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Evaluation of Bioplastics Production Potentials of Rubber Seed Oil and Cocoyam Starch

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Abstract Plastics abound in the environment and as such there has been a phenomenal rise in their usage in the production of enormous range of products. Despite the relevance of plastics, it has been discovered overtime that conventional plastics constitute nuisance in the environment because measures put in place for their disposal are inadequate, hence the need to produce alternative forms of plastics that are biodegradable and environmentally friendly. Such plastics are referred to as Bio-plastics. The research is thus to investigate the potential of producing bio-plastics using cocoyam and rubber seeds. The raw materials were processed to obtain starch and rubber seed oil using water and an n-hexane as extraction media. Proximate analysis of the starch recorded the following: moisture content (13.13±0.42%), ash content (0.075±0.010%), swelling power (17.60 ±0.91g), swelling volume (8.000±0.001ml), solubility (13.08±0.70), amylase (26.93±0.01%) and amylopectin (73.07±0.10%). Physico-chemical analysis of the rubber seed oil recorded the following: p^H(6.00±0.01), specific gravity (0.91±0.24), melting point (46.0±0.01 ℃), viscosity (10.23±0.20 poise), refractive index (1.42±0.01), acid value (1.62±0.01mgKOH/g), iodine value (135.51±0.03mgI_2/g) and saponification value (192.4±0.03mgKOH/g). The bio-plastic was subsequently produced by copolymerization of the rubber seed oil, starch, binder and plasticizer and then the produced plastic was compared with a polyethylene sample which served as control. The bio-plastic produced was tested in solvent media (ethanol, HCl and water) and the results obtained showed that the bioplastic had poor resistance in acidic media and water, good resistance in basic media and better resistance in alcoholic media whereas the control (commercial plastic) had great resistance in all media. The biodegradability test results, after weighing 0.5g each of both the bioplastic and polyethylene samples and burying in sandy, loamy and clay soil types showed that weight loss was more evident in loamy soil whereas no change was observed for the control, implying that the sample was more biodegraded than the control and best suited in loamy soil.

Keywords Starch, rubber seed oil, extraction, bio-plastic

1. Introduction

The term plastic, derived from the Greek word "*Plastikos*", refers to any material that consists of different natural or synthetic organic compounds that are flexible; hence they can be molded into various shapes such as boxes, plates, tubes and bottles. Basically, plastics are derived from crude oil which is a non-renewable fossil fuel that contributes to a high level of environmental pollution [1]. Plastics have dominance over other materials as a result of their excellent properties which include flexibility, brittleness, high water resistance and resistance to chemical reactions [2-3]. Plastics cannot be disposed by the normal methods used to dispose other waste products such as burying because they are not biodegradable and burning because toxic fumes are emitted at high temperatures which are very harmful on inhalation. Plastics however can be recycled, but this method poses so much difficulty because the plastics have to be collected and sorted. Most developing and even some developed countries have poor waste management facilities which often result in the disposal of these plastics in rivers. Although, recycling is the most efficient method of dealing with plastic wastes, its effectiveness is dependent on several factors like; public awareness, and the implementation of public infrastructures (waste bins and waste disposal trucks) to make recycling efficient. In recent times, production of plastics has been sourced from renewable biological materials which are biodegradable. Such plastics have been referred to as bioplastics [4-5]. Bio-plastics can be used in the production of disposable items such as straws, bowls and cups [6], bags, blister foils, egg crates and bottles for packaging of soft drinks and dairy products and other items such as mobile phone casings and car interiors.

Rubber tree also known as *Hevea brasiliensis* produces seeds which are rich in oil referred to as Rubber seed oil (RSO).

The RSO, a semi-drying oil has been applied in a number of ways such as lubricants, in the synthesis of alkyd resins and soap production [7-10].

Cocoyam as a source of starch has a significant possibility of substituting commercial starch in diverse industrial uses. Comparison studies have shown that starch from cocoyam exhibits traits that are completely different from starch obtained from other sources [11-13]. Although, starch alone cannot be used to produce bioplastics, on modification however, it can produce films which provide good tensile strength and high percentage elongation by either plasticization, blending or genetic modification with other materials [14-15]. Plasticizers employed include glycerol, sorbitol, sugars, urea and citric acid [16]. Starch, among other natural polymers used as raw materials have been found to be a suitable replacement for synthetic plastics because of its low cost, availability and ability to degrade without formation of toxic residues [17-19].

Despite the relevance of plastics, they have been found to constitute nuisance in the environment. They are composed of toxic chemicals which pollute the environment of water, land and air when burnt, because measures put in place for their disposal are inadequate.

There is thus an urgent need to create alternative forms of plastics which are environmentally friendly and can reduce the usage of synthetic (petroleum) based plastics thereby making the environment conducive for human habitation. Such environmentally friendly plastics (the bioplastics) may be sourced from plant substances. The idea is to use plant substances such as starch from cocoyam (least consumed carbohydrate source and can be genetically modified) and oil from the rubber seeds (they are not commonly used and have low economic value) that are given the least attention to.

