International Journal of Research and Review
www.ijrrjournal.com E-ISSN: 2349-9788; P-ISSN: 2454-2237

Original Research Article

Eco-Safe Handmade Paper Production from Rice Straws

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Received: 30/06/2016 *Revised: 15/07/2016* *Accepted: 15/07/2016*

ABSTRACT

The study sought alternative eco-safe materials for production of handmade paper from rice straws. The rice straw fibers were pulped using selected eco-friendly materials *viz*; wood ash, soda ash (*magadi*), urea, potassium hydroxide and marcel soap each at concentrations of 4%, 6%, 8%, 10% and 12%).Starch and rosin were used as sizing agents. Selected paper properties namely; grammage, water absorbency, and tensile breaking strength were determined for each sample produced. Wood ash and marcel soap registered high grammage of 182gm^{-2} and 180 gm^{-2} respectively at 12% w/w. Urea, soda ash, and potassium hydroxide registered lower grammage. Marcel soap produced paper samples with the lowest Cobb value of 356 gm^{2} followed by wood ash at 360gm^{2} at the maximum concentrations. At the concentration of 12%, wood ash and marcel soap registered superior tensile breaking strengths of 1,520N and 1,518N respectively and the weakest breaking strength of 1,116N was recorded by urea at the same concentration.

Keywords: Eco-safe, marcel soap, cob value, grammage, delignifying.

INTRODUCTION

Paper is a fundamental part of most aspects of the society, worldwide a total of approximately 300million metric tons of paper are produced each day and approximately 90% of this paper is produced from mature pulp wood. [1] In addition, the demand of paper is expected to increase to approximately 490 metric tons by 2020 because today's activities require a high consumption of paper to an extent that little can be done without it even with the increasing use of electronics.

The increased demands of paper production and limited wood resources have directed researchers to look for appropriate additional resources of non-wood materials and agricultural residues for pulp and paper manufacturing. Several non-wood lingo cellulosic by-products of agricultural cultivation have been investigated by researchers. They include rice straws, cotton wastes, banana fibres, jute wastes, wheat straws, elephant grass, among others. [2] Among all the agricultural residues, rice straw appears to be a promising material because it is inexpensive and abundantly available. [3]

Rice *(Oryza sativa*) is recognized as an important strategic component of food security and crucial element in the staple food economies of sub Saharan Africa as such the crop has gained prominence in the farming systems and diets in Africa. In Uganda, rice is among the emerging staple and commercial crops grown. Over a decade ago, rice ranked first in returns per labor among the major crops grown in the country. Rice straw is considered an excellent material for production of handmade papers mainly due to its abundance from agricultural industries worldwide. The paper industry is a forest based industry associated with the depleting forest cover hence it is one of the major causes of deforestation and environmental degradation.

The production of papers, industrial or handmade is associated with the use of various chemicals which are detrimental to the environment and human health. These includes; chlorine, chlorine dioxide, sodium hypochlorite, hydrogen peroxide and peroxy acids among other. For handmade paper production from rice straws to gain economic and environmental benefits, alternative eco-safe materials and methods of production have to be harnessed.

MATERIALS AND METHODS

Materials

Rice straw sample (25 kg) was collected from a rice field in Tororo district in Eastern Uganda and transported to Busitema university textile lab. Marcel soap was purchased from BIDCo Uganda limited located in Masese, Jinja district. Soda ash was purchased from Owino market. Wood ash was collected from burnt wood. Urea, potassium hydroxide, alum, rosin and starch were purchased from BDH Kampala. Holland blender beater and calendaring machine from Uganda Industrial Research Institute in Kampala was used. Analytical balance was use.

Extraction of the rice straw fiber

The straws were cut into uniform lengths (approximately 1 inch) using a paper cutter. The plant samples were separately delignified by boiling in the following chemical agents: wood ash, potassium hydroxide, soda ash, marcel soap and urea. The rice straw samples (1 kg) were separately boiled in the delignifying solutions (2000 cm^3) made at concentrations of 4, 6, 8, 10, and 12% (w/w) for each chemical agent. The fibers were washed with hot water.

Pulping, sizing and sheet formation

The washed fiber samples were beaten for 30 minutes using a Holland beater machine to form pulp. The pulp was sized by adding starch, alum and rosin in ratios of 6:8:4 respectively. The pulp was transferred to a trough and sheets were uniformly spread on a wire mesh fixed on a wooden frame. The pulp on the wire mesh was hand pressed with a soft cloth and sun dried. Smoothening was done by the use of a calendaring machine. The smooth papers were then cut into uniform sizes.

Determination of selected paper properties

Basis weight: The paper samples were cut into small equal pieces and weighed on analytical scale. The basis weights /grams per square meter (GSM) were calculated using the formula (i) below;

$$\text{GSM} = \frac{\text{Weight ofpaper}}{\text{Area of the papaer}} \ldots\ldots\ldots\ldots\ldots\ldots.... \text{(i)}$$

Water absorbency (Cobb value): Paper samples were cut into uniform sizes and immersed in water for 60 seconds, removed and pressed between blotter papers. This was done in accordance to standard Cobb Test TAPPI T 432 [4] for sized boards. The water absorbency was then measured as the weight difference between the wet and the dry sample and calculated using formula (ii) below

$$\text{Cobb value} = (\text{W2} - \text{W1})\text{g} \times 100\text{m}^2 \ldots... \text{(ii)}$$

Tensile breaking strength: Paper samples were cut into equal sizes and subjected to tensile stresses that elongated the strips as they were pulled to failure by clamps attached at their ends according to TAPPI 54: 674 procedure. [5] The tensile strain tensile stress was calculated. The maximum value of the stress at failure is the measure of the tensile breaking strength of the paper.

