

A Review of Literatures Related to Kenaf as a Alternative for Pulpwoods

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Abstract: The increasing of world population, quality of life and industrialization will lead to increase of consumption of paper and paperboard globally, this will cause the increase demand for fiber. New legislative regulations enacted in response to the demand of environmentalists, environmental groups and governmental organizations in various countries are restricting the logging of trees which is expected to affect the supply and price of wood to the international pulp and paper industry. So, the insufficient supply of fiber for papermaking has necessitated the paper industry to search for alternative fiber. Generally, lignocellulose material from wood or non-wood plant consists of cellulose, hemicellulose, lignin, extractive and a minor part of inorganic matter. Information on the chemical composition is important in deciding techno-commercial suitability, pulping method and paper strength. Kenaf has been identified as one of the potential sources for pulp and paper production. Generally, the selection of pulping process depends on the function of the end product. Kraft, soda and soda-AQ processes have been the most frequency used for kenaf. In comparison to kraft pulping, soda-AQ process has higher yield at the same kappa number and better delignification without environmental damage due to no sulphur emissions. Soda-AQ pulping with kenaf whole stem needs less chemical consumption with higher pulp yield than soda. Also, it is considered to be suitable for small scale mills.

Key words: Kenaf, chemical composition, fiber morphology, pulping process, soda-AQ, Iran

INTRODUCTION

Kenaf is an annual plant and member of the Hibiscus family (*Hibiscus cannabinus* L.). It is a close relative of cotton and jute and has been cultivated in its native Africa since 4000 B.C (Keshk *et al.*, 2006). There are >50 related Hibiscus species that occur in the tropical and subtropical environments of every continent but only two of these species, kenaf (*H. cannabinus* L.) and roselle (*H. sabdariffa* L. var. *altissima*) have economic importance for the production of pulp and paper (Rowell *et al.*, 1997) and due to identical pulping conditions can be dignified together (Dutt *et al.*, 2009).

Kenaf has high growth rate and can reach a height of 3.7-5.5 m with a stem diameter of 25-51 mm, within 4-5 months in suitable temperature, soil and rainfall conditions. As a summer crop, kenaf seeds are planted

during the spring and the crop harvested in early autumn. In tropical area kenaf can produce two crops per year (Kaldor *et al.*, 1990).

The yield per hectare varies considerably. It is reported that the kenaf yield ranges from 12-30 tons ha⁻¹ a year which is generally 3-5 times higher than *Pinus radiata* (Villar *et al.*, 2009). The differences in yield are associated with different kenaf cultivars, soil type, location, climate and the management practices that could be an important consideration in selecting the best cultivar for a given region and a desired end user (Mahapatra *et al.*, 2009; Alexandre *et al.*, 2007; Webber III, 1992).

Kenaf been a dicotyledonous plant has two distinctive stem regions. The outer portion or bast which is the portion used for cordage fiber is about 34% of the stem by the weight and inner, woody core which is about

66%. Fibers from the bast portion of stem are about 2.48 mm in length and resemble softwood fibers while those from the core are shorter, 0.72 mm and resemble hardwood fibers (Ashori, 2006). The long bast fibers could be used to manufacture products such as high grade pulps for the pulp and paper industry, protective packaging for fruits and vegetables, filters, composite board and textiles. The short fibers could be used to manufacture products such as animal bedding and horticultural mixes (Villar *et al.*, 2009; Dutt *et al.*, 2009; Paridah *et al.*, 2009; Kawai, 2005; Fisher, 1994).

The fibers of kenaf bast fiber are comparatively long, slightly shorter but much thinner than soft wood fibers. This is favorable for the ability of bonding and strength development. Bast fibers with thicker cell wall and smaller lumen diameter are favorable for porosity and opacity. The outer layer of the bast is a dense, thin epidermis film which can readily be removed.

The bast is composed of fiber bundles, separated by parenchyma cells, some of which contain starch and pectin. The structure of the xylem is similar to that of hardwood and consists of fiber, parenchyma cells, vessel elements and ray cells. The ray structure starting from pith goes all the way through the xylem and the bast to the epidermis film. Ray cell and pith are abundant in kenaf (Voulgaridis *et al.*, 2000; Juhua *et al.*, 1996).

Chemical composition of kenaf: Generally, lignocellulose material from wood or non-wood plants consists of cellulose, hemicellulose, lignin, extractive and a minor part of inorganic matter. Information on the chemical composition is important in deciding techno-commercial suitability, pulping method and paper strength (Abdul-Khalil *et al.*, 2010; Hng *et al.*, 2009; Ates *et al.*, 2008; Ververis *et al.*, 2004; Voulgaridis *et al.*, 2000). Thus, many researches have been carried out extensively to understand the chemical composition in various raw materials such as kenaf.

