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Physical, chemical and mechanical properties of corn sheath as pulp and paper raw material

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Abstract-
Most papers are made from virgin wood-based pulp of hardwood sources but recently, softwood have received enormous attention as alternative to hard wood because the hardwood takes a significant number of years to mature enough for use in the pulp and paper industry unlike softwood which are majorly annual plants. The annual crop in focus in this work is the yellow open-pollinated variety of corn which generates tons of waste at harvest. A novel attempt is made to ascertain the viability of corn sheaths as raw material for the pulp and paper industry by carrying out a comprehensive analysis on the pulp and paper made from the pulp. The sheaths were dried, shred and cut into pieces suitable for the digester and the pulps obtained were analysed for physico-chemical properties. Hand sheets were also made using the generated pulp and its physico-mechanical properties were analysed. Results obtained were compared with pulp from corn husks from other parts of the country, three Nigerian fibre sources – silk cotton, bagasse and rice straw and other foreign non-wood sources and found to be of competitive properties. Pulp properties of Lignin content, ash content, cellulose, hot and cold water solubility of the fibres were 13.72 ± 1.21%, 1.27 ± 0.23%, 53.26 ± 1.11%, 15.20 ± 2.11 and 6.14 ± 2.43 respectively while the mechanical properties of paper from the pulp were Bursting strength (282.163 KPa m^2/g), Tear strength (146.119), Tensile strength (257.6N/m) and Tensile Index (3.9Nm/g). It was found that in all properties, the corn sheath was better than the rice straw fibers but not as good as the silk cotton and bagasse fibers. However, the corn sheath has been identified, as a viable raw material for the pulp and paper industry in Nigeria.

Keywords: corn sheath, open-pollinated, tensile strength, hand sheets, lignocellulosic waste, corn variety.

1. Introduction

The demand for paper in printing, packaging and other sundry uses is always in the increase globally. This is due to the more recent use that has been found from paper. In order to meet up with this increasing demand caused by a positive technology disruption, alternative to wood and less expensive raw materials are now being sourced. Non-wood plants, like hemp [1] alfalfa stem, switch grass, poplar and willow biomasses [2], okra stalk [3], rapeseed straw [4], dhaincha [5, 6], cotton stalk [7], jute [8], rice straw and husk [9, 3], to mention but a few, have been researched on and found to give acceptable fibre yield and quality. A major drawback in these findings is the hitch posed by variations in the properties of the raw materials since they have not been genetically modified for this purpose [7].

Since the non-wood sources of lignocellulosic materials (like stem, stalk, sheath and leaves) are soft, chemical pulps from them are easily produced via the soda cooking procedures. In some processes, small quantity of anthraquinone or ethanol is added to improve on some fibre properties. So, there is now a deliberate and conscious shift in the research methodology of evaluating these plants as having economic value in the pulp and paper making industry to modifying these processes for optimum characteristics of the pulp and paper [10].

In Nigeria, there's an intentional attempt to return to agriculture amidst the abundant petroleum resources in the land. Corn is a staple crop in Nigeria and in every corn farm, a huge heap of waste is generated after harvest. In the event that this is not properly handled, which is the case most times, these heaps become a source of environmental concern from its smell from putrefaction, unsightly presentations along the roads where they are usually dumped and the heaps now become breeding grounds for rodents and reptiles.

The white and yellow open-pollinated varieties are commonly cultivated in Nigeria. The planting starts in the month of march and harvesting is done in the month of May [11]. The harvested corn find immense use as food for man (cereals, flour, …etc) and animals (animal feed). The corn sheath (also known as corn husk) is the outer covering for the corn cob. A very small percentage of corn sheath find relevance and use in culinary services to impact a special taste or aroma to the food covered or wrapped with corn sheath. As much as 2 – 4 tons of corn can be harvested from a hectare of cultivated farmland [12]. With this volume of harvest comes at least twice this volume, as waste. This farmland waste are gathered in heaps in or near the farm and either allowed to decompose naturally or burnt by fire. They become ready homes for rodents and reptiles and also make the environment unsightly.

By definition, the corn sheath easily falls into the classification of lignocellulosic waste [13, 14]. Therefore, this study attempts to find economic value to corn sheath (which are agricultural wastes) in its suitability as raw material for the pulp and paper industry.
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2. Methodology

The corn sheaths of the yellow open-pollinated variety used for this study were obtained from a farm at Ikorodu, Lagos, Nigeria. The sheaths were cleaned and rid of blades and soil. They were sun dried outside the laboratory for two days and shred with hands to loosen the fibres. They were then manually cut into an approximate length of 4 cm, using a knife. The methods of [15] and [3] were followed to analyse the standard composition according to TAPPI standards. Cooking and washing was carried out according to [3]. The fibres from the cooking were then analysed for their chemical analysis.

