POTENTIALS OF BAMBOO (BAMBUSA) VULGARIS STEM AS A RAW MATERIAL FOR PULP AND PAPER MAKING

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Abstract
The investigation on the potentials of Bamboo (Bambusa Vulgaris) stem as paper making raw material was investigated. The effort was carried out to search for raw materials to replace the presently imported long fibre pulp for the production of pulp and paper in Nigeria. Bamboo stems were manually reduced to chips of average dimensions 1-2.5cm along the grain direction and were used for pulping. 200g of chips were cooked with 1 mole, 2 moles and 3 moles concentration of NaOH respectively in an earthen pot for an average time of 1 2hours of which the pulp yield for the respective concentrations were obtained. The pulp was washed and subjected to bleaching in order to improve the brightness using sodium hypochioride solution. $CaCO_3$ (Calcium Carbonate) was added as a filler and commercial hot water starch was also added as a sizing agent. Some physical and mechanical tests were carried out to determine the properties of the paper produced. Some of the results obtained were pulp yield — 67.5%, 55% and 40.5%; calliper thickness — 0.60mm, 0.48mm, 0.50mm; tearing strength -- 37.27N/rn^2,28.44N/m^2 and 31.38N/rn^2 hardness - 1 .45N/mm, 1 .62N/mm and 1 .82N/mm for cooking liquor of 1 mole, 2 moles and 3 moles concentration respectively. Results obtained indicated mostly that the properties of the resultant paper were enhanced as the concentration of sodium Hydroxide (NaOH) used was increased except for unbleached pulp yield which decreased as the molar concentration of the cooking chemical was increased.

Keywords: *Bamboo stem, Bambusa Vulgaris, pulp, paper,*

Introduction

The per capita consumption of paper has been suggested as an indication of the degree of advancement, which nation attain. Certainly, world development as we know it could not have taken place without a means of communication in which speech is supplemented by written or printed records. Papers have undoubtedly been the principal media for such records. Man has always felt the need to record his ideas and impressions of the world around him. Primitive man hunted wild animals and painted their pictures on the walls of his residential cave. The people of Sumarians, who lived in the valley of Tigris and Euphrates, in present day Iraq, were the first people who started writing on clay tablets (Dereck, 1969). The earliest writing materials were stones, clay tiles, bones, metals, skins, leaves of certain plants, waxed wooden tablets etc. All these had their obvious limitations. Then came the ancient Egyptians of' over 5,000 years ago who used a water reed known as papyrus from the bank of River Nile to make a much lighter writing material. Most of the works of great Greeks and Romans were recorded on papyrus, from which the term "paper" is derived.

One of the problems in pulp and paper industry in Nigeria and some part of Africa is inadequate supply of long fibre pulp for paper production.

Nigeria's paper mills were designed to utilize mixtures of short and long fibre pulp. Short fibre pulp woods are available in commercial quantities and the chemical, morphological and pulping characteristics of some of them have been reported. However, due to climate restriction Nigeria has not been able to grow enough softwood to locally source for long fibre pulp. As a result it became increasingly difficult to operate the pulp and paper mills in the country on economic basis because of long fibre component is at exorbitant price.

Apart from raphia palms, there exist potential of produce long fibre pulp (even at small scale basis) from some non-woods, woody grass and agricultural products (Odeyemi, 2005). Unlike woods, these plants are easily delignified and can be produced annually. Besides it, they offer wide variety of physical and chemical properties that can be utilized has therefore become necessary to characterize their puips and ascertain their suitability or otherwise for paper-marking. In this way, there would be substantial saving of the foreign exchange arising from reduced importation of long fibre pulp.

One of such plants in Bambusa vulgaris (bamboo) which is fast growing and high yielding naturally accuracy perennial , giant, woody grass. It is self-propagatory plant that takes 2 to 6

years to mature depending on the species. Bamboo is popular as a raw material for pulp and paper making in many countries of the world including Malaysia, china and india. (Khristora et al, 2004) reported that bamboo is an ideal fibre blend for bagasse pulp in any desired proportions depending upon the grade of paper to be manufactured. Various studies have been reported on the fibre dimensions, chemical composition of different bamboo species from different countries and their suitability for commercial pulping. The proximate chemical composition are similar to those of hardwoods namely, holocellulose, 60-70%, pentosans, 20-25%, hemicellulose and lignin, 20-30% and other minor constituents like resin, taninis, waxes and inorganic salts .The average fibre length ranged from 1.3 to 5.0mm.

