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Comparative Soda Pulps from Corn Husks and Plantain Stalks

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ABSTRACT

Wood is a common raw material in the production of pulp and paper. However, due to the global environmental impact of forest depletion, research is focusing on non-wood material as alternate sources of fiber and as a remedy to environmental destruction of forest reserve. Corn husk and plantain stalk are readily available agricultural wastes in Nigeria that can be utilized for the production of pulp and paper. This present study is an investigation into the paper making potentials of cornhusk and plantain stalk. Corn husks and plantain stalks regarded as wastes were collected at Bodija foodstuff market, Ibadan, Oyo state, Nigeria. They were cut into small chips and their moisture contents were determined. The raw materials were subjected to chemical pulping process (soda pulping). The effects of three operational variables, namely, pulping time (30 – 90 minutes), liquor-to-solid ratio (10:1 – 20:1) and alkaline concentration (8-12%) were investigated on the pulp yields, Kappa number and residual lignin contents, respectively. The results showed that the highest pulp yields were obtained at a liquor-to-solid ratio of 10:1, pulping time of 30 minutes and 8% concentration of cooking alkali for both corn husk and plantain stalk. However, the least kappa number and lignin contents for both materials were obtained at a liquor-to-solid ratio of 20:1, pulping time of 90minutess and alkali concentration of 12%. Comparatively, plantain stalk gave higher pulp yield and lower lignin content than corn husk. The overall results of this study revealed that corn husk and plantain stalk have promising potential as alternative fiber feedstock in paper making industry.

Keywords: Pulp, Paper, Corn husk, Plantain stalk, Lignin, Soda pulping, Kappa number, Pulp yield, Non-wood.

Proceedings Citation Format
Ogunsile B.O. & Popoola O.E. (2022): Comparative Soda Pulps from Corn Husks and Plantain Stalks. Proceedings of the 31st Accra Bespoke Multidisciplinary Innovations Conference. University of Ghana/Academic City University College, Ghana. 1st – 3rd June, 2022. Pp 85-94, www.isteams.net/ghanabespoke2022.
dx.doi.org/10.22624/AIMS/ABMIC2022P10

1. INTRODUCTION

Tree is important because it stabilizes our ecosystem and is also a major feedstock in the pulp and paper industry, one of the oldest industries in the world. The pulp and paper industry plays a vital role in our daily activities, from communication, to education and packaging (Hiller, 1982). Paper production poses serious threat to perennial trees that are mostly soft woods which are used in pulp and paper production (Maddern and French, 1989). The need for a shift to a sustainable source of fiber is a global concern as the demand for paper and paper related products has increased over time. The unavailability of woody materials for paper production is also a matter of concern and it contributes to the operational challenges in the industry (Ogunwusi, 2013). The threat on forest woods and environmental sustainability has led to intensive research on the suitability of several agricultural waste materials for pulp and paper production (Rousu, *et al.,* 2002).

Nigeria's pulp and paper production capacities are limited due to reliance on imported long - fibered pulps. The country forest reserves are mostly made up of mixed tropical hardwood species with short fiber lengths (Casey, 1980). However, there exists many non-woods and agricultural wastes whose pulp and paper potentials have not been exploited (Raw Material Research and Development Council 1996; Waranyou, 2010).

Interestingly, the pulp quality of non-woody materials and some fibrous agricultural wastes are suitable to replace woody materials (Ogunwusi, 2013). Some of the potential non-woods being used today include *Sesbania aculeate, Saccharum spontaneum*, *Bambusa vulgaris*, banana stem , empty fruit bunches and wheat straw (Jahan *et al*., 2007; Ogunsile and Uwajeh, 2009; Ferrer *et al*., 2013; Snelders *et al*., 2014). The non-woods have low lignin contents which can easily be delignified with little chemical requirements. Corn husks and plantain stalks are fibrous agricultural waste materials with very little or no commercial value and are available in abundance in Nigeria. Also, Lignin from these plant materials which has been largely underutilized has great potential in synthesis of drugs (Oloyede *et al*., 2019). Therefore, the need to investigate Corn husks and plantain stalks pulping potentials for pulp and paper production becomes highly necessary. In this present study, the pulpability and the chemical suitability of the selected raw materials for pulping practice is investigated under soda pulping.

2. MATERIAL AND METHODS

Sample Collection

Samples of cornhusks and plantain stalks were collected at Bodija foodstuff market, Ibadan, Oyo state, Nigeria. Raw materials were collated and cleaned from sand particles and other extraneous materials.

Moisture Content

The samples were cut into small chips of about 0.5 to 4.0 cm in length and width, and 0.2 – 1.0 cm in thickness, in order to improve the surface area, facilitate easy penetration of pulping chemical and also enhance drying. The moisture contents of the materials were determined by selecting some samples at random, and then weighed them before and after over drying to constant weight at 110^{0}C.

