Processing And Evaluation Of Chemically Treated Kenaf Bast (Hibiscus Cannabinus)

Umoru, Patricia Ese., Boryo, Doris E.A., Aliyu, A.O, Adeyemi, O.O

ABSTRACT: The processing and evaluation of chemically retted kenaf bast *(Hibiscus cannabinus*) was carried out using sodium hydroxide and sodium sulphite. The bast of the kenaf plant was retted with 5 % sodium hydroxide (NaOH) and 5 % sodium sulphite (Na_2SO_3) at 100 ^oC for 10 mins. The extracted fibres were subjected to bleaching with hydrogen peroxide (H_2O_2). Mercerization process was carried out on the bleached fibres in order to improve the quality of the fibres. The kenaf bast was converted into clean, lustrous, smooth and soft fibres using the retting, bleaching and mercerization processes. The effects of these treatments were further evaluated using a tensile strength machine and a viscometer. It was observed that the samples retted with Na_2SO_3 and its corresponding bleached fibre had relatively high tensile strength and low viscosity values while those retted with NaOH and its corresponding bleached samples gave lower tensile strength and high viscosity values. The implication of this is that the samples retted with Na_2SO_3 were slightly affected while those retted with NaOH were affected most. This was attributed to the inefficiency of NaOH in removing the impurities of the fibre completely and as such lead to lower tensile strength and high viscosity while the reverse is the case for Na_2SO_3 retted and bleached fibres. The corresponding viscosity of mercerized fibre of NaOH retted samples was low whereas that of Na_2SO_3 was high. From the results obtained, it indicates that Na_2SO_3 is a better retting agent than NaOH.

Key words: Kenaf bast, chemical retting, tensile strength, viscosity, fibre quality.

INTRODUCTION

Kenaf is an annual crop that is common to ancient Africa. It is a member of the hibiscus family (*Hibiscus cannabinus* L, Malvaceae) and related to cotton and jute [1]. Kenaf is a warm-season annual raw crop suitable in the South and West of the United States, including California, Mississippi, Texas, Georgia, Louisiana, Kentucky, and Tennessee [2]. Kenaf is made up of a single, straight, unbranched stem consisting of two parts: outer fibrous bast and an inner woody core. Kenaf grows very fast between 4-5 months after planting, with heights of 12-16 feet (4-5 m) and 25-35 mm in diameter [3]. The bast fibres offer the advantage of renewability and biodegradability that is essential for making environmentally friendly textile products. Production of Kenaf is less costly and less time-consuming than other raw crops and produces high yield with minimal use of chemicals [4]. Pulping kenaf plant (bast and core) can benefit the environment because the process requires fewer chemicals and less energy compared to standard pulping processes for wood fibres. Although the kenaf bark (or bast) fibre strands were once only considered for use as a cordage fibre in such products as rope, twine, carpet backing, and burlap [5], a diverse list of additional uses have been developed for the bark fibre strands. These include use in automobile dash-boards, carpet padding, corrugated medium [6], as a "substitute for fibre glass and other synthetic fibres"[7], textiles [8], and as fibres for injection molded and extruded plastics [9] Kenaf bast fibre strands are presently in commercial use in other environmentally friendly products such as fibre lawn mats impregnated with grass seed, and spray-on soil mulches for use along high-way rights-of-way or construction sites to prevent soil erosion from water and wind. According to [1], reported other end-use products made from kenaf, such as canvas, animal feeds sack and bedding, paper, fishing net and potting media. Kenaf bast, when properly processed, is more lustrous, has greater tensile strength, and greater resistance to rot when compared to jute [10], [11]. The quality of fibres is largely determined by the retting condition and duration. Basically there are five (5) types of retting processes namely: dew, water, mechanical, enzymatic and chemical retting. The chemical retting is a quicker process than the natural processes (dew, water and enzymatic) that affects several properties, including a loss in tenacity, colour, and luster [12]. Paridah *et al* (2011) [13], in a review reported that enzymatic retting has apparent advantages over other retting processes by having significant shorter retting time and acceptable quality fibres, but it's quite expensive. NaOH is the commonly employed retting agent, however, [12], [14], [115], reported that NaOH has degrading effect on the mechanical property. This is due to oxycellulose formation on the fibre. In this work, the quality of retted kenaf bast using sodium hydroxide and sodium sulphite was carried out. The aim of this work therefore, is to evaluate the effect of chemically retted kenaf bast *(Hibiscus cannabinus*) using tensile strength and viscometric studies.

