Effects of Temperature and Time on the Morphology, pH, and Buffering Capacity of Bast and Core Kenaf Fibres

Majid Dehghan Nayeri,[a] Paridah Md Tahir,[a,*] Jalaluddin Harun,[b] Luqman Chuah Abdullah,[a] Edi Suhaimi Bakar,[a] Mohammad Jawaid,[a] and Farideh Namvar [a,c]

This study investigated the effects of heating on the morphology, pH, and buffering capacity of bast and core kenaf fibre. The bast material yielded longer and thinner fibres (with a higher aspect ratio) compared to the core. Changes in fibre morphology were clearly visible when the temperature of pulping was increased. The morphology of the bast fibre displayed significant variations following treatment at different pulping temperature (150, 160, 170, and 180 °C), time (1, 2, and 3 hours), and with the interaction between both parameters. Core fibre also exhibited significant variation in length, width, and wall thickness in all parameters, but lumen diameter and aspect ratio were not significantly affected by the same processing conditions. The pH value of both fibres was reduced as the temperature increased; core fibre was more acidic compared to bast fibre. Bast fibre exhibited greater acid buffering capacity and core fibre greater alkaline buffering capacity.

Keywords: Fibre characteristics; Buffering Capacity; Kenaf core; Kenaf bast

Contact information: a: Institute of Tropical Forestry and Forest Products (INTROP), Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia; b: Malaysian Timber Industry Board (MTDC), Cheras 56100, Kuala Lumpur, Malaysia c: Mashhad Branch, Islamic Azad University, Iran
**Corresponding author: parida_introb@yahoo.com*

INTRODUCTION

Over the past few decades there has been growing interest in the use of natural fibres in composite fabrication. Natural fibres possess many advantages over synthetic fibres; they are recyclable (Aji *et al*. 2009), biodegradable, renewable, less abrasive to processing equipment, and are lower in density and cost. Natural fibres are widely available in most countries, subject to easy fibre surface modification, and the mechanical properties are comparable to those of inorganic fibres (Abdul Khalil and Suraya 2011). Natural fibres such as kenaf, flax, hemp, jute, *etc.* have been applied by researchers for the production of pulps, paper products, and cellulose derivatives (Russo *et al*. 2012).

Kenaf, *Hibiscus cannabinus*, is a herbaceous annual of the family Malvaceae and is grown in tropical, subtropical, and warm-temperature areas. It is a biodegradable and environmentally friendly crop and is an important source of fibres for composites and other industrial applications. Kenaf has excellent properties for pulp and paper, medium density fibre board (MDF), and other composites, as it has a low density, little abrasion during processing, high filling levels, and high specific mechanical properties (Paridah *et al.* 2011). The kenaf stem is composed of an outer layer (bark) and a core. It is easy to separate the stem into bark and core, either by chemicals and/or by enzymatic retting. The bark constitutes 25 to 40% of the stem dry weight and shows a dense structure. On the

other hand, the core is wood-like and makes up the remaining 60 to 75% of the stem. The core exhibits an isotropic and almost amorphous pattern (Aji *et al*. 2009). However, the bark shows an orientated, highly crystalline fibre pattern. Kenaf bast and core are quite different with respect to their chemical compositions. The chemical compositions and physical properties of the core and bast kenaf fibres are illustrated in Table 1. Research indicates that kenaf core fibres are higher in holocellulose and lignin, while kenaf bast fibres are higher in cellulose, extractive, and ash content (Abdul Khalil *et al*. 2010).