Soda Pulping

The pulping experiment was carried out in the Industrial Laboratory of the Department of Chemistry University of Ibadan. The cornhusk and plantain stalk samples were pulped inside a12-literpressure pot at about 120^{o}C. Four stainless steel cups were fitted into the pressure pot containing 1ltr of water. 10 g of either the air-dried plantain stalk or cornhusk samples were placed into each of the stainless-steel cup containing the appropriate amount of soda liquor, covered and then pulped. The soda pulping was carried out under the following operational variables: (a) Liquor-to-solid ratio of 10:1, 15:1 and 20:1, (b) Concentration of soda liquor, 8%, 10% and 12% and (c) Time in minutes, 30, 60 and 90 minutes. After every cooking cycle, the pressure pot was taken off the cooker and left to cool then the pulp was separated from the cooking liquor to be washed under running water and ensured that no pulp sample was lost. The pulp sample was dried in the oven at 100^{o}Cfor 1hour then the weight of each pulp yield is taken. This process was carried out for every of the pulp sample.

Kappa Number and Residual Klason Lignin

TAPPI T236CM-85 (1993) method was used for the determination of the Kappa number as described by (Ogunsile and Uwajeh, 2009). One gramme of the oven-dried pulp sample was disintegrated in 200 mL distilled water into a 500 mL beaker while ensuring that no fiber bundles exist. The mixture was placed on a magnetic stirrer and a solution of 25 mL 2M H_2SO_4 acid and 25 mL 0.1M $KMnO_4$ was added to make the solution acidic and stirred for 10mins. After 10mins of reaction, 5 mL 0.1M KI was added to terminate the reaction. The free iodine in the pulp sample was titrated against 0.2M $Na_2S_2O_3$ solution using 2% starch indicator to determine the Kappa number. The procedure was repeated using no pulp sample for the blank.

$$K = {}^{P \times F}/_{W} \qquad \text{..............................(1)}$$

$$P = {}^{(b-a)M}/_{0.1} \qquad \text{..............................(2)}$$

where;
K = Kappa number,
W = weight of moisture free pulp in grams,
P = amount of 0.1M $KMnO_4$ consumed by the test specimen in cubic centimeters,
b = amount of thiosulphate consumed in the blank titration cubic centimeters,
a = amount of $Na_2S_2O_3$ consumed by the test specimen cubic centimeters,
M = molarity of $Na_2S_2O_3$,
F = factor for correction to a 50% $KMnO_4$ consumption depending on the value of P.

The residual Klason lignin was calculated from the Kappa number using the relation;
% Residual lignin = 0.13 * Kappa number

3. RESULTS

The results of the moisture content in plantain stalk and corn husk were presented in Tables 1 and 2. Tables 3-5 contained the soda pulp yields, Kappa number and residual lignin contents of corn husk at liquor-to-solid ratios of 10:1, 15:1 and 20:1, respectively. The results of soda pulp yields, Kappa number and residual lignin contents of plantain stalk at liquor-to-solid ratios of

10:1, 15:1 and 20:1, respectively, were presented in Tables 6-8. Fig. 1 showed the effect of pulping time and liquor to solid ratio on residual lignin content.

Table 1: Moisture content in plantain stalks

S/N	Initial weight (g)	Final weight(g)	Difference in weight (g)	Moisture content (%)
1	3.52	0.299	3.221	91.5
2	2.66	0.279	2.381	89.5
3	2.78	0.290	2.49	89.6
4	2.87	0.270	2.60	90.6
5	2.87	0.271	2.599	90.6

Table 2: Moisture content in corn husks

S/N	Initial weight (g)	Final weight (g)	Difference in weight (g)	Moisture content (%)
1	4.32	3.72	0.6	14.0
2	3.65	3.17	0.48	13.2
3	4.24	3.65	0.59	13.9
4	3.75	3.22	0.53	14.2
5	3.79	3.26	0.53	13.9

Table 3: Soda pulping of corn husk at liquor-to-solid ratio of 10:1

Cooking time (mins)	Concentration of soda liquor (%)	Pulp yield (g)	Kappa number	Residual Lignin content (%)
30	8	3.92	50.86	6.61
60	8	3.42	48.90	6.36
90	8	3.25	46.35	6.03
30	10	3.24	43.61	5.67
60	10	2.83	39.2	5.10
90	10	2.71	31.26	4.06
30	12	2.83	29.59	3.85
60	12	2.62	29.20	3.80
90	12	2.34	24.89	3.24