The aim of the study is to investigate the potential of producing bio-plastics using rubber seed oil and cocoyam starch.

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2. Materials and Methods

Taro (old) cocoyam was obtained from a local market in Port Harcourt, while the rubber seeds were obtained from Gio-saamene Rubber plantation, Nwe-ol in Gokana Local Government Area, all in Rivers State.

The tubers were peeled, washed thoroughly, diced carefully to smaller cubes and blended. The blended cocoyam was then mixed with water to form slurry which was sieved in order to separate the starch granules extract from the cocoyam residue. The slurry was allowed to stand for 1 hour and the excess water was decanted. The slurry was stirred again and sieved, followed by quick water washing which was used to get rid of any residue left in the bowl. The starch slurry was then transferred to aluminium foils and put in an oven for 1 hour.

The rubber seeds on the other were dehulled, cleaned and dried under the sun for about 5 hours after which the seeds were transferred into the oven to heat at 105℃ for an hour in order to remove moisture. The dried seeds were allowed to cool and then ground to paste which was stored in an air tight container. The oil from the seeds was extracted using n-hexane solvent for 168hours in order to ensure maximum separation. The mixture was filtered with a filter paper after which the sludge or residue was discarded leaving just the extracted oil which was then transferred into glass bottles and stored in a refrigerator until ready for use.

2.1. Characterization of starch

Physical characteristics of the starch such as pH and gelatinization temperature as well as Proximate composition characteristics which include Moisture content, Ash content, Swelling Power, Swelling Volume and Solubility were determined following AOAC, (1990) guidelines [20].

2.2. Characterization of Rubber seed oil

The parameters measured with accompanying devices include; pH (pH meter), colour (tintometer), odour (olfactometer), specific gravity (density bottles), viscosity (viscometer), melting point and refractive index (refractometer). Acid value, iodine value, and saponification value, were measured according to AOAC, (1990) guidelines.

2.3. Production of Bioplastic

Bioplastic production requires a polymer (starch), a solvent (water), a plasticizer (glycerol), a binder (vinegar) and oil.

5g of the starch, 2ml of rubber seed oil, 20ml of water, 4ml of glycerol, and 2ml of vinegar were measured into a beaker and stirred properly. The mixture was heated and stirred continuously till a sticky gel-like precipitate was formed. The gel-like substance was then spread evenly on a flat surface and allowed to dry for a week.

2.4. Characterization of bio-plastic

The bio-plastic produced was characterized and its characteristics compared with the characteristics of polyethylene which served as the control

Characteristics determined included: Clarity and transparency, tensile strength, water uptake, heat and chemical resistance, as well as biodegradability of the samples.

3. Results & Discussion

Table 1: Mean levels of physico-chemical characteristics of cocoyam starch

Parameters	Mean Values
pH	6.70±0.01
Gelatinization Temperature (℃)	81.0±0.01
Moisture Content (%)	13.13±0.42
Ash Content (%)	0.075±0.01
Swelling volume(ml)	8.000±0.001
Swelling power (g)	17.60±0.91
Solubility (%)	13.08±0.70
Amylose (%)	26.93±0.01
Amylopectin (%)	73.07±0.10

The characteristics of the cocoyam starch are presented in Table 1. The Swelling power (17.60±0.91g), Amylose and Amylopectin content (26.93±0.01% and 73.07±0.10 %), Gelatinization temperature (81.0±0.01C), Solubility (13.08±0.70%), are in agreement with the ranges (2.29-34.10g), (69.4℃-81.4℃), (0.22- 15.68%), obtained by Wickramasinghe *et al*. [13], Wioletta *et al* [21] and Mweta *et al* [22] respectively. Moisture content (13.13±0.42%) is higher than the result (10.25%) obtained by Omotoso *et al* [23] while ash content (0.075± 0.01%) is low when compared with result (0.55%) obtained by Omotoso *et al* [23].

Table 2: Physico-chemical characterization of rubber seed oil

Parameters	Mean Values
Colour	Amber
Odour	Unpleasant
pH	6.00±0.01
Specific gravity	0.91±0.24
Melting point (℃)	46.0±0.1
Viscosity (poise)	10.30±0.20
Refractive index	1.42±0.01
Acid value (mgKOH/g)	1.62±0.01
Iodine value (mgI_2/g)	134.51±0.03
Saponification value (mgKOH/g)	192.40±0.03

Amber colour was different from the dark brown colour observed by Rubber Research Institute of Nigeria [24]. The specific gravity (0.91), refractive index (1.42) and melting point (46 ˚C) were in-line with the results and ranges (0.916, 1.3-1.6, 45-48 ˚C) obtained by Aigbodion and Bakare [24], Kovo and Bawa [25] and Asuquo *et al* [26] respectively. Acid (1.62mg/KOH) and iodine (134.51mg /g) values were higher than values obtained for pure oil (0.51mg/KOH) and palm oil (52mg/g) by Ascherio and Willet [27] and Onyeike and Ascheru [28]. The saponification (193.6 mgKOH/g) and viscosity (10.23 poise) values are close to the values reported by Abdullah and Salimon, [29] and Asuquo *et al* [26] which are 182 ± 0.27mgKOH/g and 10.32poise respectively.

