IJST EXPLORE International Journal of Science and Technology
CENTRE OF PROFESSIONAL RESEARCH PUBLICATIONS
ISSN 2049-7318

International Journal of Science and Technology Volume 6 No. 3, March, 2017

Investigation of Strength Properties of Paper Samples from Pulp Blends of *Hibiscus Cannabinus* and Pineapple Leaf Fibres

O.D. Fagbemi, Taiwo K. Fagbemigun, E. Mgbachiuzor, C.C. Igwe, F. Buhari
Department of Chemical, Fibre, and Environmental Technology
Federal Institute of Industrial Research, off Agege Motor Rd. Oshodi, P.M.B. 21023 Ikeja, Lagos, Nigeria

ABSTRACT

Natural fibres from non-wood materials are important resources being exploited to meet the increasing demand for pulp and paper products. This study investigated the impact of pulp blending on the strength properties of papers obtained from the combination of pulp from Kenaf bark (*Hibiscus cannabinus*) and pineapple leaves (*Anannus comosus*). Chemical analyses of both materials were carried out according to respective methods. Pulp of Kenaf bark and pineapple leaf were obtained using soda pulping process at 18 % and 7 % alkali respectively. Handmade paper sheets were subsequently produced from bleached pulp samples combined in ratios 75%:25%, 50%:50%, and 25%:75% (kenaf bark: pineapple leaves) respectively. Paper samples were also produced from individual fibrous materials. Results showed that strength properties (modulus of elasticity, tensile stiffness, tear strength and elongation at peak) of paper samples produced from different ratios of pulp mixture vary significantly from the properties of paper from individual materials. Tear strength of paper from 100 % pulp of pineapple leaves (542.7 mN) increased by 62 % when combined with pulp of kenaf bark in ratio 50 % : 50 %, while the highest modulus of elasticity (63.02 N/mm) was observed in paper produced from pulp mixture (25 % : 75 %). Papers of differing strength properties can be obtained from the combination of pulp from kenaf bark and pineapple leaves in varying ratios and this can serve as a veritable alternative for softwoods.

Keywords: *Fibre, Paper, Pulp, Kenaf Bark, Pineapple Leaf*

1. INTRODUCTION

Deforestation and several other environment-related climatic changes which stem from cutting of woods for pulp and paper production and other purposes have become national and international issues and this has not reduced the increasing demand for pulp and paper. Nonetheless, world demand for paper and paperboard is expected to reach an estimated 490 million tonnes by 2020 [1]. There is therefore an urgent need to ensure equilibrium - look for alternative source of fibre for pulp and paper production, and at the same time reduce the environmental footprints of paper industries. Subsequently, countries around the world, particularly those with shortage of good forest woods, like India, China, Malaysia, Europe, Africa and North America have turned their attention to agro-based non-wood natural fibres sources which are sustainable, renewable and eco-friendly [2,3,4,5]. Natural cellulosic fibres from empty fruit bunches of oil palm, oat straw, banana pseudostem, carpet grass, switch grass, corn husk, cereal straw, rice straw bagasse, bamboo, reeds, flax, hemp, kenaf, jute, corn husk, sisal, abaca and pineapple leaf have been isolated and studied for pulp and paper manufacture [6,7,8,9,10]. In China and India, over 70 % of raw materials used by the pulp industry come from non-woody plants [11]. The impressive chemical composition and fibre morphology of these materials have given an indication of the papermaking potential of various species [12]. Papermaking fibers from timber sources can thus be successfully supplemented by fibers from non-wood species [13].

Kenaf (*Hibiscus cannabinus*) have been identified by the U.S. Department of Agriculture as a viable substitute for trees in the pulp and papermaking process [14,15]. Likewise, pineapple leaf, obtained from pineapple (*Anannus comosus*), which is widely cultivated only for its delicious and fragrant fruit in tropical and subtropical regions of the world, is a good and valuable source of fiber (PLF) which have the composition, properties and structure that make them suitable for uses in composite, textile, and pulp and paper manufacture [16]. The leaf which is considered as waste has potential in paper production and the development of low density polyethylene composites [17,18,19]. Usage of fibers from such leaves would not only be beneficial to pineapple plantation farmers but also be an effective waste management of the plantations [20]. Pulps prepared from the bark fraction of kenaf with long fibres compares favourably with softwood pulps in their general papermaking whereas those from the woody fractions are more like hardwood pulps but drain more slowly and have lower tearing strength [21].