EXPERIMENTAL METHODS

Sample Collection

The bast of the kenaf plant used for this research was obtained in Kaduna, Nigeria. The fresh stems were collected and air-dried under laboratory conditions for 3 weeks. The bast of the kenaf plant were removed by cutting

- *Umoru, Patricia Ese., Boryo, Doris E.A. Aliyu, A.O, Adeyemi, O.O*
- *Department of Chemistry, Nigerian Defence Academy, N.D.A Kaduna, Nigeria*
- *Department of Chemistry, Abubakar Tafawa Belawa Bauchi, Nigeria*
- *Corresponding Author: patriciaumoru@yahoo.com*

the stem into convenient sizes and then removed from the woody part for chemical treatment.

Methods of Processing

The bast of the kenaf plant was processed into useful materials by retting, bleaching and mercerization process.

Retting Process

A comparative chemical retting method was employed using NaOH and Na_2SO_3. The method proposed by [14] was used. Specific sample weights of the rib boned kenaf bast were immersed into a beaker containing 5 % NaOH and was allowed to boil for 10 mins at 100^oC and washed properly under flowing tap water. The whole procedure was repeated using 5 % Na_2SO_3 retted at 100 ^oC for 10 mins. The retted samples were kept in the laboratory over night and were weighed until constant weights were obtained for calculation of the percentage yield.

Bleaching Process

Bleaching process is the removal of natural colouring matter from the fibres. Hydrogen peroxide (H_2O_2) has been reported to give a permanent colour than other oxidizing agents according to [15]. Hence the bleaching liquor formulated by [16] was prepared by measuring 7.5 ml of 70 % H_2O_2, 1.8 g sodium carbonate, 1 g NaOH, 3 g of Sodium silicate (as a stabilizer) and 1g lissapol N was measured into a 1000 ml volumetric flask. This was made up to the mark with distilled water. This was made up to the mark with distilled water. Known weights of the retted samples were immersed into a beaker containing the bleaching liquor. This was boiled for 30 mins and the bleached samples were properly washed under flowing tap water. The bleached samples were kept in the laboratory over night and were weighed until constant weights were obtained for calculation of the percentage yield.

Mercerizing Process

Mercerization process improves the quality of fibres [17], [12] and [13] reported that mercerization improves the mechanical properties (tensile strength, luster, crease recovery etc) of retted and bleached fibres and cotton/polyester blend fabric. It also improves the tensile strength and the dye ability of the fibre [17], [16]. The procedure proposed by [17] was employed for this work in which known weights of the bleached samples were immersed into the beaker containing 20 % of NaOH. This was allowed to stand for 30 mins at a temperature below 5 ^oC. The samples were properly washed with water, then neutralized with acetic acid to remove any alkali present and rinsed finally to prevent any further reactions. The mercerized samples were kept in the laboratory over night and were weighed for percentage yield determination.

Viscometric Measurement

A Malcom viscometer (PM-28) was used for the determination of the viscosity of the chemically treated fibres. The procedure outlined by [17], [16] for the preparation of the sample solution was adopted in this study. 0.5 g of the retted bleached and mercerized samples were dissolved each in a beaker containing 70 % H_2SO_4 and the viscometer immersed into each beaker with content and the viscosity values were recorded.

RESULTS AND DISCUSSION

Table 1, shows the effect of chemical processes on the fibre yield. Figure 1, gives the tensile strength of samples of the fibre retted with NaOH and Na_2SO_3 at 100 ^oC for 10 mins. Table 2, shows the values of tensile strength and specific viscosities of NaOH and Na_2SO_3 retted fibres for 10 mins. Figuue 2 is the effects of retting process on specific viscosity of fibre retted with NaOH and Na_2SO_3 for 10 mins. Figure 3 is the effects of bleaching process on specific viscosity of fibre retted with NaOH and Na_2SO_3 for 10 mins while Figure 4 is the effects of mercerization process on specific viscosity of fibre retted with NaOH and Na_2SO_3 for 10 mins.

Effects of Chemical Processes on Percentage Yield of the Fibres

From Table 1, it shows that the fibres yield 60.66 and 65.99 % for NaOH and Na_2SO_3 respectively. It implies that Na_2SO_3 retted fibres have greater percentage yield than those of NaOH.