Table 1. Chemical Composition and Physical Properties of Core and Bast Kenaf Fibres (Aji *et al.* 2009; Abdul Khalil and Suraya 2011; Abdul Khalil *et al*. 2010)

Macrofibril size /Chemical content	Bast	Core
Fibril length, L (mm)	2.22	0.75
Fibril width, W (lm)	17.34	19.23
L/W	128	39
Lumen diameter (lm)	7.5	32
Cell wall thickness (lm) Cellulose (%)	3.6	1.5
Lignin (%)	14.7	19.2
Hemicellulose (%)	26.2	29.7
Ash content (%)	5.4	1.9
Holocellulose	86.8	87.2
α-Cellulose	55.0	49.0

Fibre morphological characteristics play a key role in determining the suitability of any wood species or other raw materials for fibreboard manufacturing (Xing *et al.* 2006). The separation of kenaf stem into the bast and core parts may affect the commercialization of this raw material (Voulgaridis *et al.* 2000). Previous researchers have proposed fibre separation and pulping of each fraction separately and using each pulp separately or blending refined bast pulp and unrefined core based on final product properties (Udohitinah and Oluwadare 2011). Other research suggested the use of kenaf as whole stem (bast and core together) for technical and economical advantages (Azizi *et al.* 2010). Beating or refining pulp is an essential process of paper manufacture and is carried out to a greater or lesser degree in all paper and board mills. On the other hand, some variables such as fibre properties, equipment characteristics, and process variables affect the refining process and final pulp and paper properties.

The importance of plant materials, fibre dimensions, and their derived values (slenderness ratio, flexibility coefficient, and Runkel ratio) on pulp and paper mechanical strength is well documented (Azizi *et al*. 2010). In order to assess the suitability of kenaf stems for the panel and pulp and paper industry, it is important to investigate basic characteristics and properties of this material. The goal set by this work was to develop a pulping process with optimal conditions. The objectives of the present study were to examine the effect of temperature and time on fiber dimensions, pH, and buffering capacity of core and bast kenaf fibres.

EXPERIMENTAL

Raw Material Preparation

Stalks of *Hibiscus cannabinus* were collected from the kenaf plantation in Pasir Putih, Kelantan, Malaysia. The plant stalks were predominantly 3 cm in diameter at the base and about 280 cm in length. The moisture content of the kenaf stem was about 85% as collected. The kenaf bast and core of the kenaf stalks were separated manually, and whole kenaf stem (referred to as "whole stem" hereafter) was also used. The bast to core output was measured at intervals of 50 cm starting from the end of cutting level. The top portion of the stalk above 250 cm was too soft in texture to enable separation into bast and core. The average composition for the whole stem was 67.3% core and 32.7% bast on an oven dry weight basis. The large bast pieces were cut into 35 to 50 mm lengths. The raw materials were air dried and then stored in bags for future use.

Before conducting pulping and fabricating boards, a completely randomized designed experiment (with four replications) was run to quantify the main chemical components for each fraction of kenaf. Thus, some samples of bast, core, and whole stem fractions were separately used.

Chipping and flaking

The kenaf core and whole stem were chipped using a Pallmann Drum Chipper and the kenaf bast was chipped using a manually cutter.

Pulping and refining

Pulping was carried out in a stainless steel digester (MK model, USA). The samples for fibre measurement were obtained from each of the pulping conditions (Table 2) of bast and core. The material in the vessel was squeezed to ensure that all the materials were soaked in the water for a homogenous pulping effect. The digester was then heated to the required temperature. Upon completion of the pulping, fibres were collected and then refined in a refiner mechanical pulp (RMP).

Table 2. Pulping Process Condition for Bast and Core Fibre

Pulping process	Value
Water to fibre ratio	7:1
Target Temperature (°C)	150,160,170,180
Time to target Temperature	60 minutes
Time at target Temperature	1,2 & 3 hours

Morphological Characteristics

Image analysis

A typical PC-based image analysis system consists of a camera mounted on a microscope and attached to a frame grabber. With the use of sophisticated image analysis software, laboratory technicians are able to easily manipulate images into their accurate binary components of interest and then analyze their binary structures from an analytical, statistical point of view (Ong *et al*. 1996). These systems used integrated light pen technology to digitize and quantify single objects of interest when pointed at a screen. Significant advancements in hardware coupled with new developments in mathematical algorithms applied to image processing have contributed to the growing acceptance of

image analysis technology as an effective tool for image quantification. Image analysis is not a tool used exclusively in quality control laboratories. The use of image analysis in different fields of science created new domains of research and applications: biomedical imaging, industrial vision, remote sensing, scientific visualization, and virtual reality (Paridah *et al.* 2011).

