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Development of Biodegradable Food Package Using Agro-Wastes

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ABSTRACT

The escalating environmental concerns surrounding the massive production and improper disposal of non-biodegradable food packaging materials have led to the urgent need for sustainable alternatives. In response to this demand, the present study aims to model a biodegradable food package utilizing abundant agro-wastes, specifically rice husk, plantain stem, and sugarcane bagasse. The primary objective is to develop a packaging material that not only reduces environmental pollution but also utilizes readily available agricultural residues. Various formulations were tested to optimize the proportion of cooking starch, ensuring maximum binding efficiency while maintaining desirable physical and mechanical characteristics of the packaging material. The resulting mixture was then molded into the desired shape using a suitable technique such as compression molding or extrusion. The mechanical properties, such as tensile strength, flexibility, and impact resistance, were assessed to evaluate the performance of the developed packaging material.

1. INTRODUCTION

Today's society has had so many problems when it relates to plastics and environmental pollution [1, 2]. It now has become more critical in this industrial and technical age. And now we hold a responsibility to our nature (planet earth) [3]. Plastic is a good material, but the way we are using it is very wrong. Through system development and vast technology, a system has been made so we could make use of agricultural residuals (rise husk, sugarcane leaves, banana stems etc.) to produce biodegradable and disposable food packages and utensils from these plants which are raw materials that would have been discarded due to lack of knowledge and ideas that these plants could actually be the saving grace that planet earth might have long searched over the years of trying to produce and recycle plastics for human and environmental health [4].

It is said that waste is anything that is discarded because it has no value to the user anymore and solid wastes are basically unwanted substances or materials that come from the activities of man and animals in the environment [5, 6]. The problem associated with non-biodegradable waste is that these wastes do not get to transform from one form to the other (A plastic dump into the river or dumped on the soil would remain in that same soil for the next 1000 years and there would be no transformation in the form of that plastic waste). In terms of land area, India currently accounts for around 16% of global population, and the increase in industrialization affects the agricultural economy of the land [7].

2. LITERATURE REVIEW

Yearly, about 1.25 to around 2.4 million tons of plastic wastes are disposed into the sea and this is a major problem for marine organisms and aquatic life and these wastes causes different problems for the life in the sea such as malnutrition, choking, strangulation and even death of the life in the sea and these are caused most of the time because of the micro plastics in the sea in which some of these marine life tends to get into their body for food consumption [8]. This food consumption by aquatic life would eventually go up the food chain and get transferred into us humans because humans also feed on aquatic life so eventually, we would start ingesting these micro plastics into our systems and this would lead to a lot of health problems for human life over time.

Bisphenol A is a known monomeric building block that this from polycarbonate plastics and was first synthesized in 1981 [9]. It is and additive for other plastics such as PVC. The problem with this building block molecule is that over time, it gets distributed into foods that their containers were made with it and so this gets into the packages which could be water bottles, beverages, drinks made from these plastics and the consequences of this contamination most times show up later over the years. This is very detrimental to human health. The problem is that a lot of people use these packages over time and reuse them without knowing the consequences of their acts [9].

Fly ash is produced by burning rice husk ash and coal [10]. These rice husks are also known as rice hulls and these are hard coverings that protect the grains of rice. It is these rice protecting coverings that are now processed to form building material, fuel, insulation material or fertilizer [11]. They are basically the shaft of rice. The combustion of these rice hulls forms rice husk ash (RHA). It is said that the rice husks are very unique because of how they contain approximately twenty percent opaline silica combined with a significant amount of lignin. The combination of lignin and silica in rice hulls gives them remarkable features [12, 13]. Figure 1 shows the transformation process in rice husk.

Studies concerning the body, thermal and the mechanical characteristics of polymers packed with rice husk has been able to show how the incorporation of these composition like silica affect the thermosets, elastomers and thermos-plastics has been implemented [14]. Rice husk polyethylene composites has been said to be a synthetic thermoplastic polymer that was originated or made from monomer ethylene [15]. This resin belongs to the polyolefin family and is very significant. It has a long history of dominating in plastics and is one of the most extensively used polymers in the world because to many factors, including its excellent water and oxygen barriers, high elongation break, low price, and light weight. It has significantly aided in the high performance of materials and the massive expansion in their production use [16, 17].