The species of bamboo which grow in Nigeria includes:

Bambusa vulgaris, Arundinancea, Tulda, Dentrocalamus Sinicus, Gigantes

Oxytenanatherca obyssinia. These bamboos are found on land owned by individual, families, private organization, entities, religious, educational institutions and even the government. Bambusa vulgaris is one of the most common species especially in the southern part of Nigeria. The production of paper is an industrial process, that is, paper is produced through a continuous process starting with tree trunk and finishing with cut-sheets. Available records show that forest timber in Nigeria is short industrial fibre requirements needed in pulp and paper production. There is therefore an urgent need to source for alternative sources of fibre to bridge the wood demand-supply gap. Deforestation as a result of clean cutting of available forest-timber will expose our environment to dangers such as erosion. Therefore, to achieve sustainable industrial fibre management and environmental friendly industrial policy there is need to diversify the source of raw materials for pulp and paper production, other than using only forest timber.

Bamboo, despite growing fast also produce a large biomass remains yet to be used for viable industrial raw materials for production of pulp and paper in Nigeria.

This research was designed to address the following problems:

1. The three-grounded Nigeria paper mills were importing long fibre pulp for production of paper and paper products.
2. A search for a more environmentally friendly source of pulp.

The aim and objectives of this work are:

1. To determine the pulping characteristics of Bambusa vulgaris stem grown in Enugu State, Nigeria using variable concentrations of kraft liquor.
2. To make a handmade paper from the resultant pulp.
3. To determine the some physical and mechanical properties of the pulp and the resultant handmade paper (e.g. Pulp brightness, calliper thickness, water absorption, bulk density, tearing strength, fold endurance, and tensile strength).

MATERIALS AND METHODS

The raw material bamboo (Bambusa Vulgaris) stem which was used for this research work was collected inside a swamp very close to Mornarch Motel behind Federal Government College Enugu. The analytical chemicals were purchased at Ogbete Market, Enugu; Sodium Hydroxide (NaOH), Calcium Carbonate ($CaCO_3$), Hot water starch, Disttled water and Sodium Hypochloride (liquid). Also, there are the pictures of the apparatus/equipment used in preparing the samples for the work.

Experimental Procedure

Preparation of 1mole, 2moles and 3moles concentration of Sodium hydroxide (NaOH) solutions were made.

1. 40g of sodium hydroxide (NaOH) crystals was dissolved after weighing into 1000ml of distilled water to get 1mole concentration of sodium hydroxide.
2. 80g of sodium hydroxide crystal was weighed and dissolved in 1000ml of distilled water to get 2 moles concentration of sodium hydroxide.
3. 120g of sodium hydroxide crystal was weighed and dissolved in l000ml of distilled water to get 3 moles concentration of sodium hydroxide solution.

The bamboo stem was cut and the greenish outer covering was peeled off before removing the nodes with the aid of a matchet. The bamboo stem was later cut into chips (with the aid of knife) with dimension 1-2.5cm along the grain direction and 0.2-0.3cm in the grain width direction. Three samples were prepared and each weighed 200g. Each of the sample was put in an earthen pot and cooked using 1mole, 2 moles and 3 moles of NaOH.

The weighed bamboo chips together with the dissolved NaOH mixture in the cooking earthen pot was placed on lighted kerosene stove and boiled for 9hours at a temperature of 160°c ±5°c for complete chip digestion to take place. The content of the cooking earthen pot was agitated at intervals of 1 hr until end of cook was reached. The resultant fibrous mass was poured out at the end of cook and spent liquor drained.

The digested pulp was washed after ageing several times with distilled water to remove all traces of black liquor and residual sodium hydroxide. At the end of washing, the weight of the wet pulp were measured based on wet weight. The wet pulp were allowed to dry under the sun and then reweighed. The unbleached pulp yield was determined.