Runkel ratio (RR)

The Runkel ratio, twice the cell wall thickness / lumen diameter ($2w/l$), is a microscopic extension of the wood density in that wall thickness and lumen width are the basic factors used in their determination. In this expression w is the cell wall thickness and l is the lumen diameter. Therefore, the Runkel ratio should not be expected to provide much more basic information beyond what is provided by the measured wood density. Wood-fibre characteristics that have often been associated with pulp and paper strength are the aspect ratio, length to diameter ratio (L/D), and the Runkel ratio. It is important to reflect on this in that differences in performance of fibre-based products are traced to the pulp fibre. Consequently, performance can only be assessed by measuring morphological parameters of the pulp fibre because existing data clearly demonstrate that wood fibre undergoes internal dimensional changes under conditions of pulping (Stockmann 1971a,b).

Aspect ratio (AR)

The aspect ratio is the ratio of fibre length to diameter (L/D); thus fibres with high aspect ratio are long and thin, while fibres with low aspect ratio are shorter in length and broader in the transverse direction. In certain processes, such as chemical or thermo-mechanical pulping, much of this aspect ratio can be maintained; however, hammer milling reduces the fibres to a particulate form, with low aspect ratio. The aspect ratio of individual bast fibre cells is somewhat higher and in the region of 1000 to 1200. Broadly speaking, it is advantageous to retain as much fibre length as possible, since higher aspect ratios give rise to greater reinforcing efficacy (Fowler *et al*. 2006). The long fibre length (up to 500 aspect ratio), results in high strength (Gejo *et al.* 2010).

Compression ratio

Fibre diameter and wall thickness governs fibre flexibility. Thick-walled fibres adversely affect the bursting strength, tensile strength, and folding endurance of paper. The paper manufactured from thick-walled fibres will be bulky, coarse-surfaced, and will contain a large amount of void volume. Paper from thin-walled fibres will be dense and well formed.

Three derived values are calculated using fibre dimensions: slenderness (aspect) ratio as fiber length/fiber diameter, (compression ratio) or flexibility coefficient as (fiber lumen diameter/fiber diameter) × 100, and (Runkel ratio) as (2 × fiber cell wall thickness)/lumen diameter (Ververis *et al*. 2004).

Determination of fibre buffering capacity

Fifteen grams of refined fibre from each refining condition were weighed and placed in a beaker, and 200 mL of distilled water was added. The mixture of fibre and distilled water was boiled for 1 h. After boiling, the mixture was filtered using a glass crucible, and 200 mL of the filtered solution was cold until the solution reached 20 °C. The solution was titrated first with 0.01 N hydrochloric acid (HCL) until it reached pH

3.0. The procedure was repeated by using 0.01 N sodium hydroxide (NaOH) until it reached pH 11. The same step was completed in three replicates, and a graph of pH versus volume (mL) was plotted to observe the changes in pH values.

Data analysis

The data were statistically analyzed using the statistical analysis system (SAS) software. An analysis of variance (ANOVA) was used to examine the effects of each refining condition. Duncan's Multiple Range Test was used for mean separation to further evaluate the effects of pulping temperature and time, and the interaction between both factors. This method calculates the least difference that must occur between two means and compares them at $p \leq 0.05$. Means that differ more than this value is considered significantly different from each other and are ranked as a, b, c, d. Means followed by the same letters are not significantly different at $p \leq 0.05$.

RESULTS AND DISCUSSION

Summaries of the analysis of variance for the fibre morphology of kenaf bast and core parts are given in Table 3 and 4, respectively. From Table 3, it can be seen that there were significant variations in all aspects of fibre morphology of bast fibre at different pulping temperature, pulping time, and the interaction between both parameters.