Although the recycle of agrowastes for several vital purposes have been established before now, this study is unique because the production process has several advantages, one of which is that, this opens room for an alternative income for farmers to make a whole lot of financial benefits because farmers would normally discard these materials because they would have little or no use for them but now there could be getting paid to supply the production industries with this material and since there is an increase in demand for these materials, the price goes up in the market allowing farmers to make almost double of what they make from farm productions [18-20]. So, this idea creates more room for financial establishment. The diagram below shows the general summarized process for the experiment.

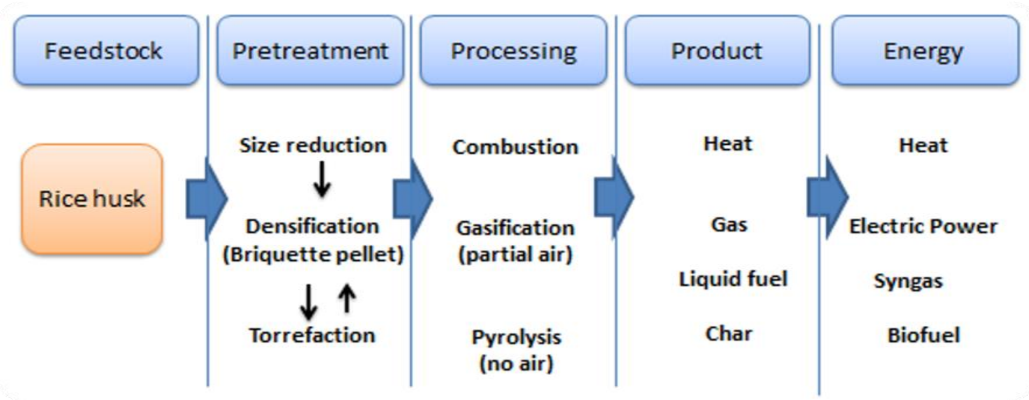

Figure 1. Transformation process of rice husk [4]

3. METHODOLOGY

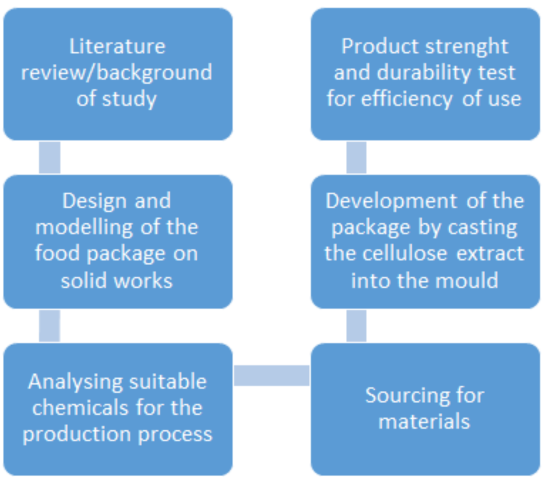

Figure 2. Methodology flow chart

The study employed the method of the development of a biodegradable package for food items as against the use of plastics for such purpose. This method was preferred as it served the purpose of ensuring that the package developed was easy to decompose and as well served the purpose of conversion of waste to wealth. Various sub-processes such as cellulose extraction from agro-waste, Delignification, mould development and characterization were employed for the study. A flowchart representing the methods employed is shown in Figure 2.

3.1 Materials

The materials employed for this experimental procedure includes rice husk, plantain stem, sugarcane bagasse, sodium hydroxide, hydrogen peroxide, hydrochloric acid, sodium chlorite, acetic acid, sulfuric acid and distilled water.

3.2 Equipment

The materials employed for this experimental procedure includes an industrial grinder, digital heating mantle, Digital weighing apparatus, Oven, Magnetic stirrer, Thermometer and a Mesh (600 µm).

3.3 Material sourcing and selection

The three agricultural residuals used for this research were typically sourced for in the local markets. Material selection was influenced by factors such as availability, renewability, biodegradability, versatility, durability and non-toxic tendencies of such materials. Sugarcane stem was first of all sourced for and bought at a relatively reasonable amount of money and after which when it was bought, the sugar cane was then brought to a residential home in which the juice in the stems were extracted by the residents of that home and after which the bagasse which is basically what is left after the juice has been extracted was then dried under the sun before taken the lab. Figure 3 shows the state of the sugarcane bagasse after the juice has been extracted.

