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Biodegradable Plastic from Renewable Source

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ABSTRACT

Materials used for food packaging today consist of a variety of petroleum-derived plastic polymer, metals, glass, paper and board, or combinations thereof. Among these packaging materials, plastic is found to be the best because of its long life properties. Thus, its utilization is increasing every day. However, plastics cannot be degraded by natural processes in a short period of time; therefore, they are left as plastic waste, causing environmental problems. Methods normally used to destroy other types of waste such as burning and burying are not suitable for plastic destruction. In response to these problems associated with plastic waste management, there has been considerable interest in the development and production of biodegradable plastics. The study aims to produce biodegradable plastic using cassava starch as its main component. Cassava and rubber seeds were obtained from Aluu and Omagwa villages in River state. The cassava tubers and rubber seeds oil were processed to obtain the starch and rubber seed oil respectively. The starch (filler) was mixed with water, rubber seed oil (cross linking agent), glycerol (plasticizer), and polyvinyl alcohol (binder). The mixture was heated at a temperature of 105 °C. Two different preparations were made by varying the starch, water, RSO and glycerol content mixture. The first preparation contained 50 grams starch, 50.0 grams water, 50.0 grams PVA, 10.0grams RSO, and 10.0 grams glycerol for the first batch. The mixture was stirred until it forms a thick sticky paste. The paste was then coagulated and passed through a two row mill. The resulting plastics and the polyethylene plastic which served as the control were cut into strips of equal dimensions (100 by 23 mm) for testing. The tensile strength test for the two different batches respectively were found to be 20.56 N/mm² and 12.28 N/mm², while the polyethylene plastic was found to be 11.22 N/mm². The biodegradability test after burying the products for two weeks before unearthing revealed that the samples have biodegraded by reduction in dimensions; 22 by 12mm, and 28 by 15 for the two different batches respectively as against 100 by 23mm dimension for the polyethylene control which remain unchanged. The plastic produced showed biodegradability potential. It is therefore recommended that more work should be done in this field, especially in Nigeria so that we can have cleaner nations by reducing the conventional plastic waste in the environment.

Keyword: plastics, environmental problem, biodegradation, starch and RSO.

1.0 INTRODUCTION

Accumulation of non-biodegradable plastics leads to increase in land and water pollution. Polyolefins including polyethylene and polypropylene are the major plastics to be dumped in the environment and due to their recalcitrant nature persist in the environment. The hydrophobicity, high molecular weight, chemical and structural composition of these polymers hinder their biodegradation (Thompson *et al.* 2009)

Packaging waste forms a significant part of municipal solid waste and has caused increasing environmental concern, resulting in the strengthening of various regulations aimed at reducing the amount generated among other materials, (Lee *et al.*, 1999). A wide range of oil-based polymers is currently used or in combination of more than one material as composites. Most of these packaging materials

enter municipal waste stream at the end of their service life (Jain *et al* 2010)

Since plastics cannot be degraded by natural processes in a short period of time, they are left as „plastic waste“, causing environmental problems. Methods normally used to destroy other types of waste such as burning and burying are not suitable for plastic destruction. When some types of plastics are burnt, they can release dangerous gases to the atmosphere while burying plastics in soil cannot destroy plastics because they are not biodegradable. Degradation at high temperature, such as in pyrolysis (burning) tends to cause emission of toxic fumes. Plastic accumulation in the environment thus creates tremendous problems for the world, presently and in the future. (Demetres *et al*, 2013)

There has been a widespread interest in films made from renewable and natural polymers which can degrade naturally and more rapidly than the petroleum-based plastics. Among all biopolymers, starch is being investigated as a potential material for biodegradable films.

This study aimed to produce biodegradable plastic using agricultural raw materials

2.0 METHODOLOGY

2.1 Collection and preparation of Rubber seed

Rubber (*Hevea brasiliensis*) seeds were collected from from rubber plantation at Omagwa Town in Ikwere Local Government Area of Rivers State. The shells were removed from the rubber seeds to obtain the kernels, The Kernels were the cleaned and dried under the sun for a day. They were later dried in the oven for three hours at 35°C to ensure that water and moisture are removed. 1000g of the kernels was ground using mortar and pestle into a paste in order to weaken and rupture the cell. The resulting paste was stored in a labeled airtight container for oil

2.2 Collection and Preparation of Starch

Cassava tubers were obtained from Aluu, Ikwere Local Government Area of Rivers state. Cassava tubers were manually uprooted from the farm

using cutlass, peeling was done using knife. The tubers were then washed with portable water, followed by mechanical grating of the tubers. The grated cassava was mixed with water (3 ratio 1) water/cassava. the measurement was done using 1000 mL volumetric cylinder. The mixture was then sieved and filtered using a coarse sieve and filter cloth respectively. Thereafter, the filtrate was allowed to settle for six hours. The resulting starch was mixed with water again and allowed to settle for twelve hours. This is called starch washing. At the twelfth hour, it was decanted. The starch (wet) was dewatered manually and then oven-dried at a temperature of 55°C for 4 hours. This was to make sure the starch was in its barest minimum moisture content. Infra red moisture meter was used to analyze the moisture in the processed cassava starch . The processed starch was then kept for further use.