Bleaching was carried out to improve the brightness of the pulp. The bleaching was done by adding 250ml solution of sodium hypochlorite to 35g of pulp and allowed to stay for 1 hour. The pulp-sodium hypochlorite mixture was agitated every 10 minutes to ensure uniformity. The pulp colour gave little bright and brown colour.

25g of $CaCO_3$ was measured and mixed with the resultant pulp from each cook. This was done at all concentrations of NaOH used. The pulp- filler mixture was manually mixed to ensure homogeneity.

Sizing

Commercial hot water starch was used as a sizing agent, 20g of commercial dry starch was weighed, prepared into a paste using hot water and then used in treating the resultant pulp from each cook. The pulp-filler mixture was manually mixed to ensure homogeneity.

Production of Paper From Pulp

The dry pulp was weighed and 35g was collected for each sample. The samples were put in different bowl containing about 3 litres of distilled water. 25g of $CaCO_3$ and 20g of hot water starch was added to each bowl and stirred vigorously until a uniform mixture was achieved. The mixed pulp slurry was transferred to a flat surface frame which was covered with a white cloth while another white cotton cloth was used to cover the carefully and uniformly spread pulp. Once the web was formed, the sheet was placed under a press. A pressing iron was used as a press. It removed some water content from the formed pulp and also aided in reduction of paper thickness to get a thin, uniform and smooth surface after which it was dried under the sun.

After which, the under listed physical test were carried out. Tests for each property represented a minimum of tests carried on three randomly selected specimens. Specimen selection was done using a table of random numbers. Tests were done in accordance with the provisions of TAPPI (1989)

Calliper Thickness: This was estimated by taking readings from four different points along the plane of the paper and then taking the average thickness of the paper. Paper used for test was first conditioned for two weeks under laboratory room conditions (25^{o}c and 65% Relative humidity)

Bulk Density: Different samples of equal sizes and shape were prepared from paper generated from pulps produced from digestion conditions used in this study. The mass of each specimen was taken and the mean was calculated. Their volumes were also measured and recorded. The mean mass of each paper divided by the volume of the paper gives the bulk density.

Pulp yield: The weight of the chips was weighed before cooking. After cooking, the resultant pulp was washed, dried and weighed and the weights recorded. The pulp yield was determined as the percentage of the weight of the pulp divided by the original weight of chips.

Water Absorption: The weight of the water absorbed was determined from the difference between the weights of paper after soaking and the initial weight of paper before soaking. The percentage of water absorbed is determined by the difference between the weight of paper after soaking and the initial weight divided by initial weight of paper multiplied by 100. Each water soaked specimen was soaked in distilled water for 2 hours before removal.

Moisture Content: Some sample chips were weighed and weights recorded. The samples were placed in a ventilated oven operated at a temperature of 105^{o}c ± 2^{o}c and allowed to stay for about 24 hours until a constant weight was obtained and recorded. The moisture content (Mc%) is determined using the formula (See appendix)

Mechanical Tests

Hardness Test: The sample was prepared according to the specification stipulated in TAPPI (1989). A force was applied which made an indentation on the paper. The hardness was determined.

Tearing strength: the sample was prepared in accordance with the specification of TAPPI (1989) for handmade paper. The specimen was clamped to the smooth side of the machine such that it faced the axis of the instrument. A force was applied which tore the paper. This force was recorded. The test was performed in accordance with the specifications of TAPPI standard methods (1998). The equipment used was tearing resistance Testing /Machine. Tear strength was deduced from the formula;

Tear Strength = 9.807e

Where e = force to tear the paper

RESULTS AND DISCUSSION

The result of the properties of paper produced from alkaline pulping of *Bambusa vulgaris (*bamboo) using different concentration of sodium hydroxide (NaOH) are shown in table 1.