Table 3. Summary of ANOVA on the Fibre Morphology of Bast Fibre

Parameter	d.f	Length	Width	Lumen Diameter	Thickness Wall	Runkel Ratio	Aspect Ratio	Flexibility Ratio
Pulping Temperature	3	***	***	***	***	***	*	***
Pulping Time	2	***	***	***	**	***	***	***
Temperature ×Time	6	***	**	***	***	***	**	***

* Note: ***: Significantly different at p≤ 0.01, **: Significantly different at p≤ 0.05, *: Significantly different at p≤ 0.10, ns: not significant

Table 4. Summary of ANOVA on the Fibre Morphology of Core Fibre

Parameter	d.f	Length	Width	Lumen Diameter	Thickness Wall	Runkel Ratio	Aspect Ratio	Flexibility Ratio
Pulping Temperature	3	***	***	ns	***	***	ns	***
Pulping Time	2	**	***	ns	***	**	ns	***
Temperature ×Time	6	ns	**	ns	*	ns	ns	ns

* Note: ***: Significantly different at p≤ 0.01, **: Significantly different at p≤ 0.05, *: Significantly different at p≤ 0.10, ns: not significant

Table 4 shows the ANOVA result for the morphology of core fibres. The analysis shows there were significant variations in fibre length, fibre width, and wall thickness in all parameters.

Lumen diameter and aspect ratio were not significantly affected by pulping temperature, pulping time, and the interaction between both parameters. Duncan's multiple range test was used to examine the significant difference between pulping temperature and time.

The mean values of fibre dimensions, Runkel ratio, aspect ratio, and flexibility ratio of bast and core fibres are presented in Tables 5 and 6. In Table 5, it can be seen that there was significant variation in fibre length of bast fibre with pulping temperature, pulping time, and in the interaction between both parameters.

Table 5. Fibre Dimensions and Properties of Bast Fibre

Temp. (°C)	Time (h)	Length (mm)	Width (mm)	Lumen Diam.(mm)	Thickness Wall (mm)	Runkel Ratio	Aspect Ratio	Flexibility Ratio
150	1	3.2233**a** (0.1181)	0.0152**a** (0.7014)	0.0044**a** (0.4452)	0.0054**a** (0.5359)	2.690**d** (0.403)	213.400**a** (14.627)	28.900**a** (4.024)
	2	2.7233**b** (0.0365)	0.015**a** (0.9450)	0.0034**bc** (0.0748)	0.0058**a** (0.4364)	3.430**dc** (0.217)	184.620**bc** (10.804)	23.130**bc** (0.806)
	3	2.5984**b** (0.0683)	0.0139**ab** (0.3131)	0.0029**bcd** (0.1407)	0.0055**a** (0.0910)	4.050**abc** (0.152)	191.090**abc** (4.865)	20.810**bcd** (0.498)
160	1	2.5951**b** (0.1447)	0.0146**ab** (1.8447)	0.0035**b** (0.8131)	0.0055**a** (0.5527)	3.390**dc** (0.703)	184.410**bc** (14.200)	24.800**ab** (3.567)
	2	2.5789**b** (0.0961)	0.0144**ab** (0.4659)	0.0032**bc** (0.1775)	0.0056**a** (0.1688)	3.770**bc** (0.204)	180.850**bc** (12.427)	22.620**bcd** (1.370)
	3	2.5296**b** (0.0847)	0.0141**ab** (0.1927)	0.0026**ced** (0.0823)	0.0057**a** (0.1184)	4.700**a** (0.332)	181.280**bc** (5.254)	18.500**cd** (0.819)
170	1	2.6029**b** (0.0747)	0.014**ab** (0.4715)	0.0026**ced** (0.0467)	0.0057**a** (0.2367)	4.430**ab** (0.159)	192.600**abc** (14.625)	18.990**cd** (0.677)
	2	2.504**b** (0.1425)	0.0138**ab** (0.2771)	0.0032**cb** (0.3345)	0.0053**a** (0.0852)	3.460**dc** (0.336)	188.500**abc** (11.362)	23.180**bc** (2.120)
	3	2.222**c** (0.0930)	0.0129**b** (0.6342)	0.0027**ced** (0.1850)	0.0051**a** (0.3865)	3.980**abc** (0.504)	174.570**c** (1.548)	21.020**bcd** (2.392)
180	1	2.5947**b** (0.1336)	0.0127**b** (0.4494)	0.0023**fed** (0.2073)	0.0052**a** (0.1280)	4.690**a** (0.332)	206.510**ab** (10.565)	17.950**d** (0.996)
	2	2.0231**cd** (0.1302)	0.0106**c** (0.2381)	0.002**fe** (0.1109)	0.0043**b** (0.1201)	4.390**ab** (0.303)	192.360**abc** (7.856)	19.120**cd** (1.005)
	3	1.8167**d** (0.0670)	0.0097**c** (0.3578)	0.0018**f** (0.0446)	0.0039**b** (0.1569)	4.470**ab** (0.100)	189.540**abc** (4.006)	18.600**cd** (0.308)

