IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 15, Issue 7 Ser. I (July 2021), PP 47-52
www.iosrjournals.org

Functional Properties of Cassava Peel Cellulose, Plantain Peel Cellulose and Commercial Cellulose: A Comparative Analysis.

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Abstract

In this study, functionalproperties ofcellulose produced from cassava and plantain peels were compared with those of commercial cellulose. The Cassava Peel Powder (CPP) and the plantain peel powder (PPP) were defatted with 90% ethanol for 16hrs, with intermittent shaking using mechanical shaker at a speed of 150rpm. Each defatted PP was dried in a hot air oven at 80°c for 7hrs. The defatted CPP and PPP were deproteinated by soaking in 1 Mol of NaOH solution in the ratio of 1:10w/v. (100g PP/1000ml) at a pH of 11.6 for 24hrs. The defatted -deproteinated CPP and PPP were soaked in 15% Hydrogen Peroxide for 3hrs to produce cassava peel cellulose (CPC) and plantain peel cellulose (PPC). The CPC, PPC and commercial cellulose (CC), were analyzed for bulk density, packed density, hydrated density, emulsifying activity, water and oil retention capacities and Hausner's Quotient, according to standard methods.Data were subjected to descriptive statistics and analyses of variance were used to test for significant differences at probability less than 0.05. The result showed that crude fat contents of the peel powders were 3.22± 0.03% (CPP) and 2.20±0.03 %(PPP), while the protein contents were 4.52±0.03% (CPP) and 3.86 ± 0.02% (PPP).The CC recorded the least values of bulk, packed and hydrated densities, water retention capacity and setting volume than the CPC and PPC. There was significant difference ($p < 0.001$) in the functional properties of CPC, PPC and CC except in setting volumes ($p = 0.099$) and Hausner's Quotient ($p = 0.082$). Recycling of cassava and plantain peels into cellulose will provide raw materials for industries and mitigate environmental pollution as well as promote entrepreneurial opportunities to the teaming unemployed graduates of life sciences.

Keywords: *Cellulose, agricultural wastes, cassava peel powder, plantain peel powder, functional properties*

Date of Submission: 02-07-2021 Date of Acceptance: 17-07-2021

I. Introduction

Cellulose, the most important constituent of all plant materials, forms about 33.3 – 50% of all plant tissues (Sundarraj *et al.*, 2018). It can be extracted from a wide range of sources, including agricultural wastes. Recently, the quest for cellulose-based materiasl has increased in line with the growing demand for renewable resources in the global community and cellulose extraction from agricultural wastes is fast becoming an interesting research area. Among the agricultural biomass of significant environmental problem is cassava peel, generated during cassava processing. Cassava, a chief source of low-cost carbohydrate is an important staple food in the tropics. However the crop is possibly the most widely distributed major human food crop containing cyanogenic glycosides (Otuu *et al.*, 2018). In Nigeria, cassava production is well-developed as an organized agricultural crop. It has well-established multiplication and processing techniques for food products and cattle feed. There are more than 40 cassava varieties in use. Though the crop is produced in 24 of the country's 36 states (USAID, 2005), cassava production dominates the southern part of the country, both in terms of area covered and number of farmers growing the crop. Planting occurs during four planting seasons in the various geo-ecological zones.

One of the unavoidable consequences of cassava processing is the generation of large volumes of gaseous, liquid, and solid wastes in the forms of hydrocyanic acid gas, viscous whitish effluent and cassava peels, respectively (Inya-Agha *et al.*, 2014). While the cyanide gas disperses into the atmosphere where it may be diluted, and the liquid effluent discharge during grating may percolate into the soil where it joins the water table, the cassava peel remains the only solid cassava waste product that is most physically present for relatively longer period. Beside its unaesthetic in the environment, cassava peel heap is a breeding ground for rodents and microbial particles of public health interest. Hydrolytic decomposition of cassava peel also generates obnoxious ammoniac compounds that are also implicated in public health diseases.

Plantain (*Musa paradisiaca*) is among the major fruit crops in tropics and is fast becoming common food substance in the daily diets of the world. Plantain-based foods occupy the fourth world rank of the most significant foodstuffs after rice, corn and milk. Peel-the main by-product of the plantain processing industry represents approximately 30 % of the fruits. This by-product constitutes an environmental problem because it contains large quantities of nitrogen and phosphorus and its high water content makes it susceptible to modification by microorganisms.