Table 3: Comparison of characteristics measured in bioplastic and commercial plastic

Samples	Bioplastic	Control (Commercial plastic)
Clarity	Slightly clear	Extremely clear
Transparency	Semi-transparent	Transparent
Thickness (mm)	0.025±0.027	0.010±0.100
Flammability (sec)	137.00±3.54	205
Tensile strength (N/mm^2)	16.72±0.3	15.20±0.01

Table 4: Chemical Resistance and air test on bioplastics

Solvent	Resistance	
	Bioplastic Sample	Control Sample
Ethanol	A, C, D	A,D, F
Conc. HCL	E, G	A,D, F
0.1M NaOH	B,D	A, D, F
NaCl	B, D	A, D, F
Air	A	A
Water	B, E	A, D, F

A: No change in dimension; B: Change in dimension; C: Wrinkle; D: Not dissolved in the solution; E: Dissolved in the solution; F: Not absorbed in the solution; G: Absorbed in the solution

3.5. Biodegradability Test

Table 5: The rate of biodegradability using different soil samples weekly for 5 weeks

Time (weeks)	Sandy soil	Clay Soil	Loamy Soil
1	1.6	1.04	3.12
2	3.2	2.29	6.21
3	5.12	3.18	9.15
4	7.25	4.06	11.36
5	9.50	5.20	13.57

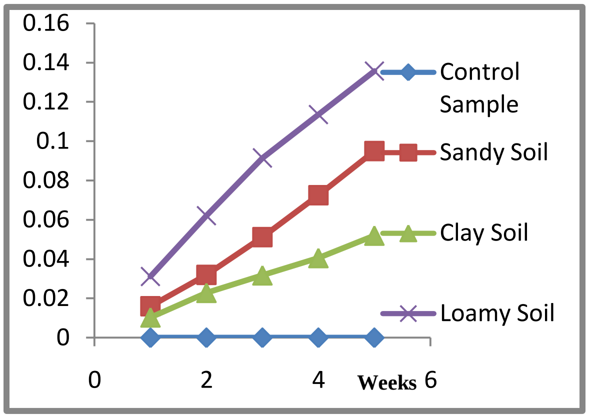

Figure 1: Variations in weight loss of the different soil samples

Tensile strength (Tables 1) performed on the bioplastic and polyethylene control sample were 16.72±0.3N/mm^2 and 15.20N/mm^2 respectively. The value obtained for the bioplastic can be attributed to the glycerol used to improve the mechanical properties while the value of the control sample was found to be lower. More can be done however to improve the quality of bioplastics. For the heat resistance test , the bioplastic samples melted completely when heated in water between 70˚C -100℃ as against the control sample that took longer time to melt. For flammability test, all the samples burnt completely, however, the control sample took longer time.

Chemical resistance and air test performed on the 3 samples, the strong acid (HCl) had serious effects on the bioplastic samples but had no effect on the control sample. In the case of the strong bases (NaOH and NaCl), instead of being dissolved in the liquid, the bioplastic samples were absorbed. The base had no effect on the control sample. When exposed to air, no significant change was observed for both the bioplastic samples and the control samples. When dissolved in ethanol, there was no change in dimension and all the samples did not dissolve. However it was observed that ethanol made the bioplastic samples brittle, hence they broke easily. The bioplastic samples dissolved in water, unlike the control sample where there was no effect at all.

The results from the biodegradability tests as shown in Tables 5 using three different soil types (sandy, loamy and clay) showed that there was significant weight loss and reduction in size of the bioplastic samples when buried for 5 weeks. From the graph (Figure 1), it can be deduced that weight loss and reduction in size was more evident in loamy soil when compared to clay soil and sandy soil. The 3 different soil samples had no effect on the control sample. The weight loss is as a result of micro-organisms in the soil that decomposed the starch and other components used in the production of the bioplastics.

4. Conclusion and Recommendations

This study was carried out with the aim of producing plastics from plant materials that are biodegradable and environmentally friendly. In this stud however, the use of starch from cocoyam and oil from rubber seeds produced plastics that are biodegradable within a short period of time when compared with the control. The bioplastic had poor resistance in acidic media and water, good resistance in alcohol and basic media whereas the control (commercial plastic) had great resistance in all media.

For further research, it is recommended that

- Photostablility tests should be carried out on bio-plastics
- Other natural plasticizers and binders should be used in order to improve the quality of bioplastics.

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