Table 1: Percentage Yield of the Fibre and Impurities by the Chemical Processes

Retting Conditions	Retting Process		Bleaching Process		Mercerization Process	
	Fibre yield (%)	Impurities Removed (%)	Fibre yield (%)	Impurities Removed (%)	Fibre yield (%)	Impurities Removed (%)
NaOH at 100 ^oC	R_1 60.66	39.34	B_1 57.66	42.34	M_1 98.50	1.50
Na_2SO_3 at 100 ^oC	R_2 65.99	34.01	B_2 61.56	38.44	M_2 99.00	1.00

R_1 and R_2 = Samples retted at 100 ^oC with NaOH and Na_2SO_3.
B_1 and B_2 = Bleached samples of respective NaOH and Na_2SO_3 retted fibres at 100 ^oC.
M_1 and M_2 = Mercerized samples of respective NaOH and Na_2SO_3 retted at 100 ^oC.

The combing process also contributes to the loss of cellulose in fibres retted with NaOH due to weakness caused by the NaOH retting agent. For the bleached samples the percentage impurities were not too pronounced because the bleaching process was only meant to remove the colouring matter. However, the mercerization process was meant to improve the quality (properties) of the fibres as such the loss is negligible but due to combing and washing process very few fibre were lost. This is the reason why the percentage yield was high.

Effects of Chemical Processes on Texture of the Fibre

The samples retted with Na_2SO_3 showed cleaner, softer and smoother products compared to those retted with NaOH. Mooney *et al* (2001) [18], reported similar result with kanaf fibre rettted with NaOH. The bleached samples were not too soft and lustrous but smoother and cleaner, especially for Na_2SO_3 retted samples. The mercerized process relatively improved the texture of the fibres compared to the corresponding bleached and retted fibres. This agrees with the report of [17 and [15] on the effect of mercerization process on cellulose. Although, the mercerized samples of Na_2SO_3 retted fibres were softer, lustrous and smoother than the mercerized samples of NaOH retted fibres. This suggests that the retting agent employed determine the efficiency of other processes, quality and yield of the fibre as observed in this work and as reported by [17], [14] and [19]. Furthermore, the mercerized fibre retted with NaOH is brittle when few strands are snapped by hand and gave shorter length of fibre compared to that of Na_2SO_3, this could be attributed to much damage caused by NaOH on the fibre.

Effects of Chemical Processes on Colour of the Fibre

The treated samples showed that NaOH and Na_2SO_3 removed the mucilaginous matter by the change in colour. Although, the samples retted with Na_2SO_3 gave cleaner and brighter products while those retted with NaOH gave brown, dirty and less bright fibres. Similar results for NaOH retted fibre were obtained by [20]. This may be attributed to the incomplete removal of lignin by NaOH leading to the brown colour observed. This also is because NaOH is a stonger alkali compared to Na_2SO_3 and so NaOH has much effect on the fibre than Na_2SO_3. The bleached fibres were whither and beautiful for those treated with Na_2SO_3 while those treated with NaOH gave a yellowish product. The mercerized samples were a little bit yellowish due to the action of mercerization liqour (NaOH) used on them. This observation agrees with the work of [14].

EFFECTS OF RETTING ON THE TENSILE STRENGTH OF NaOH AND Na_2SO_3 RETTED FIBRES

Samples retted with Na_2SO_3 gave higher tensile strength values as compared to that retted with NaOH figure. 1, this could be due to the fact that NaOH is a stronger retting agent than $Na_2SO_3$and as such has more weakening effect on the fibre. Similar result has also been reported by [21] using 5 % NaOH and 5 % C_6H_5COONa. A range of 310-750 mm has been rated as fair by other authors [22], [22], [24] with chemical retting.

