Pertanika J. Trop. Agric. Sci. 40 (3): 449 - 458 (2017)

PERTANIKA JOURNALS

TROPICAL AGRICULTURAL SCIENCE

Journal homepage: http://www.pertanika.upm.edu.my/

Characterisation of Pulp and Paper Manufactured from Oil Palm Empty Fruit Bunches and Kenaf Fibres

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ABSTRACT

In papermaking, blending or mixture of fibres is one of the ways to enhance mechanical properties of paper. The objective of this study was to evaluate the properties of paper manufactured from mixture of oil palm empty fruit bunch (EFB) and kenaf fibres. The papers were prepared according to 10, 30, 50 and 70 percentages of kenaf whole stem blended into oil palm empty fruit bunch fibres. The preparation and testing of papers were carried out based on TAPPI Test Methods. Results showed that using kenaf whole stem fibres improved the mechanical properties of the blended papers and complied with the standard requirement for writing and printing grade paper.

Keywords: Kenaf whole stem, papermaking, paper properties, pulp properties, oil palm empty fruit bunch

ARTICLE INFO

Article history:
Received: 01 February 2017
Accepted: 03 July 2017

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ISSN: 1511-3701

INTRODUCTION

Malaysia is the largest producer for oil palm which accounts for 67% (4.85 million ha) of its plantation area. In 2011, the land under oil palm cultivation reached 5 million hectares. The expansion of palm oil industry worldwide led to an increase in the amount oil palm biomass residues. One of the residues is empty fruit bunches which accounted for about 95.3 million tonnes of dry lignocellulosic biomass in 2009 (Basiron, & Simeh, 2005; Wan Rosli & Law, 2011). The enormous amount of lignocellulosic biomass includes fresh fruit bunches which can be transformed into many resources such as pulp, paper, paper board and other composites (Faizi et al., 2017). It was reported that in 2010 up to 7 million tonnes (dry weight) empty fruit bunches (EFB) were generated in Malaysia. Every 5 tonnes of EFB could produce up to a tonne of pulp (Shuit, et al., 2009). Earlier works proved that EFB is a suitable raw material for pulp and paper production (Rushdan, 2003). Availability in large quantity, continuous supply, low lignin content, high cellulose content and high strength placed EFB has a potentially high commercial value as a non-wood fibre to substitute recycled fibre. The products may be produced from the fibre alone or may be mixed with other Fibres. A study showed that blending EFB with recycled pulps enhanced the structural, mechanical and optical properties of paper (Rushdan, 2003). Recycled paper is enhanced by adding EFB pulps (Wan Rosli, et al., 2005).

There is a great potential for kenaf to be used as a national commodity by the paper industry. Kenaf is an herbaceous plant which can be harvested after 4-5 months of planting, allowing two cycles of harvest in a year (Kaldor, et al., 1990). Kenaf is readily considered as an alternate fibre, derived from its stem (Kaldor, 1992; Mossello et al., 2010). The long fibres contribute to strength while the core provides better smoothness and formation. Thus, the quality of paper could be improved by using both fibres (Villar, et al., 2009). Soda-anthraquinone (NaOH-AQ pulping) was selected based on its better pulp quality (Akamatsu, et al., 1987; Law & Jiang, 2001; Rushdan, 2002) in which no sulphur was incorporated during the pulping process. Blending is a common practice in papermaking to attain certain physical and mechanical properties to meet the demand for high strength papers to be used for packaging, furniture, paperboard and even as building materials (Fagbemi et al., 2017).

In most applications, two types of fibres are used, hardwood or softwood blended with non-wood fibres. The interaction of oil palm EFB fibres with a hardwood kraft pulp of Acacia mangium had been studied (Wan Rosli, et al., 2012). They also investigated the effect of blending EFB Fibres with softwood pulps and found that the product had great potential as liners and medium. Rushdan, et al. (2007) studied the blending of EFB with old corrugated container (OCC) to produce medium paper. The findings showed that by mixing EFB Fibres to OCC the product was similar to commercial hardwood species, *Acacia mangium* and *Eucalyptus globulus*.

Due to the increasing demand for fibre, the sources of raw material for it has become important. The reality is that paper production is dependent on the availability of fibre. Substituting the lignocellulosic material can reduce the burden on forest while supporting the natural biodiversity and ameliorate its waste management problem. This research is anticipated to reduce the dependency on wood fibres by taking into consideration the abundant raw materials in the form of EFB and by blending it with the fast-growth kenaf whole stem fibres. Therefore, the focus of this study is to determine the suitability of adding two types of non-wood fibres in papermaking. To date, no study has been carried out on blending of non-wood to make paper and specifically, on the use of kenaf and EFB in papermaking.