Lignin: Lignin contents in different woods range between 20-30%; typically 25-35% in softwoods and 18-25% in hardwoods (Biermann, 1996). While, non-wood fibers contain between 5-23% lignin (Goring, 1971). Lignin is a polyphonic, amorphous, three-dimensionally branched network polymer that plays an important mechanical support in plant.

This structure serves as binder in lignocellulosic plants that hold the fiber together and stiffening agent within the fibers (Biermann, 1996). Lignin concentration varies in different morphological regions of the plant and in different types of plant cells. Lignin is distributed

throughout the secondary cell wall with the highest concentration in the middle lamella. Because of the difference in the volume of the middle lamella to the secondary cell wall about 70% of lignin is located in the secondary wall (Abdul-Khalil *et al.*, 2010; Rowell *et al.*, 2000). In most cases wood utilization lignin is used as an integrated part of wood cell wall. Only in the case of pulping and bleaching is lignin more or less released in degraded and altered form (Kock, 2006).

During chemical pulping lignin is removed from the bundle fibers and allows the fibers to be separated easily. The ease of delignification of the material during the chemical pulping process can be estimated from the lignin content.

It requires high chemical consumption and or reaction time during pulping process (Abdul-Khalil *et al.*, 2010; Rodra-Gueza *et al.*, 2008; Ogunbile *et al.*, 2006; Ververis *et al.*, 2004).

Lignin consists of phenylpropane which unites chemical bonds together by C-C and C-O bonds to form a three-dimensional network structure. The basic structural units of lignin are p-coumaryl alcohol, coniferyl alcohol and sinapyl alcohol. Softwood lignin is based primarily on coniferyl alcohol whereas hardwood lignin contains a mixture of coniferyl and sinapyl alcohol units. The third type of monomeric unit, based on p-coumaryl alcohol is found in other plants such as cereals, grasses and other non-woods. It is also a minor component in hardwood and softwood lignin's (Rowell *et al.*, 2000; Biermann, 1996).

Abbott *et al.* (1987) described that milled wood kenaf lignin was of the guaiacyl-syringyl type with a predominance of syringyl structure. The main inter-unit linkages were found to be β -O-4 but some β -5 linkages were found to be present. Ralph *et al.* (1995) stated that kenaf may have one of the highest (7.8) syringyl/guaiacyl ratios. Ohtani *et al.* (2001) study on nitrobenzene oxidation products of kenaf core and bast found syringyl/guaiacyl ratios of 4.3 and 1.5, respectively.

Cellulose: Cellulose is the most abundant natural polymer in the world, it is estimated that 830 million of cellulose is produced each year through photosynthesis. Cellulose molecules consist of long linear chains of homopolysaccharide, composed of β -D-glucopyranose units which are lined by (1-4)-glycosidic bonds.

Actually the building block for cellulose is cellobiose since the repeating unites two sugar units. The number of glucose units in a cellulose molecule is referred to as the Degree of Polymerization (DP) that is above 10000 in native wood but <1000 for highly bleached kraft pulp.

Cellulose is a white solid material that may exist in crystalline or amorphous states. Most plant derived cellulose is highly crystalline and may contain as much as 80% crystalline regions (Rowell *et al.*, 2000).

The crystalline form of cellulose is particularly resistant to chemical attack and degradation. Hydrogen bonding between cellulose molecules results in the high strength of the cellulose fiber (Rowell *et al.*, 2000; Biermann, 1996).

Microfibrils are aggregations of cellulose molecules into thread-like structures approximately 3.5 nm in diameter, containing both crystalline and amorphous regions. Microfibrils occur in the secondary cell wall. Microfibrils are oriented in different directions in each of the three layers within the secondary cell wall. The fibril angle is measured from the longitudinal axis of the cell (Biermann, 1996).

There is a correlation between fiber angle and strength properties. Kenaf fibers have low fibril angle compared to woody raw materials (Aravamuthan *et al.*, 2002). For instance the fibrils of bast fibers lie generally parallel to the fiber axis, unlike wood fibers whose fibrils are spirally wound.

Kenaf fibers can therefore be split lengthwise by mechanical action to yield fine, relatively long fibrous threads (Clark, 1985) and only need a fraction of beating to develop strength properties (Firouzabadi *et al.*, 2008). Ohtani *et al.* (2001) determined the monosaccharide composition of kenaf holocellulose by the alditol acetate method. Xylose was dominant in the holocellulose (apart from glucose, much of which comes from the cellulose fraction). Xylose contents were reported to be 18.1% for bast and 29.8% for core.