Properties	**Concentration OF Naoh**		
Physical properties	**1 mole**	**2 mole**	**3 mole**
Pulp yield (%)	67.5%	55%	40.5%
Bulk density (kg/m^3)	136.19kg/m^3	117.83kg/m^3	94.31kg/m^3
Calliper thickness (mm)	0.60mm	0.48mm	0.50mm
Water absorption (%)	61.5%	72.7%	90.9%
Moisture content (%)	21%	21%	21%
Mechanical properties			
Tearing strength (N/mm^2)	37.27N/m^2	28.44 N/m^2	31.38 N/m^2
Hardness (N/mm)	1.45N/mm	1.62 N/mm	1.82 N/mm

Physical Properties

Pulp Yield: From Table I and figure 9, it was observed that the pulp yield decreased with increased concentrations of NaOH used in pulping. Hence, high concentration of NaOH leads to greater removal of lignin and other substances. The observed lower yield of 40.5% might be as a result of massive degradation or hydrolysis of cellulose with lignin at higher concentration hence the lower yield was low when compared with what was expected from semi-chemical pulping as reported by Casey, 1974 which ranged from 45-47%.

Bulk Density: The bulk density for paper produced under different pulping conditions was represented in Table 1 and figure 10. It could be observed that it decreased with increased concentration of NaOH. This was understandable as the higher concentration would lead to greater delignification and removal substances. The effect of decrease in pulp density with increase in molar concentration of NaOH was significant at 5 percent level in t- test and was in conformity with the findings of other workers.

Calliper Thickness: the effect of variable concentration of NaOH on the calliper thickness is presented in table 1 and figure 11. Since the same quantity of chips was used for each pulping conditions, higher concentration of chemicals would lead to reduction in volume and mass of resultant pulp and since the pressing and drying conditions were kept constant, it was expected that if a paper sheet of uniform web was formed, the less delignified wood would provide more volume of pulp and thus greater calliper thickness. This was in keeping with known behaviour of paper (Casey, 1980, Suleman, 2006)

Water Absorption: The effect of variable concentration of NaOH on the water absorption properties are presented in table 1 and figure 12. It was observed that the water absorption of the locally handmade paper produced from bamboo chips increased with increased NaOH concentration. The differences were very significant in the test. The high water absorption of this handmade paper was due to low sizer content used during production. It could be attributed to poor pressing conditions which could have allowed more void spaces within the paper web.

Moisture Content: The effect of variable concentration of NaOH on the moisture content of the chips used was also presented in table 1. It could be seen that the moisture content of the chips used for the production of locally handmade paper was 21%.

Mechanical Properties

Tearing Strength: This is presented in the table 1 and figure 13. It could be seen that tearing strength decreased with increased concentration of NaOH. The tearing strength of paper produced from pulp using any of the NaOH concentration used in this experiment compare favourably with properties of paper board produced from semi-chemical pulps. High concentration of sodium hydroxide (NaOH), if all conditions being equal will lead to improved delignification and removal of pectic substances which will give the resultant pulp high paper properties.

Hardness: this is presented in table 1 and figure 14. It was observed that the hardness of paper increased with increasing concentration of NaOH . This quality revealed that handmade paper produced from soda pulping of bamboo chips will be good for paper board.

Conclusion

It was observed that pulp and paper could be produced from bamboo stem, hence, there will be a continuity in supply of raw materials since bamboo stem are fast growing and high yielding naturally occurring woody gross.

The research work indicated that handmade paper with high concentration of sodium hydroxide solution would compete in quality with industrial made paper (machine made paper). The brightness of the paper can be improved by using the appropriate bleaching agents.

Pulp produced from bamboo chips by semi-chemical pulping process using sodium hydroxide (NaOH) would be suitable for corrugated board, carton paper and other industrial papers.

Recommendation

In Nigeria today, paper is a highly consumable product due to its importance in the society but virtually all the raw materials used in the production of paper are imported. This has affected our economy negatively. People do not know the value of bamboo sticks hence they neglect it.

It is recommended because of the environmental friendliness of substituting bamboo to forest trees as a source of pulp. The massive job creation potentials; adaptability to cottage industrial venture and potential impact on the local economy all attest to it.

Finally, adequate protective measures should be taken when dealing with pulp and paper production because of poisonous chemicals used in the production process to avoid harm and pollution of the environment. Safety wears like hand gloves, lab coats, safety boots etc should be used when working in paper production section to ensure adequate protection.

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