Table 2: The Tensile Strength and Specific Viscosities of NaOH and Na_2SO_3 Retted Fibres for 10 Minutes

Retting Conditions	Tensile Strength (mm)	Specific Viscosities
Untreated Sample U_n	110	0.47
NaOH Retted at 100 ^oC (R_1)	320	0.30
Na_2SO_3 Retted at 100 ^oC (R_2)	410	0.22

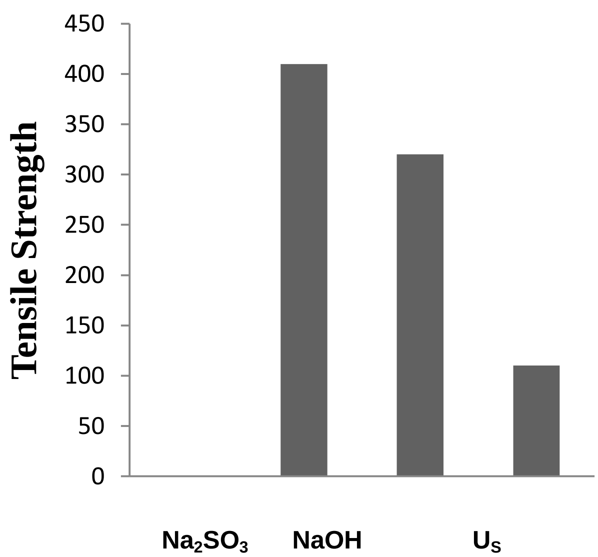

Fig: 1 Effects of Retting on the Tensile Strength of NaOH and Na_2SO_3 Retted Fibres

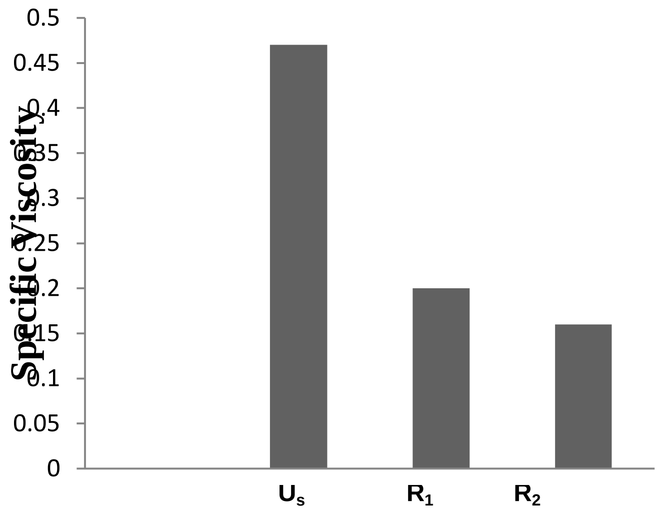

Fig 2: Effects of Retting Processes on the Specific Viscosity of Fibres Retted with NaOH and Na_2SO_3 for 10 min.

Key
U_s = Untreated Sample
R_1 = Retted Fibre of NaOH Retted at 100 ^oC
R_2 = Retted Fibre of Na_2SO_3 Retted at 100 ^oC

EFFECTS OF BLEACHING AND MERCERIZATION ON THE SPECIFIC VISCOSITY OF NaOH AND Na_2SO_3 RETTED FIBRES

With reference to Figures 3 and 4, it was observed that the efficiency of the subsequent chemical treatments (bleaching and mercerized processes) also depends on the previous retting agents and conditions of retting employed. For the bleached fibres of NaOH retting on Fig. 3 (B_1), the specific viscosity showed a sharp decrease as compared to the untreated sample, while the bleached fibres of Na_2SO_3 retting (B_2), showed a very drastic decrease compared to the untreated sample. Knowing that bleaching process is also a purification process, this might imply that complete bleaching was achieved for the retted fibres (B_2), coupled with the complete retting process, which led to the solubility of only the white fibre hence low specific viscosity. Whereas the NaOH with its incomplete retting led to incomplete bleaching process which made the viscosity value high compared to the bleached fibres of Na_2SO_3 retted.