Table 4: Soda pulping of cornhusk at liquor-to-solid ratio of 15:1

Cooking time (mins)	Concentration of soda liquor (%)	Pulp yield (g)	Kappa number	Residual Lignin content (%)
30	8	2.92	41.75	5.43
60	8	2.65	42.92	5.58
90	8	2.47	41.16	5.35
30	10	2.91	36.26	4.71
60	10	2.49	33.61	4.37
90	10	2.46	27.15	3.53
30	12	2.64	24.30	3.16
60	12	2.41	25.97	3.38
90	12	2.30	22.83	2.97

Table 5: Soda pulping of cornhusk at liquor-to-solid ratio of 20:1

Cooking Time (mins)	Concentration of soda liquor (%)	Pulp yield (g)	Kappa number	Residual Lignin content (%)
30	8	2.76	38.22	4.97
60	8	2.45	36.26	4.71
90	8	2.36	38.81	5.05
30	10	2.58	32.05	4.17
60	10	2.43	33.03	4.29
90	10	2.25	26.75	3.48
30	12	2.39	20.19	2.62
60	12	2.26	23.81	3.10
90	12	2.13	17.35	2.26

Table 6: Soda pulping of plantain stalk at liquor-to-solid ratio of 10:1

Cooking Time (mins)	Concentration of soda liquor (%)	Pulp yield (g)	Kappa number	Residual lignin content (%)
30	8	5.75	44.98	5.85
60	8	5.34	44.30	5.76
90	8	5.26	42.43	5.52
30	10	5.38	40.18	5.22
60	10	5.17	36.55	4.75
90	10	4.97	33.32	4.33
30	12	4.93	29.79	3.87
60	12	4.71	27.05	3.52
90	12	4.52	23.03	2.99

Table 7: Soda pulping of plantain stalk at liquor-to-solid ratio of 15:1

Cooking Time (mins)	Concentration of soda liquor (%)	Pulp yield (g)	Kappa number	Residual lignin content (%)
30	8	5.24	36.46	4.74
60	8	5.18	43.51	5.66
90	8	4.94	41.55	5.40
30	10	4.81	36.85	4.79
60	10	4.74	31.26	4.06
90	10	4.24	28.62	3.72
30	12	4.57	24.40	3.17
60	12	4.34	20.09	2.62
90	12	4.26	17.25	2.24

Table 8: Soda pulping of Plantain stalk at liquor-to-solid ratio of 20:1

Time for cooking (mins)	Concentration of soda liquor (%)	Pulp yield (g)	Kappa number	Residual lignin content (%)
30	8	4.96	43.12	5.61
60	8	4.73	42.24	5.49
90	8	4.45	38.61	5.02
30	10	4.57	32.93	4.28
60	10	4.31	26.85	3.49
90	10	4.12	23.52	3.06
30	12	4.38	18.03	2.34
60	12	4.25	15.58	2.03
90	12	4.13	11.96	1.55

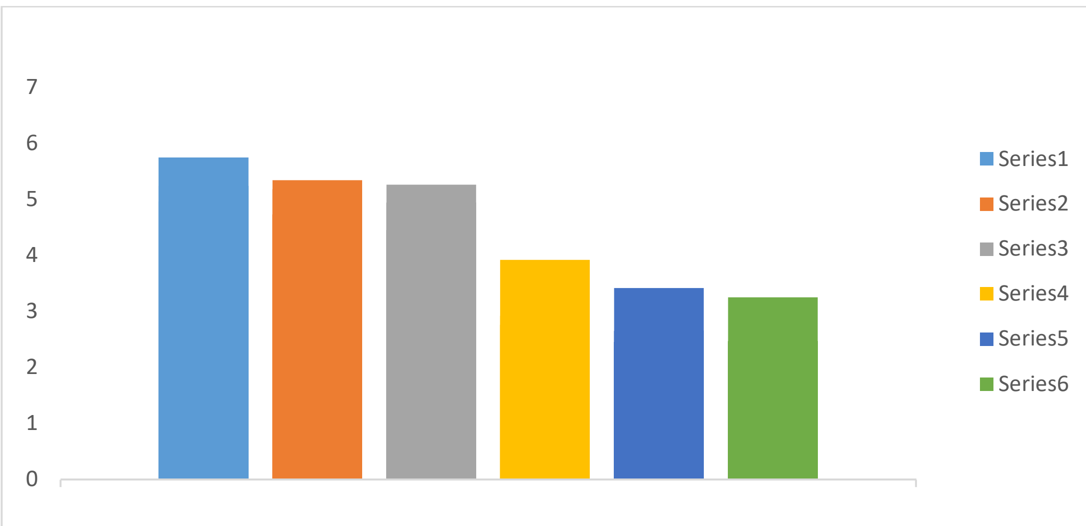

Figure 1: The effect of pulping time and liquor-to-solid ratio on residual lignin content (%).