* Note: Values in parentheses are standard deviations. Means followed by the same letters are not significantly different at $p \leq 0.05$ according to Least Significant Difference (LSD) method

Table 6. Fibre Dimensions and Properties of Core Fibre

Temp. (°C)	Time (h)	Length (mm)	Width (mm)	Lumen Diam.(mm)	Thickness Wall (mm)	Runkel Ratio	Aspect Ratio	Flexibility Ratio
150	1	0.9902**a** (0.1830)	0.0243**a** (1.2788)	0.0147**a** (0.7854)	0.0048**a** (0.2468)	0.690**a** (0.007)	40.980**a** (6.290)	59.870**c** (0.212)
	2	0.9127**ab** (0.2246)	0.0215**b** (1.8195)	0.0146**a** (0.9000)	0.0035**b** (1.2660)	0.590**ab** (0.370)	43.140**a** (11.588)	68.850**b** (9.491)
	3	0.8447**ab** (0.0445)	0.0208**bc** (0.6438)	0.0146**a** (0.2059)	0.0031**bc** (0.4070)	0.440**abc** (0.056)	41.380**a** (2.214)	70.610**b** (3.157)
160	1	0.8902**ab** (0.0211)	0.0208**bc** (0.7032)	0.0146**a** (0.9014)	0.0031**bc** (0.3716)	0.460**abc** (0.076)	43.870**a** (2.601)	70.060**b** (3.794)
	2	0.8595**ab** (0.0311)	0.0204**bc** (0.7782)	0.0146**a** (0.6906)	0.0029**bc** (0.1626)	0.430**abc** (0.050)	42.830**a** (1.569)	72.050**b** (1.438)
	3	0.7791**ab** (0.0158)	0.0199**bc** (1.0972)	0.014**a** (0.3815)	0.003**bc** (0.3976)	0.430**abc** (0.057)	40.470**a** (3.187)	71.490**b** (3.038)
170	1	0.8687**ab** (0.0237)	0.0204**bc** (0.4536)	0.015**a** (0.3880)	0.0027**bc** (0.1068)	0.380**bc** (0.026)	42.820**a** (1.912)	73.500**b** (0.979)
	2	0.8541**ab** (0.0329)	0.0199**bc** (0.7174)	0.015**a** (0.2689)	0.0024**bcd** (0.2244)	0.330**bc** (0.020)	43.350**a** (1.679)	75.810**ab** (1.701)
	3	0.7376**b** (0.0308)	0.0191**bc** (0.1782)	0.0146**a** (0.2005)	0.0023**cd** (0.0124)	0.310**bc** (0.008)	38.930**a** (1.767)	76.940**ab** (0.222)
180	1	0.7762**ab** (0.0565)	0.0196**bc** (0.2658)	0.0147**a** (0.2412)	0.0024**bcd** (0.1402)	0.340**bc** (0.020)	40.110**a** (2.483)	75.460**ab** (1.769)
	2	0.7433**ab** (0.0736)	0.0193**bc** (0.2495)	0.0148**a** (0.3746)	0.0023**cd** (0.0795)	0.320**bc** (0.025)	39.520**a** (3.798)	76.100**ab** (1.338)
	3	0.6711**b** (0.0733)	0.0186**c** (1.5171)	0.0155**a** (1.0456)	0.0016**d** (0.2458)	0.210**c** (0.015)	36.720**a** (3.290)	83.650**a** (1.389)

* Note: Values in parentheses are standard deviations. Means followed by the same letters are not significantly different at $p \leq 0.05$ according to Least Significant Difference (LSD) method