MATERIALS AND METHOD

Oil palm empty fruit bunch fibres (EFB) were obtained from Sabutek Sdn. Bhd.. The Fibres were packed in a bale where cleaning and cutting were done prior to pulping. The cut Fibres of about 2 cm length were kept in sealed bags. The EFB Fibres were pulped using soda-anthraquinone (NaOH-AQ pulping). Kenaf was acquired from National Kenaf and Tobacco Board (NKTB) and was harvested at the age of 4-5 months. Stalks without flowers and leaves were chipped at about 2 cm in diameter using chipper machine from Germany. These whole stem chips were screened at about 2 cm of width to allow better penetration of chemicals during pulping and air-dried until 10% of moisture content for storage. The kenaf whole stem was chosen due to their properties (physical and mechanical properties). Kraft pulping technique was used to cook the kenaf chips. Pulping conditions for both kenaf and oil palm EFB chips are summarised in Table 1.

Table 1
Pulping conditions for EFB and kenaf whole stem chips

Pulping condition	Kraft pulping	NaOH-AQ pulping
Type of fibres	300 g of kenaf chips	300 g of EFB fibres
Sulphidity	25.0%	27.3%
Active alkali	17%	-
AQ	-	0.1%
Fibre: liquor	1:7	1:8
Temperature during cooking	170°C	170°C
Time to maximum temperature	60 min	60 min
Time at maximum temperature	120 min	90 min

After pulping, the pulps were washed to eliminate the pulping chemicals and screened using fibre Somerville fractionator. Therefore, cleaned and unbleached pulps were obtained. The next process was using elemental chlorine-free bleaching to bleach both EFB and kenaf, namely D-Ep-D; D refers to chlorine dioxide and Ep is a peroxide-enhanced extraction. The bleaching condition is summarised as in Table 2. The amount of bleaching solutions was calculated based on oven-dried weight of pulp. These solutions were added with unbleached pulp in high temperature resistant container. The container was immersed in hot water bath for certain duration to allow the reaction to occur. After treatment, the bleached pulp was washed using distilled water, dried using spin dryer and kept in an opaque container to protect against direct contact with light.

Table 2
Sequences and conditions used in ECF bleaching for both EFB and kenaf unbleached pulps

Parameters	Sequences		
	D1	Ep	D2
Chemical charge, %	2	E = 1.5, p = 1	1.25
Consistency, %	10	10	10
Treatment temperature, °C	70	70	70
Reaction time, min	180	90	90

Both kenaf and EFB bleached pulps were beaten according to TAPPI Standard T 248 sp-00. The beating degrees applied was 4000 revolutions. Before beating, the bleached pulp was disintegrated in a pulp disintegrator for 20 minutes. The pulp was made to 10% consistency for beating in the PFI mill machine for 4000 revolutions. Subsequent to beating, the pulp was re-disintegrated prior to blending. The bleached and beaten pulps were obtained, ready to be blended. The blending process involved proportion, based on pulp weights of kenaf to EFB at 10, 30, 50 and 70 percentages. These blended pulps were then measured their freeness according to TAPPI Standard T 227om-99 Canadian Standard Method.

Finally, papermaking was conducted based on TAPPI Standard T 205 sp-02 producing 60 g/m^2 piece of paper. These handsheets were conditioned at temperature of 23°C ± 1°C and 50% ± 2% relative humidity for 24 hours prior to any testing. Optical, physical and mechanical characteristics namely as opacity, smoothness, tensile and tear were tested based on TAPPI Standard T 425 om-01, T 479, T 494om-01 and T 414om-98. Besides, in order to understand the morphology of the produced pulp and handsheets, observation under Scanning Electron Microscope (SEM) was done.

RESULTS AND DISCUSSION

The screened yields for both soda and kraft pulping of EFB and kenaf were 41% and 40% respectively. Both EFB and kenaf was produced at about the same screened yields. These unbleached pulps were tested for their Kappa number. The Kappa number for unbleached EFB pulp was 5 while kenaf pulp was 15. The results for EFB and kenaf are sound due to the percentage concentration of soda used in the pulping processes. The lignin content for both EFB and kenaf are considered low which may ease the bleaching process. The chosen pulping condition seemed to contribute to the elimination of lignin constituents. By using higher soda concentration of pulping condition, the Kappa number of produced EFB pulp was increased which is confirmed by Tay, et al. (2009). Udohitinah and Oluwadare (2011) found out that unbleached kenaf pulp prepared via kraft process exhibited Kappa number 12.04 to 20.50. After the D-Ep-D bleaching, the bleached pulps were tested and their Kappa number was 0 and 1.5 for EFB and kenaf bleached pulps respectively. The pulping condition was found to aid the bleaching process.