Where

Series 1= Plantain stalk at 30 minutes pulping time, pulping time.

Series 2=Plantain stalk at 60 minutes pulping time, pulping time.

Series 3=Plantain stalk at 90 minutes pulping time, pulping time.

Series 4= Cornhusk at 30 minutes

Series 5= Cornhusk at 60 minutes

Series 6= Cornhusk at 90 minutes

4. DISCUSSIONS

Moisture Content

The results of the moisture contents determination were presented in Tables 1 and 2. The plantain stalk contained approximately 90% water which makes it about 8 times higher compared to that of corn husk. This necessitates the need to pulp sufficiently dried raw materials to prevent further dilution of the cooking liquor which may occur as a result of interference with inherent water contained in the raw material. Besides, the plantain stalk must be technically dried to prevent deterioration during storage (Ogunsile, 2006).

Pulp Yields

Plantain stalk has a higher pulp yield than Corn husk on oven dry basis (Tables 3 -8) under the same pulping conditions. This was due to the fact that plantain stalks have higher cellulose content than corn husks (Ogunsile, *et al,* 2006). Generally, there was a gradual decrease in the quantity of the resulting pulp yields as the values of the operational variables increases. Plantain stalk was observed to have the highest amount of pulp yield but with much rejects. Corn husk was also observed to possess similar trend with its highest pulp yield at the mildest operating conditions.

The Kappa Number and Lignin Contents

The Kappa number and lignin content were observed to have similar trends of general decrease in the amount of residual pulp yield as the operational variables were changed to a more severe operating condition. Comparatively, plantain stalks had higher delignification rate than cornhusks at the same operating conditions (Tables 3-8)

Effect of Operational Variables

Alkali Charge

It was observed from Tables 3 to 8 that there was a relative decrease in the quantity of pulp output as the alkali charge increases. In fact, the more concentrated the cooking liquor, the higher the dissolution of lignin and other cellulosic organic substances present in the pulp sample, thereby leading to a reduction in the pulp output. Thus, high concentration of the cooking liquor, leads to degradation of cellulose. Hence, corn husk and plantain stalk had the least amount of pulp yields at the most severe operating conditions as depicted in Figure 1.

The delignification process was quantitatively similar to the trend of the pulp yield with respect to the alkali charge. A high alkali charge generates pulp with a low Kappa number and lignin contents, while a low charge produces pulp with high Kappa number and lignin contents. There was a general decrease in the kappa number and hence lignin contents of pulp output indicating that lignin is dissolved and eliminated in the pulp sample with high concentration of soda liquor.

Time for Cooking

The result showed that the longer the time for cooking, the lower the quantity of the resulting pulp yield (Tables 3-8). Long period of cooking gave room for high depletion of the crude cellulose, fiber and lignin substances present in the raw materials. Thus, a prolong cooking of raw materials is responsible for low pulp yields. Similarly, long period of cooking results in a decrease in the value of the kappa number and lignin content (Figure 1). This is desirable as more lignin is removed from the raw material which is the main purpose of pulping.

Liquor-to-Solid Ratio

It was discovered that the higher the liquor-to-solid variation, the lower the amount of the resulting pulp yield. Although, this trend was observed with the other operational variables (i.e. time and concentration of cooking liquor), the effect was more pronounced with variation in the liquor-to-solid ratio. At low liquor-to-solid ratio, a high yield pulp can be produced but rejects will be present in the output. Plantain stalk was observed to have higher pulp yields than corn husk (Tables 3-8). The same is true for the kappa number and the lignin content of the pulping materials. A high liquor-to-solid ratio results in pulps with a low Kappa number and lignin content, and vice versa (Figure 1).

In general, the overall effects of the operational variables showed that the pulp with the least kappa number and lignin content for both corn husk and plantain stalk are those with the liquor-to-solid ratio of 20:1, pulping time of 90 mins and alkali concentration of 12% caustic soda. High pulp yields from both plants required low values of the operating variables. It was also apparent that, although, plantain stalk gave a relatively higher pulp yield and low lignin content than corn husk, both agricultural residue have a promising potential as alternative fiber in paper making industry.

5. CONCLUSION

The results of this study have demonstrated that non-wood agricultural wastes such as cornhusks and plant stalks can be used as pulping raw materials in place of wood. The pulping of corn husk and plantain stalk was easier, due to their relatively low lignin contents which requires minimum amount of chemicals during the cooking process. The pulp with the least kappa number and lignin content for both corn husk and plantain stalk are those with high liquor to solid ratio, pulping time and caustic soda. High pulp yields from both plants required low values of the operating variables. Although, plantain stalk gave a relatively higher pulp yield and low lignin content than corn husk, both agricultural residues have promising potentials as alternative fibers for the pulp and paper making industry.

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