Currently, there is a growing interest in the study to profile the bioactive compounds in plantain peel and assess its antioxidant activities as well as production of raw materials for food additives and bulking agents to pharmaceutical excipients. There is the possibility of developing cookies utilizing plantain peel flour which would have potential benefits in the management and prevention of life style associated diseases.

A major problem experienced by agro-based industries in developing countries is the management of wastes. Agro wastes or plant biomasses in Nigeria are mostly subjected to open air burning with its attendant environmental implications (Babayemi *et al.*, 2009). Inefficient and improper disposal of solid wastes creates serious hazards to public health, including pollution of air and water resources and increases in rodent and insect vectors of disease, creates public nuisances as well as interfere with community life and development. The failure or inability to salvage and re-use such materials economically results in unnecessary waste and depletion of natural resources. To date, emphasis is on biological conversion of plant wastes, especially agricultural wastes into value added products.

Conversion of cassava and plantain peels into industrial raw materials such as cellulose will salvage the environmental nuisance associated with their wastes as well as adding value to the crop and economic leverage to the farmers. Cellulose is commonly used in foods and bakery formulations as a source of dietary fiber or to improve their texture. It is also used as a bulking agent in low-calorie and gluten-free baked products. The effective use of cellulose in several industrial applications is determined by its functional properties. In this study, functional properties of cellulose produced from cassava and plantain peels were compared with those of commercial cellulose

II. Methodology

Sample Collection and Treatment

The fresh cassava peels were collected from local women in acassava processing plant at Agbani, Nkanu East Local Government Area. The fresh plantain peels were collected from women operating restaurants around the Nkanu East Local Government Area in Agbani town. The peels were washed with tap water to remove sand and dust particles. They were immediately cut into pieces and room dried for seven days, and then in an oven at 85^0C for 3hrs. After cooling to room temperature, the peels were weighed, pulverized and sieved to obtain a homogenous texture. They were kept in a polyethylene bag and labelled accordingly. Extraction of cellulose commenced within 24hrs after pulverization.

Extraction of Cellulose

The method of Riantong et al (2013) was adopted in the extraction of cellulose from the peels. Alkaline hydrolysis was employed after defatting and deproteination of the peel powders, and then followed by bleaching.

Defatting of the agricultural biomass

The Cassava Peel Powder (CPP) and the plantain peel powder (PPP) were defatted as described by Riantong *et al*(2013). 100g of each of the PP was soaked in 1L of 90% ethanol for 16hrs, with intermittent shaking using mechanical shaker at a speed of 150rpm. Thereafter, the mixture was washed with enough volume (2L) of distilled water three times and then filtered with whatman filter paper, No.4, 11.0cm. Each defatted PP was dried in a hot air oven at 80°c for 7hrs.

Deproteination of CPP and PPP

Deproteination was done as described by Vail (1991) and Riantong *et al.*, (2013). The defatted CPP and PPP were soaked in 1 Mol of NaOH solution in the ratio of 1:10w/v. (100g PP/1000ml water) at a PH of 11.6 for 24hrs. Each mixture was shaken intermittently with a mechanical stirrer at a speed of 150rpm. Each deproteinated sample was washed with enough volume of distilled water three times, filtered with Whatman No.4, 11.0cm filter paper and dried in the hot air oven at 80°c for 7hrs to get alpha cellulose of each PP.

Bleaching of the Cellulose

The methods of Phongnori (2004) and Riantong *et al* (2013) were adopted in the bleaching of the cellulose. The defatted and the deproteinated CPP and PPP were soaked in 15% Hydrogen Peroxide for 3hrs. The bleached samples were washed three times with enough volume of distilled water, filtered with Whatman No.4, 11.0cm filter paper and dried in hot air oven at 60°c for 7hrs.

Functional Properties of Cassava peel cellulose (CPC) and Plantain peel cellulose (PPC).

The obtained CPC and PPC were analyzed for bulk density, packed density, hydrated density, emulsifying activity, and Hausner's quotient, according to the method reported inPrakhongpan *et al*(2002), settling volume and water and oil retention capacities (Committee on Codex Specifications, 2008).