The fibre dimensions are among the most important indices for selecting a lignocellulosic fibre for industrial purpose (Udohitinah and Oluwadare 2011). The average fibre length, diameter, lumen width, and cell-wall thickness of samples compared well with the fibre dimensions of kenaf varieties reported by other researchers (Udohitinah and Oluwadare 2011; H'ng *et al*. 2009). Generally, the fibre length of bast fibre was reduced with increasing pulping temperature and time. The reduction was considerable when the temperature was increased above the limit. The fibres width was reduced at the increasing pulping temperature and time, but lumen diameter was not significantly different when increasing the temperature and pulping time. The aspect ratio also decreased with increasing pulping temperature and time. This is consistent with the

finding of a past study, which stated that the length and the aspect ratio of kenaf core fibres increased with increasing pressure and temperature, but the aspect ratio decreased with a further increase of pressure and heating time (Xu *et al*. 2006). The length of core fibre decreased significantly with increasing pulping temperature and pulping time, as indicated by different letters in the LSD ranking. The fibre width showed a continuous reduction as the pulping condition increased. The Runkel ratio decreased with an increase in the pulping temperature and time. Nkaa *et al.* (2007) reported that a low Runkel ratio of < 1 and a high flexibility ratio above 50% but less than 60% are necessary in fibres for papermaking. Fibres having these characteristics readily collapse and produce good surface contact in addition to fibre-to-fibre bonding (Nkaa *et al*. 2007).

It is well known that fibre aspect ratio influences all properties of the final product. A high aspect ratio is desirable to have better panel properties. Table 6 shows that bast fibre produced longer fibre as compared to the core fibre, resulting in higher aspect ratio. Bast fibres material is quite similar to typical wood as compared to core fibre, because of different fiber orientation. The bast fibres lie more or less parallel to the fibre axis, unlike wood fibres whose fibrils are spirally wound. One explanation is that during refining, bast fibres not only undergo cutting, but they also divide into sections and split. Bast fibre splits length-wise by mechanical action to yield fine, relatively fibrous threads, similar to jute fibres (Sabharwal *et al.* 1995).

Effect of pulping condition on fibre pH and buffering capacity

Table 7 presents the initial pH of bast and core fibre after pulping and refining at different pulping temperature and time. The result indicates that the pH value of bast was distinctly higher than that of the core fibre. There was a general tendency for a decrease in pH value of both fibres as the pulping temperature and time were increased. This is consistent with the study conducted by Xing *et al*. (2006) who reported that the pH values of wood decreased in the course of refining.

Table 7. The pH Value of Bast and Core Fibre after Pulping and Refining

Temperature (°C)	Time (hour)	Bast Fibre	Core Fibre
150 °C	1	5.31	5.31
	2	5.29	5.27
	3	5.29	5.24
160 °C	1	5.18	5.09
	2	5.00	4.98
	3	4.74	4.94
170 °C	1	4.66	4.63
	2	4.61	4.56
	3	4.61	4.53
180 °C	1	4.58	4.44
	2	4.50	4.19
	3	4.52	3.86

Figure 1 shows the buffering capacity of bast and core fibre in acidic conditions, respectively. Buffering capacity measures the resistance of the fibre to change in acidity or in alkalinity. Both the pH and buffering capacity of the glue line affect the cure of resins used in composite manufacture. Bast fibre pulped at 150 °C for 1, 2, and 3 h required about 9 mL of titrant solution. The core fibre pulped at the same conditions required 7 mL of titrant solution. It is evident that bast fibre was more resistant to acid,

thus had greater acid buffering capacity compared to core fibre. This is probably due to different chemical composition between bast and core parts.