Pulp blending is imperative in meeting the increasing demand for relatively strong papers both for traditional use as well as in new fields of application, such as fibre-based packaging, furniture, and paperboard and building material. The purpose of this study therefore, is to carry out a preliminary investigation into the pulp blending potential of kenaf bark and pineapple leaf fibre vis-à-vis the strength properties of papers obtained from the pulp mixtures.

2. MATERIALS AND METHODS

2.1.Materials

Samples of pineapple leaves were obtained from the bunch of freshly harvested pineapple fruits collected from local pineapple processing stores around the vicinity of the Institute. Pineapple leaves were washed with water to remove all debris and unwanted particles, and then air-dried for 48 hours (2 days). Samples of kenaf were collected from the Institute of Agricultural Research and Training (IAR&T), Ibadan, South West, Nigeria. Separation of kenaf bark from its core was done in the laboratory under room temperature. Both samples were further oven-dried at 110ºC until absolute dryness is achieved. Dried pineapple leaves were chopped manually into about 3 cm long pieces prior to grinding and size selection using a sieve of mesh size 0.4 mm. The samples were stored for further analyses.

2.2. Chemical characterization

Chemical analysis of pineapple leaf and kenaf bark mill was carried out based on the respective Technical Association of the Pulp and Paper Industry (TAPPI) standards for the different components. Alcohol-Cyclohexane solubility, lignin, Ash and cellulose contents were determined according to Tappi Standard Test Methods: 2007 [22].

2.3. Pulping study

Pulp of pineapple leaves and kenaf bark were obtained in a 5-litre conventional autoclave using soda pulping process. Following pulping, the cooked materials were thoroughly washed with water to remove residual cooking liquor and defiberized in a laboratory disintegrator (Lexus Optima Mixer grinder MG 2053) for 10 minutes. Defiberized materials were passed through a standard size 1 mm x 1 mm netted sieve in order to remove materials not well cooked. The screened pulp was washed, pressed, drained and allowed to dry to a moisture content of 10% at room temperature. Pulp samples were bleached in a mixture of acetic acid and Hydrogen peroxide (2:1 v/v). Kappa numbers of bleached pulp samples were determined according to TAPPI T236 om-299 standard procedure. Table 1 highlights the pulping parameters and pulp characteristic.

Table 1: Pulping parameters and pulp characteristics

	Kenaf bark	Pineapple leaf
Soda Concentration (%)	18	7
Liquor : sample ratio	5 : 1	6 : 1
Temperature (ºC)	121	121
Pressure (atm)	4.08	4.08
Cooking time (min)	105	105
Kappa number	45	16

2.4. Preparation and testing of laboratory paper sheets

Bleached pulp of kenaf bark and pineapple leaf were blended together in ratios, 50 % : 50 %, 75 % : 25 % and 25 % : 75 % respectively and handmade paper sheets were obtained from the mixture and also from individual pulp samples. The paper samples were then tested for strength properties such as modulus of elasticity, elongation at break, tensile stiffness, tensile strength and tear strength (ASTM D2261 test method) was done by testing of paper strips using the universal testometric machine (M500 – 25 KN. DBBMTCC – 250kg, Rochdale, England) according to TAPPI T 220 and T404 standard procedures. These values were used to obtain the tear index and tensile index of the various paper samples as highlighted in TAPPI T 414 procedural standard.

2.5. Sheet surface observation

Representative sheet samples were observed under a Digital microscope to study the distribution of fibres.

3. RESULTS AND DISCUSSION

3.1.Chemical characteristics of pineapple leaf and kenaf bark

Crucial paper properties depend on the chemical composition of the fibrous material which consists of cellulose, hemicelluloses, and lignin. From chemical composition point of view, plant materials with over 34% cellulose content have been characterized as promising for pulp and paper manufacture [23]. Results in Table 2 shows that cellulose makes up over 50 % of the non-wood materials investigated in this study. Although, many studies have reported cellulose content of less 40 % for most hardwoods, softwoods, agricultural residues and non-wood plants [24, 25, 26, 27, 28, 29], the result from this study compares favorably with the work reported by Atul et al [30]. Low lignin content has been reported as one of the advantages associated with the use of non-wood materials for pulp production. Several non-wood materials such as wheat straw, sorghum stalks and oat straw have been reported to contain less than 20% lignin [31,32]. However, the lignin content determination in pineapple leaf and kenaf bark gave approximately 19 % and 14 % respectively. Ash content, solubility in ethanol-cyclohexane mixture of both materials was also found to be relatively low.