Bulk Density

A pre-weighed graduated cylinder was filled with 50g of sample and shaken slightly. The volume of the sample was recorded, the content of the cylinder was weighed, and the bulk density was expressed as weight per volume (Prakhongpan *et al.*, 2002). The bulk density was calculated using the following equation:

$$\text{Bulk density (g/ml)} = \frac{WeightoftheSample\ (g)}{VolumeoftheSample\ (ml)}$$

Packed Density

A calibrated 10-ml graduated syringe was filled with a known weight of sample. Pressure was applied manually until additional pressure would not further reduce the volume. The packed density was calculated as the weight of the sample per least volume of the sample (Prakhongpan *et al.*, 2002). The packed density was calculated using the following equation: $\text{Packed density (g/ml)} = \frac{WeightoftheSample\ (g)}{Leastvolumeoft\ heSample\ (ml)}$

Hydrated Density

A calibrated 10 ml graduate cylinder was filled with a known amount of distilled deionized water, and a known weight of sample was added carefully to avoid adhesion to the cylinder's walls. The difference between the volume of the water before and after adding the sample was recorded as ml of water displaced. Results were expressed as grams of the sample per ml of water displaced (Prakhongpan *et al.*, 2002). The hydrated density was calculated using the following equation: $\text{Hydrated density (g/ml)} = \frac{grams\ of\ the\ Sample\ (g)}{ml\ of\ the\ water\ displaced}$

Water Retention Capacity (WRC) and Oil Retention Capacity (ORC)

WRC and ORC were analyzed by gravimetric and sedimentary techniques. In the WRC, 2 g of sample was mixed with 30 ml of distilled water in a 50 ml centrifuge tube. The slurry was allowed to stand for 10 min, and then centrifuged at 2000 × g for 15 min. After centrifugation, the supernatant was drained and the wet sample precipitate was weighed. The result was expressed as gram of water per gram of the sample. In the ORC, the procedure was similar to the one described for the WRC except that palm oil was used instead of water (Committee on Codex Specifications, 2008). The WRC and ORC were calculated using the following equation: $\text{WRC}\left(\text{g}\frac{\text{water}}{\text{g}}\text{ dried sample}\right) = \frac{gramof\ water}{gramoft\ hesample}$ and $\text{ORC (g oil/g dried sample)} = \frac{gramofoil}{gramoft\ hesample}$

Emulsifying Activity (EA)

Seven grams of sample was suspended in 100 ml distilled water and then 100 ml soybean oil was added. The mixture was emulsified using a homogenizer (IKA Ultra Turrax-T25, Ika Japan) with the designation of the dispersing tool (S25N 25F) at 1000 rpm for 1 min. The emulsion obtained was divided evenly into 4, 50 ml centrifuge tubes and centrifuged at 1300 × g for 5 min (Prakhongpan *et al.*, 2002). The EA was calculated using the following equation:

$$\text{EA} = \frac{height\ of\ emulsified\ layer\ (cm) \times 100}{height\ of\ whole\ layer\ (cm)}$$

Quality control was ensured by reducing the amount of the sample to 1.75 g when there was no excess water and oil retained before centrifugation.

3.4.6 Hausner's Quotient

This was determined by finding the ratio between the packed density (Dp) and bulk density (Db) of each quality of the hybrid material. It is represented by the formula: $\mathrm{H.Q} = \frac{Dp}{Db}$

Settling Volume

The settling volume (SV) of the cellulose samples was measured. This experiment was performed by mixing 1 g of sample with 70 ml distilled water in a 100 ml screw-cap bottle. These bottles were subjected to ultrasonic treatment for 30 min in order to allow water to saturate the samples and also to remove some of the excess gas in the mixture. The mixtures were then degassed by vacuum suction for 30 min and placed in a cold storage room for 24 h to facilitate the penetration of water into the interstices of the samples. The individual mixture in each bottle was quantitatively transferred to a 100 ml volumetric cylinder. The content of each cylinder was adjusted to 100 ml by adding distilled water. The SV was calculated as the volume, in ml, formed by the sample residue layer, read by the naked eye after 24 hrs at room temperature (Prakhongpan *et al*., 2002)

III. RESULTS AND DISCUSSION

The results of the study are presented in tables 1 -3.