Handsheets were made in the laboratory using the Rapid-Kothen sheet former for mechanical tests to be conducted in accordance with prescribed ISO standard. Grammage, tear and burst strength were some of the physico-mechanical parameters investigated.

3. Result and discussions

Results shown in Table 1 reveal a quite high ash content of 1.27 ± 0.23 which was found to be much higher than values of other non-wood sources of pulp and paper like 0.41% in spruce and 0.25% in pine [16] but lower than values for Eucalyptus and 8.2% in canola stalks [1]. On the other hand, this value is far better than 5.09% of [18] and 3.57% of [19]

The cellulose content of 53.26 % (Table 1) fared better than fibres from eucalyptus having 44 – 48% (2) and 41.23% from Oshodi corn husk [19]. With more cellulose, the tensile strength of paper from corn sheath is expected from corn sheath over the eucalyptus wood.

Lignin content of corn shield from Table 1 was found to be less than the 20 – 40% expected in wood sources (3) and confirmed with lower values compared with oak (21.7%), spruce (30.44%) and pine (29.53%) (4; 5) but slightly higher than 12.04% found in Oshodi corn husk.

In this study, the hot water solubility was higher than the cold water solubility which is contrary to previous studies in [4] and [22] for rapeseed straw.

Table 1: Chemical analysis of the fibre samples from corn sheath

Components	**Values**
Cellulose, %	53.26 ± 1.11
Holocellulose, %	62.31 ± 4.42
Alpha-cellulose, %	48.20 ± 5.56
Lignin, %	13.72 ± 1.21
Extractives	
Alcohol-Benzene, %	2.84 ± 2.12
Hot water solubility, %	15.20 ± 2.11
Cold water solubility, %	6.14 ± 2.43
1% NaOH, %	18.39 ± 1.15
Ash, %	1.27 ± 0.23
Fibre dimension	
Fibre Length, mm	1.487 ± 0.344
Fiber Diameter, µm	18.049 ± 6.66
LW(µm)	12.170 ± 5.62
CWT(µm)	2.328 ± 0.791

Physico-mechanical properties

The tensile strength of the paper from pulp is highly dependent on the quality and quantity of cellulose and hemicellulose, present in the fibre, which are carriers of the –OH group responsible for the hydrogen bonding in paper. Therefore, more cellulose in the fibre is expected to impact positively on the tensile strength of the paper. Results of tensile strength shown in Table 2, of 257.6 N/m is better than 164.32 N/m (rice husk) but much lower than 551.81N/m 644.91N/m of cotton silk and bagasse respectively [23].

Longer fiber lengths are expected from low lignin containing pulp [24] such as fibers from no-wood sources. Comparing data with results obtained by [23], Fiber length of corn sheath fared better than fibers from rice (0.8148mm) but not as good as fibers from bagasse and silk cotton of 2.071mm and 1.674mm respectively. Burst strength is an indication of the maximum pressure applied perpendicular to the surface of a material before breaking. Higher the bursting strength implies a better use of the paper as currency, for example, where continuous handling in various conditions is expected. Values of corn sheath fibers (282.163 KPa) outshined values obtained from silk cotton, bagasse and rice straw of 42.50KPa, 57.5KPa and 7.00KPa respectively. On the flipside, the tensile index of both corn sheath and rice straw fibres are in the same neighbourhood of 3.9 m/g and 3.14 m/g as against the values for silk cotton (9.2m/g) and bagasse (6.5m/g).

Table 2: Mechanical and physical properties of paper from corn sheath fibres

Parameters	**Corn sheath**
Grammage, g/m^2	66.052
Thickness, mm	0.291
Apparent density, g/cm^3	0.227
Bulk, $1/g/m^3$	4.414
Burst Index	2.877
Burst strength, $kPa.m^2/g$	282.163
Tear strength	146.119
Tear index, Nm^2/g	2.212
Tensile strength, N/m	257.6
Tensile index, Nm/g	3.9
Brightness	47.49
Opacity	99.63
Scat coefficient, m^2/g	42.85

4. Conclusion

Properties of the pulp and paper obtained from corn sheath were found to be excellent for pulp and paper production. Although, complete comparison of results obtained could not be done

with previous works on corn husk in Nigeria, the excellent burst and tensile strength, coupled with good opacity makes paper from this source raw material attractive and can be used for products like cards, packaging and printing papers. However, more work needs to be done to make the corn sheath of uniform properties, irrespective of location and specie.

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