Table 2: Chemical composition of pineapple leaf and kenaf bark

Component	Pineapple leaf	Kenaf bark
Lignin	19	14
Ash	5.09	4.80
Alcohol-cyclohexane solubility (1:2 v/v)	8.44	3.50
α-Cellulose	54	45.0
Holocellulose	85.4	82.54
Hemicellulose	31.4	37.60

3.1. Strength Properties of Paper

The effect of pulp blending on the quality of paper produced depends on the quality of starting materials. Table 4 shows the result of test carried out on the paper samples produced from individual fibre and from pulp mixture in varying ratios. Paper sample from 100 % pulp of kenaf bark differ significantly in strength properties such as tear index (13.38 mN.m^2/g)), tensile index (0.41 kNm/g), elongation at break (12.04 mm), tensile stiffness (28.01 N/mm) and modulus of elasticity (30.45 N/mm^2) to paper from 100 % pulp of pineapple leaf with tear index (5.80 mN.m^2/g)), tensile index (1.28 kNm/g), elongation at break (4.47 mm), tensile stiffness (4.96 m) and modulus of elasticity (8.71 N/mm^2). With the addition of 25% pulp of kenaf bark, the MOE of paper from 100 % pulp of pineapple leaf (8.71 N/mm^2) increased to about 63.02 N/mm^2. This variation was also evident in the values of elongation at break. Densities of the paper sheets vary between 120 – 245 Kg/m^3. Paper sample produced from 25%:75% pulp mixture had the highest tear index (16.34 mN.m^2/g). This was higher than the tear index of paper from 75%:25% pulp mixture (9.35 mN.m^2/g) and paper from 50%:50% pulp mixture (7.04 mN.m^2/g). These results may be attributed to the strength of the kenaf and pineapple leaf fibre and also agree with Seth and Page [33] which reported that tensile strength increases with increasing fibre length and vice versa. Tearing resistance of a sheet with a low degree of bonding is also determined by the fibre length. However, it must be noted that residual lignin (kappa number), impurities, pulp consistency, degree of pulp beating, additives, relative humidity of the environment are few of the factors that could influence the properties of paper sheets produce from any pulp [34, 35].

Table 4: Strength properties of paper samples from pulp mixture of kenaf bark and pineapple leaf fibre

Blending ratio (Kenaf : PLF)	Grammage (g/m^2)	Density (Kg/m^3)	Modulus of Elasticity (N/mm^2)	Tensile stiffness (N/mm)	Elongation at break (mm)	Tensile index (kNm/g)	Tear index (mN.m^2/g)
100% : 0	111.13	120	30.45	28.01	12.04	0.41	13.38
75% : 25%	113.29	213	46.59	24.69	5.46	3.62	9.35
50% : 50%	125.09	245	61.37	31.30	7.18	5.08	7.04
25% : 75%	72.66	177	63.02	25.84	7.53	9.22	16.34
0 : 100%	93.61	183	8.71	4.96	4.47	1.28	5.80

3.3. Sheet Surface Properties

Image of the surface area of paper sheet from pulp blend of kenaf and pineapple leaf fibre (50:50) observed under a digital microscope in Fig 1. Analysis shows many bundle of packed fibre on the surface of the sheet.