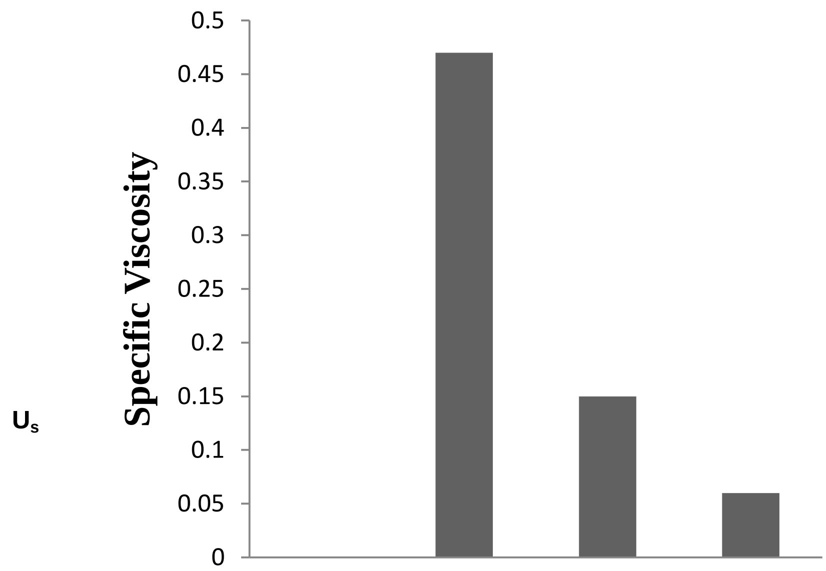

Fig 3: Effects of Bleaching Processes on the Specific Viscosity of Fibres Retted with NaOH and Na_2SO_3 for 10 mins.

Key
U_s = Untreated Sample
B_1 = Bleached Fibre of NaOH Retted at 100 ^oC
B_2 = Bleached Fibre of Na_2SO_3 Retted at 100 ^oC

Figure 4 show a different trend in the specific viscosity of the mercerized fibres compared to the retted and bleached fibres. In this case, the mercerized fibres of the Na_2SO_3 retted fibres showed a higher value of specific viscosity than the mercerized fibres of NaOH retted fibres. This may be because mercerization is not a purification process but is rather a chemical reaction between the fibre (cellulose) and the mercerizing agent. Trotman (1975) [16], suggested that the reaction leads to the formation of alkali-cellulose and these results into hygral swelling of the fibre [19]. This implies that Na_2SO_3 retted fibres must have shown more hygral swelling as a result of complete purification than the less purified NaOH retted fibres. Thus, increase in the viscosity for Na_2SO_3 retted fibres than that of NaOH retted fibres.

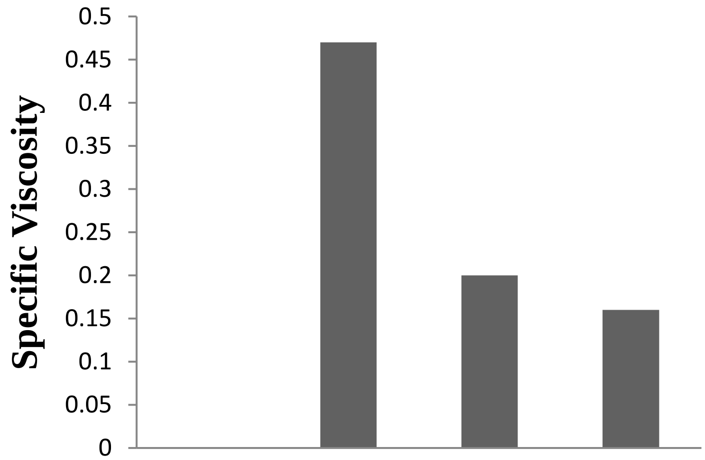

Fig 4: Effects of Mercerization Processes on the Specific Viscosity of Fibres Retted with NaOH and Na_2SO_3 for 10 mins.

Key
U_s = Untreated Sample
M_2 = Mercerized Fibre of Na_2SO_3 Retted at 100 ^oC
M_1 = Mercerized Fibre NaOH Retted at 100 ^oC

CONCLUSION

Samples retted with NaOH were dirty, brown, and less bright in colour and the fibre strands were sticky. This was attributed to the effect of NaOH on the fibres and incomplete removal of pectin substance. Those retted with Na_2SO_3 were cleaner and brighter which is due to the fact that Na_2SO_3 is a weaker alkali compared to NaOH and thus less damaging effect on the fibres. In terms of texture, samples retted with Na_2SO_3 were smoother and softer compared to those retted with NaOH for the corresponding bleached and mercerized fibres. For percentage yield, those retted with Na_2SO_3 gave higher values than those retted with NaOH. This may be because NaOH has damaged the fibre. In terms of tensile strength, samples retted with Na_2SO_3 gave higher tensile strength compared to those retted with NaOH. For viscosity, it was observed that the samples retted with Na_2SO_3 and its corresponding bleached fibres had low specific viscosity values while those retted NaOH and its bleached fibres had high specific viscosity value.