The Canadian Standard Freeness (CSF) is the rate of drainage via diluted pulp slurry. It is correlated to the efficiency of fibres in holding or releasing water either before or after beating (refining). In this study, a decision was made to beat both fibres at same level, 4000 revolutions. The freeness readings for both bleached and beaten fibres were 286.5 and 216.0 for EFB and kenaf respectively. Based on the blending of kenaf into EFB pulp slurry, the values of CSF dropped simultaneously as shown in Table 3. Such finding suggests that the fibres in the mixture held more and released less water which is most probably due to the presence of kenaf bast fibres. This finding is supported by the results of a past study (Villar et al., 2009). There was substantial difference between freeness value of kenaf bast and core. The kenaf bast fibres held more water compared with its core, which allowed less water to be released during the drainage test. Increasing percentage of kenaf fibres seemed not to exhibit extreme differences where the freeness values are at static range of 180 to 200.

Table 3
Canadian Standard Freeness, opacity and brightness values of kenaf, EFB and their blended Fibres (amount of kenaf pulps added into EFB pulp slurry).

Property	Kenaf, 100%	EFB, 100%	10%	30%	50%	70%
CSF, ml	216	287	206	204	181	206
Opacity, %	75.69	80.24	99.63	99.58	99.55	99.36
Smoothness, ml/mm	165.63	82.00	111.30	115.00	119.00	133.80

In terms of opacity and smoothness, the product is better compared with that of unblended paper as shown in Table 3. Both EFB and kenaf paper had 80.24% and 75.69% of opacity readings. The readings for smoothness are 82.00 ml/mm and 165.63 ml/mm for EFB and kenaf accordingly. The EFB paper is found to have better opacity which may be due to the arrangement of short fibres by leaving least voids between the fibre-to-fibre bonding. This arrangement will cause the surface of the paper to become smoother. These results are supported by the morphological observation of the EFB, kenaf and blended papers which can be seen in Figure 3. The EFB fibres are smaller in size compared with kenaf fibres and hence, it produces more compact paper. Higher compactness provides better paper surface smoothness.

Tensile index is a measurement of resistance of paper to direct tension divide by paper grammage (Smook, 2000). It is observed that the blending has dropped the papers earlier property of tensile strength. Referring to Figure 1, the EFB paper had the highest tensile index value compared with that of blended samples. These results may be due to the presence of kenaf core fibres in the blended samples which expand the amount of short fibres. The effect of pulp blending influences the pulp blending which in turn depends on the quality of preliminary pulps (Fagbemi et al., 2017). Therefore, the addition of 70% of kenaf pulps has the ability to increase the tensile strength better than the existing EFB paper. It is believed that the use of kenaf bast would increase the strength performance as low as blending 10% kenaf into EFB mixture instead of applying kenaf whole stem. Earlier study (Latifah, et al., 2009) proved that the incorporation of only 10% kenaf bast pulps increased the tensile index of old corrugated container pulps. Kenaf pulp contributes tremendously to the improvement of paper strength which is a better choice than softwood (Fagbemi et al., 2017)

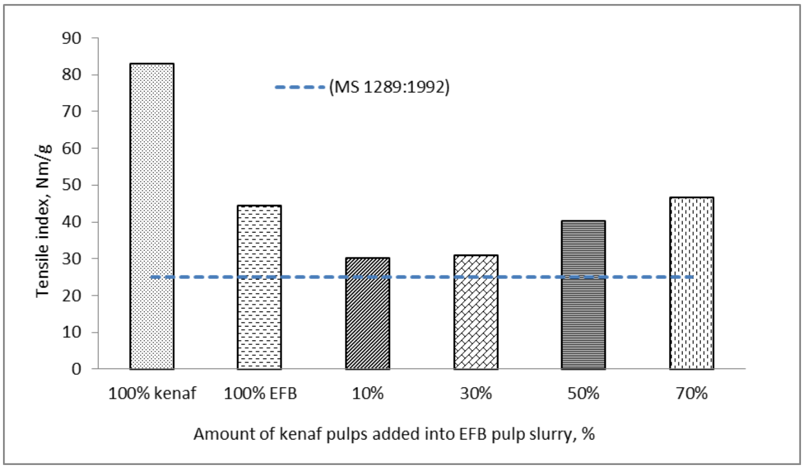

Figure 1. Tensile index versus percentage of kenaf pulps added into the EFB pulp slurry