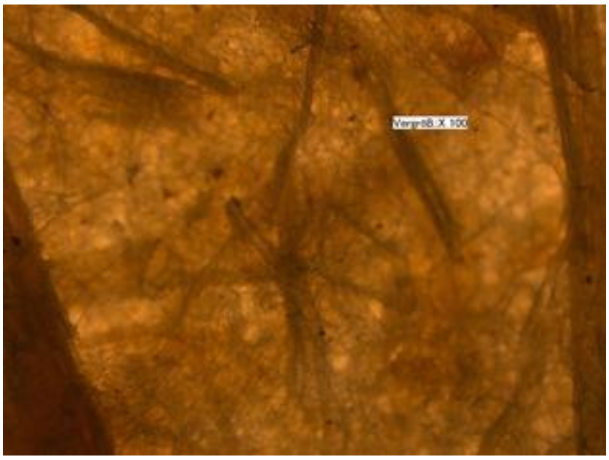

Fig 1: Surface area of paper sheet from 50% : 50% Kenaf & PLF

4. CONCLUSION

This study is a preliminary investigation into the pulp blending potential of Kenaf and pineapple leaf fibre. Strength properties of handmade papers obtained from pulp mixture of kenaf bark and pineapple leaf fibre were studied. Paper sample produced from 100 % pulp of kenaf bark was found to possess superior weight, tear index, and tensile stiffness to paper from 100 % pulp of pineapple leaf. This is attributed to the difference in fibre characteristic of the two samples. Significant variations in thickness, tear strength, tensile strength, elongation at break, tensile stiffness, and modulus of elasticity were also observed in paper samples from pulp mixture in varying ratios. Addition of pulp from kenaf contributes greatly to the improvement in paper strength properties and has the potential of producing papers of differing strength properties with usefulness in various fields of application. This can also serve as a veritable alternative to softwoods.

REFERENCES

John O’Brien, (2006). Paper demand continues to grow. *Paper Age*122:1.
Weston, L. (1996). Tree-Free Paper. The alternatives are getting better.

Dutt D, Upadhyay JS, Bahadur S, Tyagi, CH (2009) Studies on *Hibiscus cannabinus* and *Hibiscus sabdariffa as* an alternative pulp blend for softwood: An optimization of kraft delignification process. *Industrial crops and products* 29:16–26

Gisela M, Jorge R, Ana G, José C. del Río (2010) Evaluation of the Chemical Composition of Different Non-Woody Plant Fibers Used for Pulp and Paper Manufacturing. *The Open Agriculture Journal,* 3:00-00.

Nadirul Hasraf Mat Nayan, Wan Aizan Wan Abdul Rahman, and Rohah Abdul Majid (2013). The Effect of Mercerization Process on the Structural and Morphological Properties of Pineapple Leaf Fiber (PLF) Pulp. *Malaysian Journal of Fundamental and Applied Sciences Vol.10, No.1*

Cunningham RL, Clark TF, Kowlek WF, Wolff IA, Jones Q (1970). *Tappi* 53 (9), 1967

Nieschlage HJ, Nelson GH, Perdue RE (1960). A research for new fiber crops. TAPPI 43 (3):193-201.

Bagby MO, Clark TF, Cunningham RL (1973). Uniform quality pulps from wet-processed stored green kenaf. In: Tappi Non-wood Plant Fibers Conference, Atlanta, 61–67.

Clark TF, Nelson GH, Nieschlag HJ, Wolf IA (1962). A search for new fiber crops; V pulping studies on kenaf. *Tappi* 45 (10):780–786.

Fagbemigun TK, Fagbemi OD, Otitoju O, Mgbachuzor E, Igwe CC (2014). Pulp and paper-making potential of corn husk. International Journal of Agriscience, 4(4): 209-213.

Katri Saijonkari-Pahkala. (2001) Non wood plants as raw material for pulp and paper. Academic Dissertation presented for public criticism at Ifokeskus Korona, Auditorium 1 on November 30, 2001.

Muller, F.M. 1960. On the relationship between properties of straw pulp and properties of straw. *Tappi* 43, 2: 209A – 218A

Clark TF, Cummingham RL, Lindelfelser L.A, Wolff IA, Cummins DG (1970). A search for new fiber crops XVI kenaf storage. Tappi Non-wood Plant Fibers Conference, New Orleans, LA, published as CA Report No. 34. Tappi Non-wood Fiber Pulping Progress Report, pp. 107–132.

Han, J.S., and Rowell, J.S (1999). "Chemical composition from agro-based fibers," *Paper and Composites from Agro-Based Resources* 5 (1), 83-134

Atchison, J.E., (1996). Twenty-five years of global progress in non-wood plant fiber pulping. *Tappi* 70 (10), 87–95.