Hemicelluloses: Physically, hemicelluloses are white solid materials that are rarely crystalline or fibrous in nature, they form some of the flesh that helps fill out the fiber. Hemicelluloses increase the strength of paper (especially tensile, burst and fold) and pulp yield. Starch is often added to pulp to accelerate the strength of paper with about similar mechanisms of effect as the hemicellulose (Biermann, 1996). Unlike cellulose which is homopolysaccharide, hemicellulose is heteropolysaccharides. Hemicellulose has lower DP of 100-200 and is relatively easier to be hydrolyzed by chemical to their monomeric components containing mainly sugars D-xylopyranose, D-glucopyranose, D-galactopyranose, D-glucopyranosyluronic acid, D-mannopyranose and L-arabinofuranose with minor amount of other sugars. In softwood, the main hemicellulose is galactoglucomann whereas in hardwood it is glucuronoxylan (Rowell *et al.*, 2000). The major component (85-97%) of kenaf bast and

core hemicellulose was xylose, with higher glucose content for core fraction (Duckart *et al.*, 1988; Cunningham *et al.*, 1986). It has a backbone of β -(1-4)-D-xylopyranose with side chains of 4-O-methylglucuronic acid linked (1-2) with an average frequency of 1 uronic acid group per 13 xylose unit (Rowell *et al.*, 2000). Xie *et al.* (1988) using gas chromatography analysis of acetylated aldonitriles, also found main components of kenaf hemicelluloses to be xylose with moderate content of glucose and small amounts of arabinose, mannose and rhamnose. Similarly, FTIR research done by Abbott *et al.* (1987) showed that kenaf hemicellulose fraction consisted of 70% of xylose, 15% glucose, 5% mannose and trace of arabinose and galactose.

Extractives: Extractive is the extraneous plant component that is generally present in small to moderate amounts and can be isolated by organic solvent or water. Extractive is a heterogeneous group of compounds of lipophilic and hydrophilic including terpenes, fatty acids esters, tannins, volatile oils, polyhydric alcohols and aromatic compounds.

The components of extractives are strongly dependent on the plant species, the position from heartwood to sapwood and the age of the tree (Rowell *et al.*, 2000). Extractives occupy certain morphological sites in the wood structure (Sjostrom, 1993). During alkaline pulping most of the lipids from the fibers is removed and forms colloidal pitch which can accumulate on the surface of the pulp or certain part of machinery.

Consequently, this reduces the quality of paper (Yu *et al.*, 2002; Khristova and Karar, 1999). Generally, the presence of extractives in woody materials increases the consumption of pulp reagents and reduces yield. For this reason, material with little or no extractive content is most desirable (Rodra-gueza *et al.*, 2008). On the other hand, Othani *et al.* (2001) have noted that although extractives consume alkali during cooking to a significant extent, they can act to protect hemicelluloses and slight increase in pulp yield can be obtained if higher chemical consumption can be tolerated.

Inorganic content: The inorganic constituent of lignocellulosic material is usually referred to as ash content which is considered the residue remaining after combustion of organic matter at a temperature of $525 \pm 25^\circ\text{C}$ (Rowell *et al.*, 1997). The ash content consists mainly of various metal salts such as silicates, carbonates, oxalates and phosphates of potassium, magnesium, calcium, iron and manganese as well as silicon. Normally, they deposit in the cell walls, libriform fibers and

lumina of parenchyma cells and in the resin canals and ray cells (Sjostrom, 1993). High ash content is undesirable during refining and recovery of the cooking liquor (Rodra-gueza *et al.*, 2008). Ash content of kenaf core and bast fiber are lower than most of non-wood such as bamboo and rice straw but higher than these conventional woods used to produce most commercial pulps (Abdul-Khalil *et al.*, 2010; Hng *et al.*, 2009; Ashori, 2006).

Pulping: Pulping is referred to as the process of converting lignocellulosic material into a fiber mass known as pulp which is used primarily for paper making. There are three commercial processes, generally categorized as mechanical, chemical and hybrid pulping.

Mechanical pulping: Mechanical pulping is the oldest pulping process of wood. During the process, wood is debarked and mechanically grounded into pulp by disk refiner or refiners or grindstone. The temperature in the grinding zone can be raised to 150-190°C which is aimed to soften the lignin and allow the fibers to be separated from others more easily.

The common mechanical pulping processes are Stone Ground Wood (SGW), Pressure Ground Wood (PGW), Refiner Mechanical Pulp (RMP), Pressurized Refiner Mechanical Pulping (PRMP) and Thermo Mechanical Pulping (TMP) (Biermann, 1996; Smook, 1992). Among the processes, the most widely used mechanical pulping process is TMP.