REFERENCES

[1]. Cook JG (1960) Handbook of Textile Fibers, Merrow Publishing, Watford, UK, Pp: 20

[2]. United States Department of Agriculture, Economic and Research Service, Washington, DC.(1993) Industrial uses of Agricultural materials, situation and outlook Report.

[3]. Nimmo B (2002) Kenaf Fibers Presentation of the 5th Annual Conference of the American Kenaf Society Memphis, TN Pp 7-9

[4]. Calamari TA, Tao W, and Goynes WR (1997) A Preliminary Study of Kenaf Fibre Bundles and their Composite Cells, Tappi Journal, 80 (8):149-154

[5]. Wilson FD, Summers TE, JF Joyner, DW Fishler, and Seale CC (1965) Agr. Expt. Sta. Cir. S-168

[6]. Kugler DE (1988) In: J Janick and JE Simon (eds), Advances in new crops Timber Press, Portland Pp: 289–292

[7]. Ramaswamy GN and Boyd CR (1994) In: CE Goforth and MJ Fuller (eds.), Mississippi State Univ. Bul. 1011. Pp : 31–33

[8]. Ramaswamy GN, Ruff CG, and Boyd CR (1995) Research Journal, 24 (2):180-190

[9]. Webber CL III and Bledsoe RE (1993) In: Janick J and JE Simon (eds.), New Crops. Wiley, New York, Pp : 416–42

[10]. Moreau JP, Bel-Berger P and Tao W (1995) Tappi Journal, 78 (2): 96-105

[11]. Ramaswamy GN, Boyd CR, Bel-Burger P and Kimmel L (1995) Research Journal, 24 (2):180-190

[12]. Ajayi JO, Bello KA, Yusuf MD and Boryo, DEA (1997) The influence of processing variables on the mechanical properties of bast fibres A paper presented at the 20th Annual International Conference of Chemical Society of Nigeria held at Arewa House Kaduna, Nigeria

[13]. Paridah M. T., Basher A. B., Syeed O. A., Ahmed Z. (2011) Retting process of some bast plant fibres and its effect on fibre quality: A review. BioResources, **6**, 5260– 5281

[14]. Boryo DEA (1999) Evaluation Of Chemical Damage to Kenaf Fibres (Hibiscus Cannabinus) During Processing Unpublished MSc Thesis Dept. of Chemistry, A.T.B.U, Bauchi, Pp 20-50

[15]. Boryo DEA, Bello KA, Ibrahim AQ, Ezeribe AI, Omizegba FI and Offodile PU (2013a) International Journal of Engineering and Science (IJES), 2 (8): 121-132

[16]. Trotman E R (1975) Dyeing and Chemical Technology of Textile Materials Charles Giffin and Co. Ltd. Pp 40-50.

[17]. Sadov F, Korchagin M and Matesky A (1973) Chemical Technology of Fibrous Materials 5th Edition, Charles Giffin and Co Ltd. Pp: 20-105

[18]. Mooney C, Stolle-Smits T, Schols H and de Jong E (2001) Analysis of Retted and Non Retted Flax Fibres by Chemical and Enzymatic Means, journal of Biotechnology 89:205-216

[19]. Boryo DEA, Bello KA, Ibrahim AQ, Gin NS, Ezeribe AI and Wasiu KA (2013b) Effects of alternative mercerizing agents on mechanical properties of cotton/polyester blend fabric Paper presented at International conference on Science, Technology and Engineering at Education Resource Centre Abuja Nigeria, Held on November, 25-28, 2013

[20]. Kawahara Y, Tadokoro K, Endo R, Shioya M, Sugimura Y and Furusawa T(2005) Chemically Retted Kenaf Fibres Sen'I Gakkaishi 61: 115-117

[21]. Paridah MT and Khalina A (2009) Effect of Soda retting on the Tensile Strength of Kenaf (Hibiscus cannabinus) Bast Fibres, Project Report Kenaf EPU, Pp 21

[22]. Misra DK (1987) Cereal Straw, Pulp and Paper Manufacture, Secondary Fibres and Nonwood Pulping

[23]. Perry DR (1975) Identification of Textile Materials, The Textile Institute, Manara Printing Services, London

[24]. Rowell RM and Han JS (2000) Characteristics and Factors Affecting Fibre Properties, Natural Polymers and Agrofibres Composites, Frolini, E., Leao, A.L and Mattosso L.H.C. (eds), San Carlos, Brazil, 115-127