#Jarinya Wuttitien and Kawee Srikulkit. (2013). Consumer Acceptance of Innovative Water Repellent Pineapple Fiber Papers. *International Journal of Innovation, Management and Technology, 4(2).*

Fujishige, N., Tsuboi, H., Kobayashi, Y., Matsuo, R., Nishiyama, M (1977). Japenese patent. Paper from pineapple fibres. World patent no: 77118004

George, J., Joseph, K., Bhagawan, S.S (1993). Influence of short pineapple fibre on the viscoelastic properties of low-density polyethylene. *Material Letters* 18: 163

Khampan, T., Thavarungkul, N., Tiansuwan, J., and Kamthai, S. (2010). "Wet strength improvement of pineapple leaf paper for evaporative cooling pad" *International Journal of Environmental and Earth Sciences* 1 (1):16-19

Ververis C, Georghiou, K, Christodoulakis, N, Santas, P and Santas, R (2004). "Fiber dimensions, lignin and cellulose content of various plant materials and their suitability for paper production." *Industrial Crops and Products* (19), 245-254.

Fagbemi1 O.D, Taiwo K. Fagbemigun, O. Otitoju, E. Mgbachiuzor and C. C. Igwe (2014). Strength Properties of Paper from Pulp Blend of Kenaf Bark and Corn Husk: A Preliminary Study. *British Journal of Applied Science & Technology 4(28): 4124-4129*

Wise LE, Murphy M, Addieco AAD (1946) Chlorite holocellulose, its fractionation and bearing on summative wood analysis and studies on the hemicelluloses. *Paper Trade J.* 122 (2): 35–43

Madakadze, I.C., Radiotis, T., Li, J., Goel, K., and Smith, D.L. (1999). "Kraft pulping characteristics and pulp properties of warm season grasses". *Bioresources Technology* 69 (1):75-85

Jimenez, L., Lopez, F., (1990). Characterization of Spanish agricultural residues with a view to obtaining cellulose pulp. *TAPPI Journal 73 (8), 173–176.*

Jimenez L, Lopez, F, Martınez, C (1993) Paper from sorghum stalks. *Holzforschung* 47:529–533

Jimenez, L., Sanchez, I., Lopez, F., (1992). Olive wood as a raw material for paper manufacture. *TAPPI Journal 11, 89–91.*

Atul K, Brij PS, Rakesh KJ, Ashwini KS (2013). Blending Studies of Hosiery Waste Pulp with Alkaline Sulphite Cooked Pulp of Natural Fibres & the Use of Lignosulphonate. *International Journal of Innovative Research in Science, Engineering and Technology.* 2:10

Khiari, R., M.F. Mhenni, M.N. Belgacem, E. Mauret (2010). Chemical composition and pulping of date palm rachis and Posidonia oceanica – A comparison with other wood and non-wood fibre sources. *Bioresource Technology 101:775–780*

Khristova, P., Kordsachia, O., Khider, T., (2005). Alkaline pulping with additives of date palm rachis and leaves form Sudan. *Bioresource Technology 96:79–85*

Zawawi Daud, Mohd Zainuri Mohd Hatta, Angzzas Sari Mohd Kassim and Ashuvila Mohd Aripin Suitability of Malaysia's Pineapple Leaf and Napier Grass as a Fiber Substitution for Paper Making Industry. EnCon 2013, 6th Engineering Conference, "*Energy and Environment"* 2nd -4th July 2013, *Kuching Sarawak*

Manfred J (1993) Non-wood plant fibres, will there be a come-back in papermaking? *Industrial Crops and Products* 2:51–57

Alcaide LJ, Parra IS, Baldovin F (1990) Characterization of Spanish agricultural residues with a view to obtaining cellulose pulp. TAPPI Journal 73 (5):173–176

Dinwoodie JM (1965). The relationship between fibre morphology and paper properties: A review of literature, *Tappi* 48:440-447

Amidon TE (1981) Effect of the Wood properties of hardwood on Kraft paper properties, *Tappi* 64:123-126

Wood IM (1981). The utilization of field crops and crop residues for paper pulp production. *Field Crop Abstract*, 34: 557-568