The blending of kenaf whole stem fibres with EFB decreased the tear strength at earlier addition of 10% as shown in Figure 2. Later, the blending which began with 30% and more of kenaf whole stem fibres began to increase the tear strength until a drastic tear strength improvement of almost 70% increment. Tearing resistance is dependent on the amount of fibres in the sheet rupture, fibre length, fibre numbers, and strength of fibre-to-fibre bonds. The presence of kenaf fibres is believed to cause better fibre-to-fibre bonding. The presence of kenaf whole stem fibres produced better

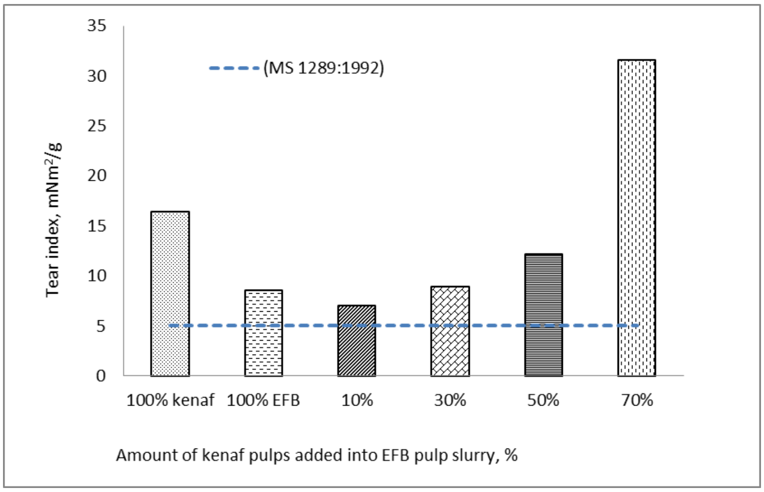

Figure 2. Tear index versus percentage of kenaf pulps added into the EFB pulp slurry

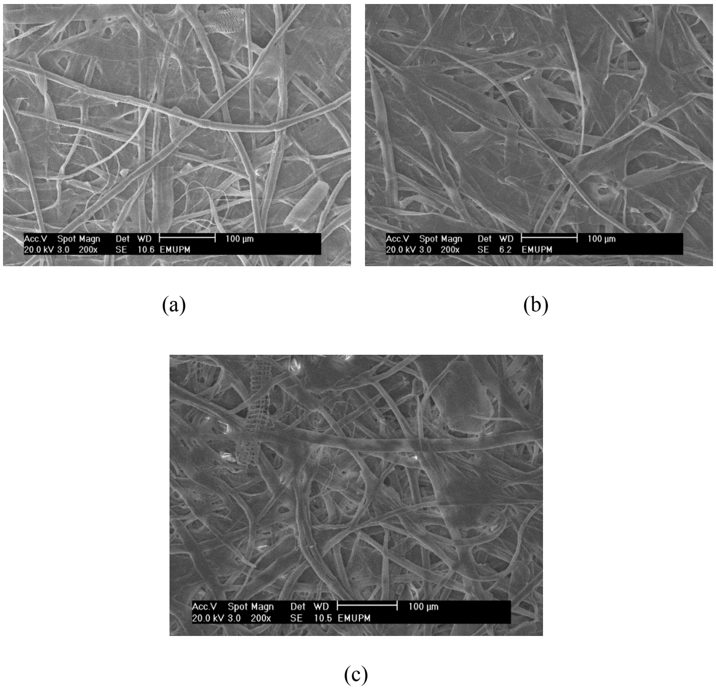

Figure 3. (a) Paper contains bleached EFB fibres; (b) Paper contains bleached kenaf fibres; (c) Paper contains blended fibres of EFB and kenaf whole stem

distribution which led to better formation of paper. Therefore, the tear index of the blended papers became more resistant. This finding is consistent with that of Gulsoy and Erenturk (2016) who used softwood fibres to enhance the strength of recycled fibres.

Results obtained from the tensile and tear index achieved higher than the minimum requirement for offset paper, which were 25 Nm/g and 5 mNm^2/g respectively. Incorporating other natural fibres may enhance mechanical properties of the paper such as its tensile strength (Sanjay, et al., 2016). The addition of at least 10% of kenaf whole stem is enough to obtain this properties which is confirmed by Latifah et al., (2009).

CONCLUSION

Results of this study showed the blending enhanced the properties of EFB paper by adding kenaf fibres. It is recommended that the blending of at least 10% kenaf whole stem fibres into EFB fibres is sufficient to fulfil the requirement for tensile, tear, opacity and smoothness paper properties as well.

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