Figure 3. Materials employed for study (a) Rice husk, (b) Sugarcane bagasse with the juice extracted, (c) Plantain stem

3.4 Material preparation

The sugar cane bagasse. Plantain stem, and rice husk were first taken to a grinding mill nearby to grind these agro wastes into smaller particles, samples were thereafter washed, sun dried and taken to the chemical lab where the powder of these wastes were sieved in a mesh of size 600 μm to obtain a powdery form and for easier extraction of the cellulose of these materials. The powdery form is as shown in Figure 4. Delignification process was carried out to break down the lignin and hemicellulose in the bagasse powder. The mixture was then heated for 5 hours at 120-130℃ using a digital heating mantle and a 1000ml beaker.

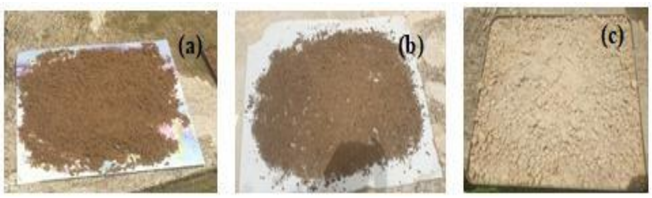

Figure 4. Powdered sundried samples after being washed (a) rice husk, (b) plantain stem, (c) sugar cane bagasse

3.5 Mould design and construction

A mould was designed using solid works software and constructed to make the preferred shape of the package using wood. The software design is as shown in Figure 5(a). Figure 5(b) shows the completed mould after development.

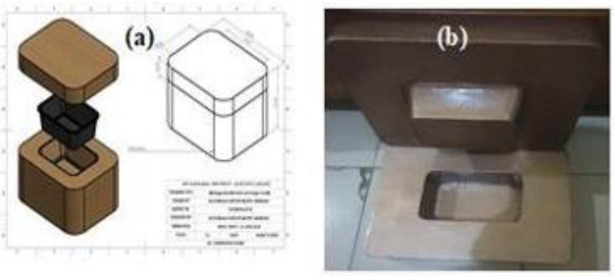

Figure 5. (a) 3D mould design, (b) Developed mould

3.6 Development of biodegradable food package

3.6.1 Plantain stem cellulose extract

The plantain Stem cellulose extract after being washed to attain its pH level was then prepared for its mixture process where it was mixed with its binding agent (starch) which was firstly prepared and mixed at a ratio of 100 grams of plantain to 50 grams of starch which after mixing together, was casted into the mould to form its container like shape, little or no quantity of water was required for this process. This process is shown in Figure 6.

Figure 6. Plantain stem cellulose extraction (a) extract, (b) Prepared starch, (c) extract on the weighing scale, (d) extract mixing with prepared starch

3.6.2 Plantain stem, rice-husk, sugarcane bagasse and starch cellulose mixtures

Another mixture variation was propagated to see the performance of the mechanical property of the food container if the 3 cellulose variations were mixed with rice husk, so the mixture was done due to the availability of the quantity of cellulose, 80g of rice husk, 80g of plantain stem and 40g of sugarcane bagasse were mixed with 150g of prepared starch and stirred properly before casting to the mould. Little quantity of water also was required for this process. The result is seen in Figure 7.

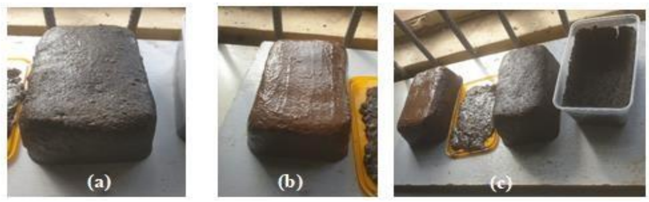

Figure 7. (a) Plantain stem cellulose and starch mixture food container, (b) Rice husk, sugarcane bagasse cellulose mixture with starch container, (c) Final results of The Developed food package

4. RESULTS AND DISCUSSION

4.1 Scanning electron microscope result of nanoparticle of extracted cellulose

Figure 8(a) shows the Scanning Electron Microscope (SEM) morphology of rice husk extracted cellulose Nano-Fibers. The rice husk cellulose extract demonstrates a porous flake like morphology and also variations in the structure shows roughness in the Nano surface and shows a bond in the particle. The particle confirms to be at micro particle level at a size of 269 μm as shown in Figure 8(a) at 1000x magnification range. Figure 8(b) shows an extended morphology of Figure 8(a) where its magnification is at a range 1500x. The extracted cellulose demonstrates a more porous morphology and micro (oval) particles at the surfaces of the structure, it confirms to be at a micro particle level at a size of 179 μm.