Table 1 represents the crude fat and protein contents of the cassava and plantain peel powders. There was a significant difference (p < .001) in the % crude fat and protein of CPP and PPP with CPP having higher compositions. The crude protein content of CPP (4.52%) was slightly higher than those (4.21% and 4.20%) reported in studies (Olufunke *et al*., 2010 and Aro *et al.,* 2010).

Table 1: % Crude fat and Protein Composition of CPP and PPP

	CPP	PPP	T	p-value
Crude Fat (%)	3.22±0.02	2.20±0.03	54.780	< 0 .001
Protein (%)	4.52±0.03	3.86±0.02	38.831	< 0 .001

Table 2represents functional properties of the cellulose from the three sources.The CC recorded the least values of bulk, packed and hydrated densities, water retention capacity and setting volume than the CPC and PPC. This agrees with previous studies (Riatong *et al*., 2014; Ding *et al.,* 2020) where the values of bulk and packed densities of cellulose extracted from agricultural wastes were higher than commercial cellulose. The values of bulk density in CPC (0.54±0.02g/ml) and PPC (0.55±0.02g/ml) were close to the bulk density value of banana peel cellulose (0.646 ±0.27g/ml) and less than that of orange peel cellulose (0.305 ± 0.00g/ml) reported by Riatong *et al* (2014).

The packed density of PPC (0.74 ± 0.01g/ml) in this study was close to that of banana peel cellulose (0.923g/ml ± 0.00) Riatong *et al* (2014).Packed density values are higher for more spherical particles and play important role in packing properties of a powder which itself affects operations critical to solid dosage manufacturing, including bulk storage. According to Aulton (2001) high density powder materials have high diluents power and substantial powder volume or bulk which improves consolidation and flow.

The water retention capacities of CPC (3.11±0.03gwater/g), PPC (2.99±0.03gwater/g) and CC (1.99±0.01gwater/g),were close to those of banana peel cellulose (2.91gwater/g), jackfruit peel cellulose (2.18gwater/g) and commercial cellulose (2.0gwater/g), reported in Sunarraj and Ranganathan (2018). Water retention capacity is an important functional property because of its role in the organoeleptic properties and shelf life of food and pharmaceutical formulations. Cellulose extracted from agricultural wastes such as cassava and plantain peels with good water retention capacities, can be incorporated into powdered food materials and pharmaceuticals as bulking or creaming agents.

Oil retention capacity is also another important functional property of powdered material in food and pharmaceutical formulations because of its role in emulsification. The ORC in CPC (0.12±0.01) and PPC (0.40±0.53) were much lower than those of orange peel cellulose (2.01g oil/g), pineapple core cellulose (2.15g oil/g) and jackfruit (2.68g oil/g) as reported in Sunarraj and Ranganathan (2018). High value of ORC is needful as an emulsifier in oil-based food formulations.

The emulsifying activities of CPC (41.06±0.01%) and PPC (40.93±0.03%) were almost the same as reported in other agricultural wastes cellulose;pineapple (40.27%) and banana (40.70%) (Sunarraj and Ranganathan, 2018).

Hausner ratio relates to the flow ability of a powder and is graded with reference value ≤1.25 considered as indication of good flow character. The Hausner ratio values of CPC (1.31±0.01) and PPC (1.31±0.02)were slightly above the reference value and therefore may be considered poor flow character.

Table 2: Functional Properties of the CPC, PPC and CC

	CPC	**PPC**	**CC**
Bulk Density (g/ml)	0.54±0.02	0.55±0.02	0.22±0.01

Packed Density (g/ml)	0.63±0.05	0.74±0.01	0.30±0.02
Hydrated Density(g/ml)	2.78±0.01	2.71±0.03	1.81±0.01
Emulsifying Activity (EA)%	41.06±0.01	40.93±0.03	55.92±0.04
Water Retention Capacity (WRC) g water/g	3.11±0.03	2.99±0.03	1.99±0.01
Oil Retention Capacity(ORC) goil/g	0.12±0.01	0.40±0.53	3.23±0.03
Setting Volumes	15.19±0.01	16.20±1.73	14.04±0.02
Hausner's Quotient(HQ)	1.31±0.01	1.31±0.02	1.33±0.01

