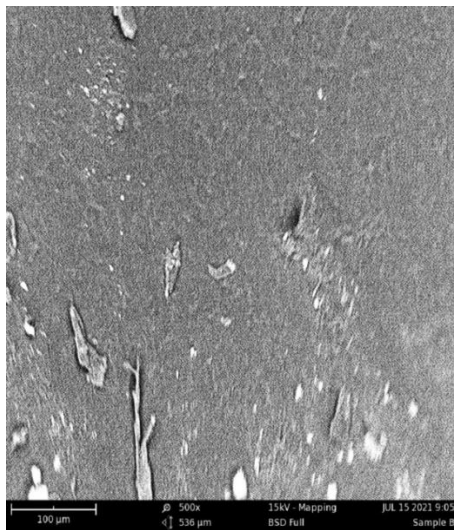


Fig. 12 b: Film B (5 % BPC)

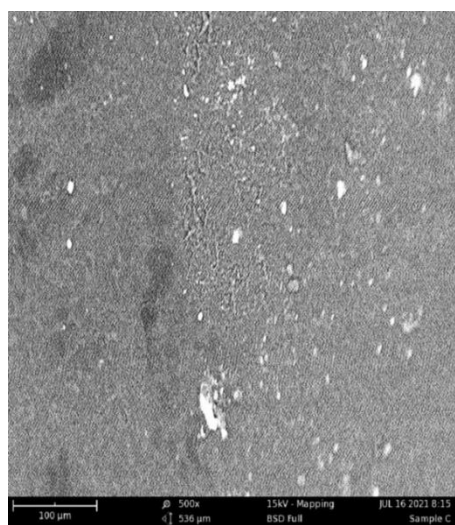


Fig. 12 c: Film C (10 % BPC)

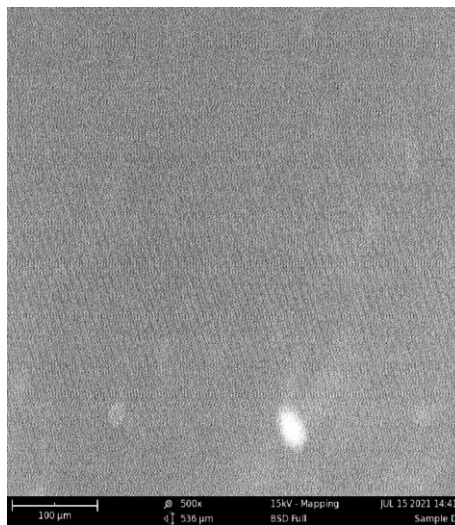


Fig. 12 d: Film D (20 % BPC)

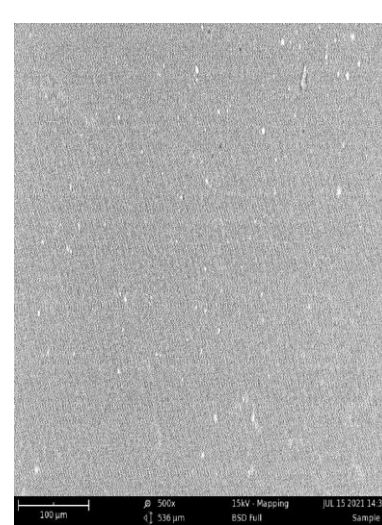


Fig. 13 e: Film E (20 % BPC)

The surface morphology of the samples as examined shows that film A without banana pseudostem cellulose (BPC) has a rough surface with pores and starch granules which may be due to incomplete gelatinization [20], while other films from B to E get smoother with increase in BPC concentration. This is due to uniform size and evenly distribution of cellulose powder used in the starch matrix. Although few pores and starch granules were observed in films B and C but were reduced gradually with smoother films and uniform dispersion as the concentration of BPC increased. Good interaction between components of the

starch matrix gives films compact and uniform structures [34]. These properties make the films good for packaging as the tensile strength has also been improved on with the incorporation of BPC.

E. Biodegradability of the Bioplastic Films Developed:

Soil burial method of biodegradability was adopted. The films were subjected to the same type of soil, the same depth of 10 cm and the same room temperature of 27 °C until all were completely degraded. The result was presented in Figure 13.