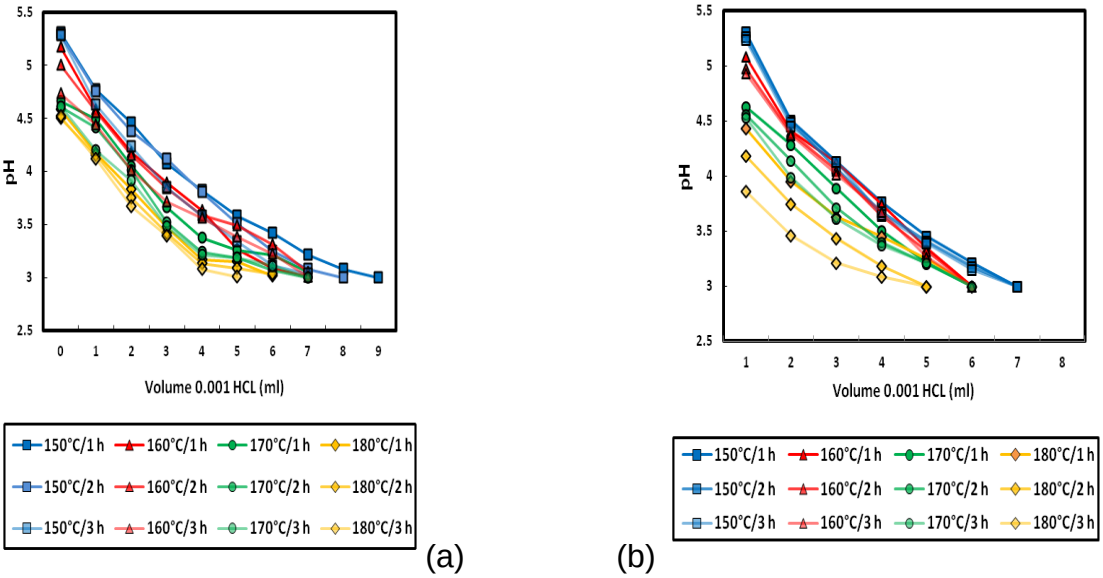

Fig. 1. (a) Bast fibre (b) core fibre buffering capacity in acidic conditions

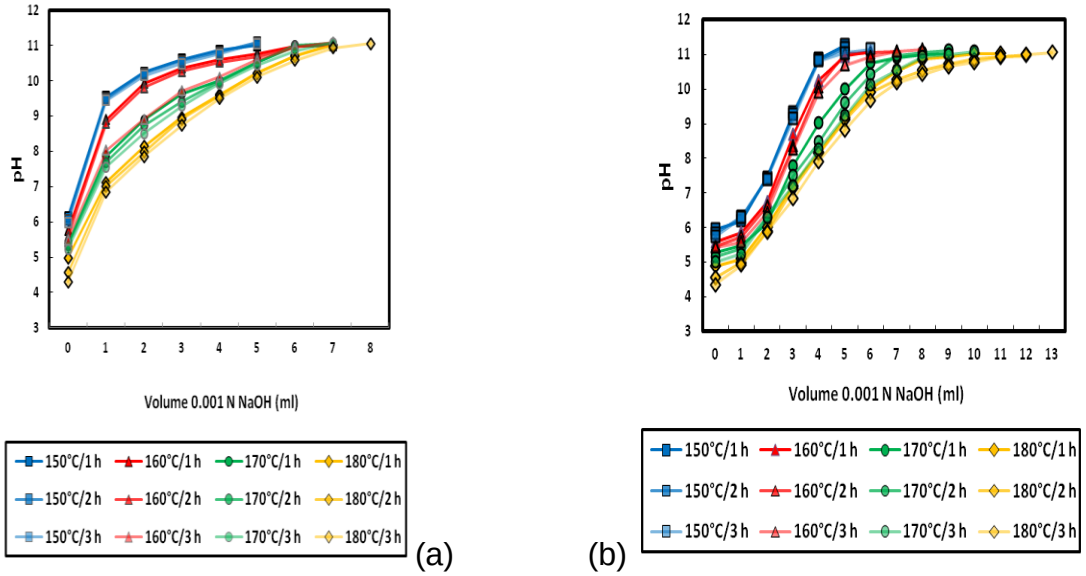

Fig. 2. (a) Bast fibre (b) Core fibre buffering capacity in alkaline conditions

As the pulping conditions were made more intense, both bast and core were relatively more sensitive toward acid as indicated by the small amount of titrant solution required to reach the final pH 3. A previous study by Shi *et al*. (2011) found that kenaf bast fibre digested at high temperature had low hemicelluloses content due to the degradation of hemicellulose when temperature used ranged from 80°C, 110°C, 130°C, and 160°C. The acid solution required to achieve pH 3 was less for fibre digested at high

temperature; therefore these fibre were more resistant to acid and had greater buffering capacity.