RESULTS AND DISCUSSIONS

In reference to this short study it should be noted that the technology and procedure used in the production of the handmade paper samples is not able to produce sheets of equal and uniform thickness. However, an average thickness is possible with the use of the same procedure and tools. This is an important factor that may greatly influence the grammage (Basis weight) The selected materials were used as delignifying agents at various concentrations.

The grammage was determined for each paper sample produced with a given delignifying agent at a defined concentration as shown in Table 1 below. It can be seen that the grammage value increases with increase in concentration for all delignifying agents. At a concentration of 12%, wood ash registered the highest grammage(182 gm^{-2}) followed by marcel soap (180gm^{-2})with urea registering the least (148gm^{-2}).This suggests that at higher concentrations, the paper becomes denser as the fibres become freer from lignin hence softer and easily compacted. Grammage influence the physical characteristics of paper hence their application. Higher grammage are suitable for boards and other non-print papers and for this type, wood ash gives a superior performance to the rest of chemical agents used. The basis weight is what determines, how much area the buyer gets for a given weight.

Water absorbency (Cobb value) is the degree of water absorbance by a paper material. This is critical in paper applications like in packaging materials. From Table 2 below, it can be noted that with all the delignifying agents, the increase in concentration used generally reduces the water absorbency of paper sample produced. A marked change in Cobb value with increase in concentration is observed in potassium hydroxide from 427 to 386 gm^{-2}. In all the samples, those delignified with marcel soap exhibited overall lowest water absorbency with a minimum value of 356 gm^{-2} at concentration of 12% w/w.

Table 1: Grammage of paper samples produced with selecteddelignifying agents at various concentrations

Concs. of delignifying agents (% w/w)	Basis weight (g/m^2)				
	Wood ash	Potassium hydroxide	Soda ash	urea	Marcel soap
4	159	121	141	100	151
6	170	143	148	126	158
8	175	157	154	140	160
10	178	163	155	144	170
12	182	175	174	148	180

Table 2: Cobb values of paper samples produced with various delignifying compounds at various concentrations

Concentrations of delignifying Compounds (%)	Cobb value (gm^2)				
	Wood ash	Potassium hydroxide	Soda ash	Urea	Marcel soap
4	398	427	430	431	374
6	391	417	423	411	371
8	384	412	414	400	363
10	373	398	402	390	362
12	360	386	394	382	356

Paper is a cellulosic material and the water absorbency of paper material is a result of absorbance by cellulose and residual lignin. It has been established that water absorbency of lignin is two third that of cellulose. [6] This illustrates that with the use of marcel soap more lignin is removed to free fibres in the rice straws and the water absorbance is largely due to cellulose. A more amorphous structure of cellulosic material favors its water absorbance and this is inversely proportional to the degree of bonding of the fibres. This also suggests that in the paper sample made from marcel soap, more fibre bonding is favored since much of the lignin from the straws is removed fibres are more flexible and compact/bonded.

Table 3: Tensile breaking strength of paper samples made from selected delignifying agents at various concentrations

Concentrations of delignifying agents (% w/w)	Tensile breaking strength (N)				
	Wood ash	Potassium hydroxide	Soda ash	urea	Marcel soap
4	1290	1167	1002	982	1424
6	1394	1178	1007	987	1458
8	1445	1189	1108	998	1465
10	1450	1261	1119	1003	1512
12	1520	1286	1122	1116	1518

Tensile breaking strength

The tensile breaking strength was determined for each paper sample produced under various conditions as described above.

From Table 3 above, it can be seen that the tensile breaking strength of each paper sample increases with increase in the concentrations of the delignifying agents used. This suggests that at a high concentration, there is high degree of fibre bonding. The bonding of cellulosic fibres is favored by their flexibility and thus the absence of lignin. Therefore in this case, the increased concentration of the delignifying agent resulted to increased removal of lignin as reflected in the values of tensile breaking strength. The selected delignifying agents were able to significantly remove lignin from the rice straws. Wood ash and marcel soap produced the best results with tensile breaking strengths of 1520N and 1518N respectively each at concentration of 12% w/w. Poor performance was registered with potassium hydroxide, soda ash and urea in that order with values of tensile breaking strength at 1286N, 1122N, and 1116N respectively at 12% w/w. It should also be noted that even at a concentration of 4% w/w, marcel soap registered a high tensile breaking strength of 1424N which is greater than for potassium hydroxide, soda ash and urea at concentration of 12% w/w. Therefore a small quantity of marcel soap can be used in the production of handmade with a satisfactory tensile breaking strength.

Fig.1 below is the photo of handmade paper products made during this study. From the photo it should be noted that the papers produced are not white and they exhibit the characteristic color of rice straws. Owing to the technology of production, these handmade papers are suitable for use as boards, paper bags and related products. They are not suitable for printing application given their rough surface, dull color and uneven thickness.

Figure 1: Photo of handmade papers samples made from rice straws using various delignifying agents.

CONCLUSION

The study harnessed alternative eco-safe chemical agents for the production of handmade paper from rice straws. It was established that marcel soap and wood ash can be effectively used in the production of handmade papers from rice straws. Both of these materials are eco-safe and have no health threat in the course of handling. Though marcel soap produced paper samples of equally good tensile breaking strengths with those from wood ash, it should be noted that wood ash is more available for use than marcel soap which is an industrial product.

ACKNOWLEDGEMENT

In a special way we recognize the contribution made by Mr. Athhaire G. K. of Uganda Industrial Research Institute (UIRI) for his support in availing equipment used for production of the handmade paper. The financial support given by the management of Busitema University towards this study is greatly appreciated.

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How to cite this article: Shamim N, Janani L, Yvonne T. Eco-safe handmade paper production from rice straws. Int J Res Rev. 2016; 3(7):26-30.

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