Figure 8(c) shows the morphology of Sugarcane bagasse cellulose extract which demonstrates a solidified binded structure with little porosity with a micro particle size of 269 µm and Figure 8(d) shows a more solidified form of the structure at a micro size of 179 µm.

Figure 8(e) shows the morphology of plantain stem cellulose extract which demonstrates a porous flake like morphology and different structural shapes at micro size of 269 µm. Figure 8(f) also shows a similar structural morphology but at a micro size of 179 µm.

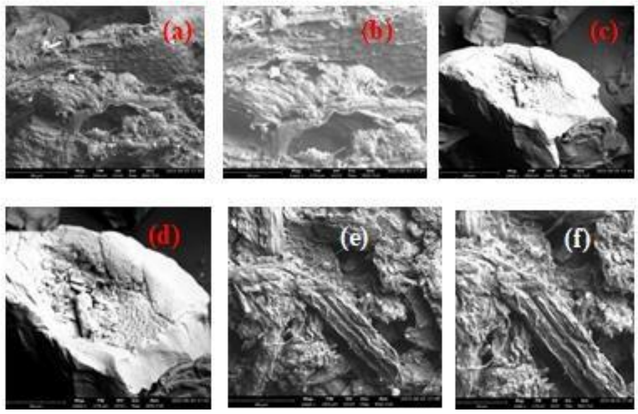

Figure 8. SEM graph of extracted cellulose (a) rice husk at 1000x magnification, (b) rice husk at 1500x magnification, (c) sugar cane bagasse at 1000x magnification, (d) sugar cane bagasse at 1500x magnification, (e) plantain stem extracted cellulose at 1000x magnification, (f) plantain stem at 1500x magnification

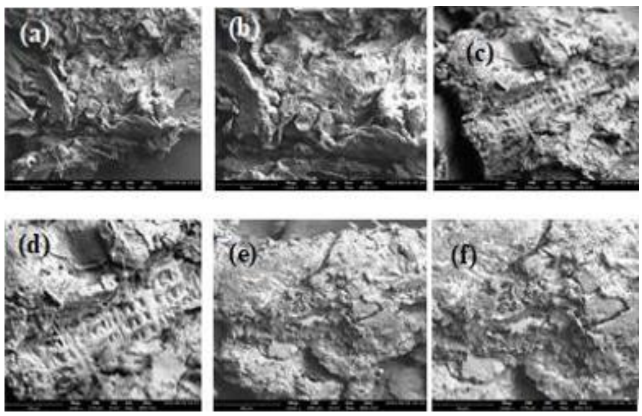

Figure 9. SEM graph of cellulose extract and starch of (a) plantain stem at 1000x magnification, (b) plantain stem at 1500x magnification, (c) RH and SGB mixture with starch at 1000x magnification, (d) RH and SGB mixture with starch at 1500x magnification, (e) PS, RH, SGB mixture cellulose extract and starch at 1000x magnification, (f) PS, RH, SGB mixture cellulose extract and starch at 1500x magnification

Figure 9(a) shows the morphology of plantain stem cellulose mixture with starch and it demonstrates a rough thread like structure binded together and this clearly states the effect of the binding agent (starch) on the structure at a micro size of 269um and Figure 9(b) shows a similar structural like image but at a micro size of 179 µm.

Figure 9(c)-(d) show the morphology of RH and SGB mixture with starch as its binding agent and the morphology demonstrates a thread like binded structure due to the influence of the binding agent at which filled the pores of the cellulose extract and this structure mixture shows difference from that of Figures 9(a) and (b), It is at a micro size of 269 µm and Figure 9(e) shows the same structure but at a micro size of 179 µm. Figure 9(f) shows the morphology of RH, PS, SGB with a starch mixture which demonstrates a rough flat binded surface structure at a micro size of 269 µm and 179 µm respectively.

4.2 Biodegradability analysis

The cellulose extracts were also casted in a flat sheet mode and buried into the soil to observe its biodegradable characteristics and because of time factor it was done under few days. Tables 1-3 show the result of Biodegradation process of cellulose extracts and starch from PS, RH & SG and RH, PS & SGB respectively. The results from the tables show a general weight reduction in each mixture with starch shows a slow biodegradation process which makes the different mixtures feasible for biodegradation.