Other materials such as PVA, glycerol and other reagents used for this study were procured from Chizdek Chemicals Ltd, Mission Road , Benin City. Edo State Nigeria.

2.3 Production of plastic

In order to determine the right combination, two batches of plastics with different proportions were prepared.

Batch 1 consists of 50 grams PVA (1:4 ratio Of PVA to water). 50 grams water; 50 grams starch; 10 grams glycerol. And 10 grams RSO

Batch II was composed of 40 grams PVA (1:4 ratio of PVA to water); 65 grams water; 30 grams starch, 4 grams glycerol and 7 grams RSO.;

The measured amounts of water and starch was mixed and boiled, using a hot plate at 100 °C, until a sticky paste was formed. After removing the starch-water mixture from the hot plate, the rest of the materials was then added and mixed, the mixture was later passed through a roll-mill at a temperature of 108 °C. The products were then kept in an open pan for Testing.

2.4 Characterization of the produced samples

The samples produced were cut into strips (100 mm by 23 mm dimension) for testing. Several test were conducted on the samples. The plastics were characterized along the following parameters:

2.4.1 Clarity and transparency:

These parameters were determined by visual assessment of the produced plastic strips.

Thickness:

This was done using vernier caliper

2.4.3 Tensile stress.

Plastic strips were tested using Monsanto tensometer. The individual specimens were cut into 100mm length and 23mm breadth each and their thickness were also measured. The tensile strength was calculated using the formula $\text{Stress} = F/A$

Where F = Force (N) and A = Cross sectional area (mm^2)

2.4.4 Flammability test

In this test, strips of plastics with the same dimensions were burnt using Bunsen burners. Burning time was recorded

2.5 Chemical Resistance

The plastic strips also with the same dimensions of (100mm by 23 mm) were immersed in various solvent media for to ascertain their resistance by measurin change in appearance.

2.5.1 Determination of the effects of strong acid and base

The plastic strips were immersed in concentrated hydrochloric acid (HCl), sodium hydroxide solutions (NaOH) and brine (NaCl) solution for forty eight hours. A change in appearance was recorded.

2.5.2 Organic solvent test

An organic solvent test was also conducted by immersing the material in ethanol for 48 hours. Change change in appearance was also recorded

2.5.3 Determination of the effects of water

The samples still of equal dimension (100 by 23mm) were immersed in a bottle of chlorinated water. The bottle was sealed so as to isolate its contents from the external environment. After a

week, their change in appearance was also recorded.

2.6 Air test

The strips were exposed to open air for a week. Changes in the dimensions were noted and recorded.

2.7 Biodegradability tests

The plastic strips were stapled to a piece of cardboard and buried in a can of soil. The strips were unearthed after two week and their final dimensions measured and recorded.

To serve as control, a similar test was conducted on a commercial plastic of equal dimension. The strip of the control sample was staple to a piece of cardboard paper and buried in a can of soil. This strip was unearthed after two weeks and its dimension measured and recorded.

3.0 RESULTS

Results of the visually assessed product and the control are shown in the table below

Table 1 Clarity Test

Material	Remark
Batch 1	Slight white
Batch 11	Slight white
Polyethylene (PE) control	Extremely clear

Table 2 Transparency Test

Materials	Remark
Batch 1	B
Batch 11	B
Polyethylene (PE) control	A

A = transparent; B = semi-transparent; C = opaque

Similarly, table 3 shows the result of the thickness test of the produced plastic and the control.

Table 3 Thickness of the produced plastics and PE

Materials	Thickness (mm)
Batch 1	0.02
Batch 11	0.02
PE control	0.015

Results of the tensile stress of the produced plastics and PE control are presented in tables 4-6 below

Table 4 Tensile strength for Batch 1

Force (N)	Extension (mm)	Stress F/A (N/mm ²)
0.00	0.00	0.00
5.70	0.45	12.39
6.90	2.00	15.00
9.45	5.00	20.54
9.45	8.25	20.54

Tensile Strength = 20.54 N/mm²

Table 5 Tensile strength for Batch 11

Force (N)	Extension (mm)	Stress F/A (N/mm ²)
0.00	0.00	0.00
2.50	0.32	5.43
5.65	1.75	12.28
5.65	3.80	12.28
5.65	5.70	12.28