Figure 2 shows the buffering capacity of bast and core fibre under alkaline conditions. Figure 2a shows that the amount of NaOH required for bast fibre to change the initial pH value from 6.14 (at 150 °C for 1 h) and 4.30 (at 180 °C for 3 h) to 11 was only 5 mL and 8 mL, respectively. By contrast, the amount of NaOH required for core fibre to change the pH from 5.94 (at 150 °C for 1 h) and (at 180 °C for 3 h) to pH 11 were 5 mL and 13 mL, respectively as shown in Fig. 2b. For this reason, under alkaline condition, the core fibre was more resistant to alkali and thus had greater alkaline buffering capacity compared to bast fibres. According to Roffael *et al.* (2008), pulping induced different chemical changes leading to the formation of different water solution compounds like mono- and oligosaccharides and monobasic acids, such as formic and acetic acid. Moreover, simple reactive compounds such as formaldehyde and furfural are also formed. The higher temperature resulted in more formation of soluble compounds. The results reveal that the presence of water-soluble compounds was associated with lower pH values and increases of the alkaline buffering capacity.

Lignin becomes softened at elevated temperature; therefore the middle lamella becomes a zone of weakness, allowing for easy cleavage of adjacent fibres. High temperature may not only affect how fibres become separated, and which cell layer is the primary face exposed, but may also have a significant effect on the chemical groups that are available for fibre binding. Chemical compatibility between the resin and wood can also be an issue. Urea-formaldehyde (UF) and melamine modified urea-formaldehyde (MUF) systems require an acid pH environment (generally <5) to cure the resin at a reasonable rate. The acidity of wood species varies over a wide range and can affect resin cure speed. Acid generating catalysts are generally used in particleboard. These are less effective in medium density fiberboard (MDF), where the preheating of the wood prior to separating the fibres generates further acid groups on the fibres, and where the much greater surface area of the fibre allows the buffering capacity of the wood to determine the resin cure rate. This aspect is also an issue in cement-bonded products where an alkaline environment is necessary to allow the cement to bond with the wood surface.

Within this wide range there are many possibilities. The adhesive purchase price and the required addition rate are major factors in determining the overall adhesive cost for a panel. Performance requirements, particularly durability may limit the available choice. Overall UF systems provide the lowest cost solution for MDF and particleboard and are used in the greatest proportion of these panels, in excess of 95% for MDF (Fowler *et al.* 2006; Akil *et al*. 2011).

CONCLUSIONS

1. The investigation of fibre dimensions based on pulping of bast and core fibre resulted in different behavior of the two classes of fibre. There were significant variations in all aspects of fibre morphology of bast fibre at pulping temperature, pulping time, and with the interaction between both parameters.
2. The bast fibre produced longer and thinner fibre, compared to the core fibre, thus yielding fibre with higher aspect ratio. The changes in fibre morphology were clear when pulped temperature increased.

3. The core fibre exhibited significant variations in fibre length, fibre width, and wall thickness in all parameters. Lumen diameter and aspect ratio were not significantly affected by differences in pulping temperature, pulping time, and the interaction between both parameters
4. The fibres width was reduced at the increasing pulping temperature and time, but lumen diameter was not significantly different when the temperature and pulping time were increased. The aspect ratio also decreased with increasing pulping temperature and time. The length of core fibre decreased with increasing pulping temperature and pulping time. The fibre width shows constant reduction as the pulping condition increased. The Runkel ratio decreased with increasing pulping temperature and time.
5. The pH value of both fibres was reduced as the temperature increased; core fibre was more acidic compared to bast fibre. It is evident from results that bast fibre is more resistant to acid and display greater acid buffering capacity compared to core fibre.

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