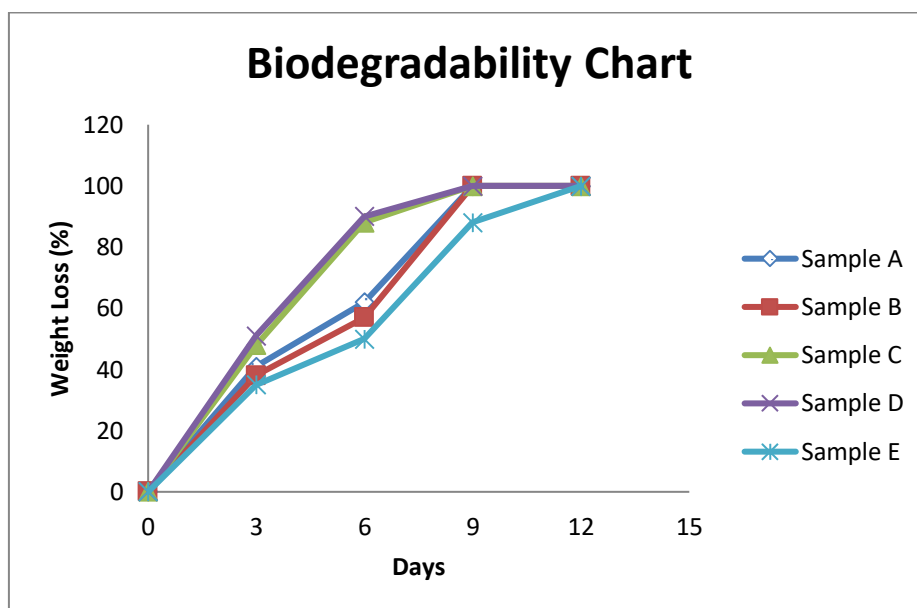


Fig. 13: Biodegradability with Percentage weight loss of the Samples at 3 Days Interval

Sample A-E as labelled in the figure is the same as film A-E

Significant degradation was observed on day 3 in all the films. Degradation at 40 % was observed in film A, 38 % in film B, 48 % in film C, 51 % in film D, and 38 % in film E. On day 6, 63 % of film A was degraded while 57 %, 88 %, 90 %, and 50 % of films B, C, D, and E have been degraded respectively. On day 9, all the films were completely degraded except film E which was at 88 % degradation, and the remaining percentage was completely degraded on day 12. Degradation of all the films in soil was completed in 12 days which shows a better degradation period compared to the reports of some authors [34] [35]. Bio-plastic film developed from potato starch reinforced with chitosan biodegraded within 25 days [35]. The biodegradability result of this study conforms to the report of [18], who reported that corn starch reinforced with banana pseudostem fibre biodegraded within 9 days. Steady weight loss was observed at an interval of 3 days in all the films but was a bit slower in film E than the control film (film A) and other films due to the highest percentage and crystallinity of BPC present.

IV. CONCLUSION

Incorporation of banana pseudostem cellulose (BPC) into the potato peel starch at different percentages decreases the moisture content, water solubility, and density of the biofilms, whereas it increases the opacity and thickness of the biofilms as the percentage content of BPC increases. This shows a good improvement in the physicochemical properties of films containing banana pseudostem cellulose (BPC). The results also revealed improvement in mechanical properties with an increase in tensile strength, young modulus, and a decrease in elongation at break from film A to E. Spectroscopically (FTIR analysis) showed the presence of some functional groups such as alkanes, alkenes, carboxylic, aldehyde, ketones, and hydroxyl groups that can be found in starch, cellulose, and glycerol (plasticizer). This shows good interaction among the components of the films.

The results of thermal analysis also showed that films C and E, both having the highest value (377 °C) of DTG, were more thermally stable than other samples. All the samples buried in soil were completely degraded within 12 days. From the results of this study, it can be concluded that films C (10% BPC) and E (30% BPC) with better characteristics can be used for packaging of light materials.

ACKNOWLEDGEMENT

I wholeheartedly appreciate God for this opportunity and for sparing my life and the lives of everyone who was directly or indirectly involved in ensuring the success of this project.

My sincere gratitude goes to my amiable supervisor, Prof. A.O. Adetuyi, for his understanding, patience, mentorship, and guidance throughout the period of this research work. I am grateful to the Head of the Department of Chemistry, Prof. A. E. Okoronkwo, the PG representative, Dr. M. A. Adebayo, and the entire staff of the Chemistry Department for their immense support during the course of carrying out this research

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