Tensile strength = 12.28 N/mm²

Table 6 Tensile strength for polyethylene

Force (N)	Extension (mm)	Stress F/A (N/mm ²)
0.00	0.00	0.00
2.60	1.20	7.50
3.87	2.60	11.22
3.87	4.30	11.22
3.87	5.80	11.22

Tensile strength= 11.22 N/mm²

Results of the flammability test are presented in table 7 below

Table 7 Flammability result

Materials	Flammability (s)
Batch 1	122
Batch 11	180
PE control	75

Results of Chemical resistance of the produced plastic and the PE control in various solvent media and air are presented in tables 8 below

Table 8 Result of Chemical Resistance

Solvent media	Resistance		
	Batch 1	Batch 11	PE Control
0.1M HCl	A, B	A, B	C, E, G
0.1M NaOH	C, F	C, F	C, E, G
NaCl Solution	C, F	C, F	C, E, G
Ethanol (50%v/v)	C, E	C, E	C, E, G
Water	C, D	C, D	C, E, G
Air	C	C	C

A = Change in dimension
 B= Wrinkle
 C = No change in dimension

D = Dissolved in the liquid and solution
 E = Not dissolve in the liquid and solution
 F= Absorbed the liquid and solution
 G= Not absorb the liquid and solution

The result of the resulting dimension of the produced plastics and the control after unearthing are presented in table 9 below

Table 9 Result of the biodegradability test.

Materials	Change in Dimension (mm)
Batch 1	22 by 12
Batch 11	28 by 15
PE control	100 by 23

4.0 DISCUSSION

Tables 4-6 shows the results of the tensile stress tests performed on the biodegradable film from Batch 1, 11 and polyethylene control respectively, displaying the forces applied and their extensions with their corresponding stress calculated.

From the results, it can be observed that Batch 1 which is the biodegradable film has the highest tensile strength and this could be as a result of the quantity of glycerol used in the film production which was added to improve its mechanical strength. The strength is much higher than that of polythene which has the least tensile strength; and therefore failed at a very short period of time when load was applied.

The result also show that the biodegradable film produced has higher mechanical strength than that of the polythene and hence can substitute it (that is; the conventional plastics used for packaging).

The difference in the amount of starch had an effect in the texture and transparency of the samples. Different proportions were formulated to test which of the samples from the different formulations would exhibit the best properties.

The strong acids had unfavorable effects on the samples, unlike the control which did not manifest any change. It was observed in the strong base test that instead of being dissolved, the samples absorbed the liquid. No significant difference was observed in the dimensions of the two preparations and the control (Table 8).

When tested for flammability, the samples completely burnt. It was also observed that the samples produced resisted heat than the control as they took longer to burn up.

The samples dissolved in water. This may be because the binder (PVA) used is water-soluble. However, the samples did not dissolve in ethanol since the binder (PVA) used is insoluble in organic solvents. Exposure to air did not have any effect on both the samples and control.

All the produced samples show the possibility of being biodegraded as was observed in the reduction in their dimensions after unearthing. The soil biodegradability test showed that there was a significant reduction in the size of the samples when buried in the soil for two weeks. The produced plastics lost weights which suggest that micro organism in the soil has decomposed most part of the ingredients mostly the starch component. However it was possible to measure the dimension because of the glycerol used as the plasticizer which is less susceptible to soil bacterial attack, Also the nature of the soil (Sandy) may have resulted in non total decay of the plastic material. However, the degradation level can be compared to that of Dametress *et al* 2013 who buried castor oil based bio plastic for one week and obtained 40% level of degradation indicating that length of time for burial, soil type, moisture content of soil (weather) could be a factor that will determine total degradation (Aarthi and Ramana, 2011).

5 CONCLUSIONS AND RECOMMENDATION

This research has shown that agricultural raw material can be utilized in the production of plastic as a substitute to petrochemicals based plastics whose wastes is a treat to the environment. The potential of producing biodegradable packaging plastic film from cassava starch is encouraging and should be further explored especially in a country like Nigeria country with high cassava productivity and large expanse of land for rubber plantation. The raw

materials used in this study are cheap and in the case of rubber seed oil, no commercial and nutrition value is known. The success of this study will help future generations of society to produce the necessary resources to address this growing environmental concern with viable, long-term solutions.

Even though biodegradable plastic for packaging was produced in this study, a better result would have been obtained if the necessary techniques and equipment needed were available.

It is therefore recommended that, further studies should be done to ascertain the following condition of biodegradation; length of burial, soil type, weather, moisture content, aerobic and anaerobic conditions. Also, there is a dire need to design and produce all the required equipment needed for production of Polylactic acid and also to design Blown film extruders which are used to produce the final product.

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