Table 1. Biodegradation process of PS cellulose extract and starch

Plantain Stem Cellulose Extract and Starch Mixture		
Period	Weight (g)	
	100/50	100/60
Initial	0.7628	0.7207
Day 1	0.7628	0.7205
Day 2	0.7627	0.7201
Day 3	0.7626	0.7198
Day 4	0.7626	0.7197
Day 5	0.7625	0.7195
Day 6	0.7624	0.7193
Day 7	0.7623	0.7190

Table 2. Biodegradation process of RH, SG cellulose and starch

Rice Husk and Sugarcane Bagasse Mixture with Starch		
Period	Weight (g)	
	100/30/80	100/30/100
Initial	0.8411	0.7149
Day 1	0.8264	0.6811
Day 2	0.8238	0.6766
Day 3	0.8106	0.6735
Day 4	0.7908	0.6631
Day 5	0.7904	0.6629
Day 6	0.7901	0.6627
Day 7	0.7890	0.6625

Table 3. Biodegradation process of RH, PS, SGB cellulose mixture and starch

Plantain Stem, Rice Husk, Sugarcane Bagasse Cellulose Mixture and Starch		
Period	Weight(g)	
	100/100/40/150	100/100/30/160
Initial	0.6894	0.7588
Day 1	0.6890	0.7586
Day 2	0.6887	0.7582
Day 3	0.6885	0.7579
Day 4	0.6882	0.7577
Day 5	0.6880	0.7574
Day 6	0.6879	0.7572
Day 7	0.6877	0.7570

4.3 Mechanical property result of produced extracts

4.3.1 Hardness analysis

The Shore-D hardness test for each sample was conducted three times to get an average value. value of 100 grams of extracted plantain stem cellulose and 50 grams of rice husk was measured to be around 29 HD. This indicated that the average shore D of plantain stem to be 29 HD, while that of Rice husk, sugarcane bagasse and starch average value was found to be 32.33 HD and the mixture of the three celluloses according to the quantity available was found to be 26 HD (Table 4). This results in the average values shows that the material cellulose mixture with the best hardness property was found to be the mixture of RH, SGB and starch with a hardness of 32.33 HD.

The second test conducted in Table 4 was also performed three times and the average hardness value was achieved and also the mixture that hard the highest and best hardness value was that of the mixture of rice husk and sugarcane bagasse cellulose extract with starch and the average hardness value for that test was 34.67 HD. It is clearly observed that rice husk has better mechanical property when mixed with sugarcane, but a mixture of the three celluloses gives about a lower hardness value than that of 2 mixtures, although the plantain stem alone gave a good hardness value of 29 HD and 29.67 HD respectively (Table 5).

Table 4. Average hardness of cellulose mixtures and starch

Average Hardness (HD)		
Sample Composition (Cellulose Extract and Starch Mixture)		
PS/Starch	**RH/SGB/Starch**	**PS/RH/SGB/Starch**
100/50	100/30/80	100/100/40/150
29	32.33	26

Table 5. Average hardness value of variations in mixtures

Average Hardness (HD)		
Sample Composition (cellulose Extract and Starch Mixture)		
PS/Starch	**RH/SGB/Starch**	**PS/RH/SGB/Starch**
100/60	100/30/100	100/100/30/160
29.67	34.67	28.67

5. CONCLUSION

The study focused on the modeling of a biodegradable food package using agro-wastes, such as rice husk, plantain stem, and sugarcane bagasse, with a binding agent of cooking starch. The objective was to develop an environmentally friendly alternative to non-biodegradable food packaging materials, addressing the growing concerns of waste generation and pollution. The SEM analysis clearly shows the atomic and weight structure of these wastes after treating it to chemicals to break down the cellulose and the resulting values in variation showing that it consists more in carbon and oxygen making it feasible for biodegradable break downs. Also shows that it is non-toxic for the use of food consumption.

The test for biodegradability shows that indeed the material can be consumed by micro-organisms because as the days went by, it began to lose its physical weight when buried in the ground. Hence a food package that is biodegradable was successfully developed. These contribution to knowledge could result in the gradual replacement of all nondegradable materials used for food packaging thereby ensuring a cleaner and safer environment and achieving the SDG goal 3 on good health for mankind. The mould design was used to give the shape of the container as seen in the diagram of Figure 6(a) and (b). It is therefore recommended that after cellulose has been extracted through the chemical process and washed to pH level with distilled water it should be casted immediately so as to give the best form of the container and also have maximum performance of its binding properties.

It is however recommended that more studies be carried out on the effects of heat on the developed food packages has this was not really considered in this study, hence the limitation of the study.

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