Table 3 represents comparison of functional properties of cellulose produced from cassava peel powder (CPC), cellulose produced from the plantain peel powder (PPC) and the commercial cellulose (CC). There was significant difference ($p <0.001$) in the functional properties of CPC, PPC and CC except in setting volumes ($p = 0 .099$) and Hausner's Quotient ($p = 0.082$). Though the bulk densities of CPC and PPC were not significantly different ($p > 0.05$), but they were significantly higher ($p < 0.05$) than that of CC. The packed density of PPC was significantly higher($p < 0.05$) than CPC and the packed densities of both were significantly higher ($p < 0.05$) than that of CC.

The relative higher bulk densities observed in CPC and PPC compared with CC would mean that CPC and PPC had lesser porosity than CC and therefore would be less compressible. According to (Ding *et al.*, 2020), porosity may hinder densification of powder bed when external stress is applied. Higher values of bulk density also presupposes existence of materials with higher sphericity, lower interstitial air content and higher inter-particulate cohesiveness as opposed to coarse particles with more irregular shapes and more particulate-container adhesiveness. Thus, the CPC and PPC produced in this study would be more ideal for incorporation in powdered raw materials or bulking agents in finished products, requiring compact packaging, than the CC.

The hydrated density and water retention capacity of CPC was significantly ($p < 0.05$) higher than PPC and bothparameters were also significantly higher ($p < 0.05$) than those of CC. Thus, CPC and PPC would be preferable to CC, in formulations that are sensitive to changes in moisture content and where long bench life and organoeleptic properties are important considerations.

The emulsifying activity of CC was significantlyhigher ($p < 0.05$) than those of CPC and PPC; and that of CPC was also significantly higher ($p < 0.05$) than PPC. The same trend followed in oil retention capacity.The CC is expected to be more favourably disposed for use as an emulsifying agent than CPC and PPC because of its higher ORC and EA.

Table 3: Comparison between Functional Properties of the CPC and PPC with the CC

	CPC	**PPC**	**CC**	F	p-value
Bulk Density	$0.54±0.02^{b}$	$0.55±0.02^{b}$	$0.22±0.01^{a}$	414.130	<0.001
Packed Density	$0.63±0.05^{b}$	$0.74±0.01^{c}$	$0.30±0.02^{a}$	197.110	<0.001
Hydrated Density	$2.78±0.01^{c}$	$2.71±0.03^{b}$	$1.81±0.01^{a}$	3070.154	<0.001
Emulsifying Activity (EA)	$41.06±0.01^{b}$	$40.93±0.03^{a}$	$55.92±0.04^{c}$	339741.169	<0.001
Water Retention Capacity (WRC)	$3.11±0.03^{c}$	$2.99±0.03^{b}$	$1.99±0.01^{a}$	2637.026	<0.001
Oil Retention Capacity (ORC)	$0.12±0.01^{a}$	$0.40±0.53^{b}$	$3.23±0.03^{c}$	94.056	<0.001
Setting Volumes	$15.19±0.01^{a}$	$16.20±1.73^{a}$	$14.04±0.02^{a}$	3.492	0.099
Hausner's Quotient(HQ)	$1.31±0.01^{a}$	$1.31±0.02^{a}$	$1.33±0.01^{a}$	3.909	0.082

IV. Conclusion

Waste to wealth is a global trending technology that impacts positively on the socio-economy and environmental health of the global community**.**This study compared the functional properties of cellulose produced from cassava and plantain peels with commercial cellulose and concludes that cassava and plantain peels are good sources of quality cellulose with competitive functional properties as those of commercial cellulose.It is therefore recommended that public awareness on the beneficial uses of agricultural biomass be embarked on by appropriate government agencies and individual business men. Conversion of cassava and plantain peels into industrial raw materials such as cellulose will salvage the environmental nuisance associated with these wastes as well as adding value to the crop and economic leverage to the farmers.

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Glory C.Okeke, et. al. “Functional Properties of Cassava Peel Cellulose, Plantain Peel Cellulose and Commercial Cellulose: A Comparative Analysis.” *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)*, 14(7), (2021): pp 47-52.