The uniqueness of this process is that high temperature steaming is applied prior to the mechanical refining. Paper made from TMP pulp are generally stronger than normal refiner pulp since the steaming serves to soften the inter-fiber lignin and thus the fiber separation mostly occurs at the primary layer of the cell wall, thereby allowing better fibrillation and this improves inter-fiber bonding by exposing more hydroxyl groups (Sixta, 2006a, b; Smook, 1992). The yield of the mechanical pulp is approximately 95%. However, the paper made from this kind of pulp is relatively low in strength properties (Law *et al.*, 2007; Rushdan, 2003a, b) and not suitable for linerboard production (Myers and Bagby, 1994).

Chemical pulping: In chemical pulping, wood chips are cooked under either acid or alkaline medium at an elevated temperature (140-190°C) or pressure (0.6-1.0 MPa). This process can be achieved by degrading >90% of the lignin that binds the fiber together and also other non-cellulose components including hemicellulose, resulting in relatively low pulp yield which is usually between 40-50% depending on the wood source and the pulping process applied. Continuing cooking beyond a certain extent of delignification inevitably results in disproportionately

large yield losses due to preferred carbohydrate degradation. Hence, the chemical reactions must be stopped at a point when the lignin content is low enough for fiber separation and where acceptable yield can still be attained (Casey, 1981; Sixta, 2006a, b). During this process, cooking liquor penetrates from the lumen via the cell walls towards the lignin rich middle lamella and the lignin will be chemically degraded into small fragment in pulping liquor, it is usually removed with black liquor (Sjostrom, 1993). Chemical pulping processes consume relatively large part of inorganic chemicals such as alkalis, paper makers devised methods for reagent chemical recovery from the spent cooking liquor; recovery has remained an integral part of chemical pulping.

Environmental and economical concerns necessitated chemical recovery as a very important part of chemical pulping (Sixta, 2006a, b). The main chemical pulping processes are alkaline and acidic (sulfite) process which differ the chemicals comprising the cooking liquor.

In the sulfite process a mixture of sulfurous acid (H_2SO_3) and bisulfite ion (HSO_3^-) is used to attack and stabilize the lignin. The sulfites combine with the lignin to form salts of lignosulfonic acid which are soluble in cooking liquor. The chemical structure of lignin is left largely intact.

The chemical base for bisulfite can be ionic calcium, magnesium, sodium or ammonium. Sulfite pulping can be carried out over a wide range of PH.

Acid sulfite denotes pulping with an excess of free sulfurous acid (PH 1-2) while bisulfite cooks are carried out under less acidic conditions (PH 3-5). Sulfite pulps are lighter in color than kraft pulps and bleached more easily but the paper sheets are weaker than equivalent kraft sheets.

The sulfite processes are very sensitive to resin of softwoods and tannin of hardwoods. This sensitivity to wood species, along with the weaker strength and greater difficulty in chemical recovery are the major reasons for the decline of sulfite pulping relative to kraft (Sixta, 2006a, b; Smook, 1992; Casey, 1981)

The two principle alkaline pulping processes used for chemical pulping of wood are soda and the kraft pulping. Soda pulping is the first introduced chemical pulping and it originated in 1851 by Huger Burgess and Charles Watt in England (Sixta, 2006a, b; Biermann, 1996). This process consumes large quantities of soda (NaOH) and the resulting spent liquor (black liquor) has to recover through evaporation and combustion (Sixta, 2006a, b). During recovery, sodium carbonate (Na_2CO_3) is added to concentrate the black liquor prior the combustion in order to compensate for the loss of soda. Carl Dahl in 1884 introduced sodium sulfate (Na_2SO_4) to replace the sodium carbonate (Na_2CO_3).

The Na_2SO_4 is reduced to sodium sulfide (Na_2S) along with soda. Surprisingly, the resultant pulp is far stronger than soda pulp (Sixta, 2006a, b; Smook, 1992; Casey, 1981). The kraft process produces the highest strength pulp this allows efficient recovery of pulping chemicals which utilizes a wide range of species and tolerates bark in the process. The strongest linerboard and unbleached kraft liners are produced from kraft pulp (Heise, 2003).

However, due to the problem arising from the release of sulfur compounds during kraft pulping process and effluent pollution from kraft bleaching, plants have become the driving force to sulfur free pulping process as a more environmentally compatible alternative (Sixta, 2006a, b; Smook, 1992; Casey, 1981).

Soda-AQ pulping: Based on previous works, numerous results demonstrates that soda-AQ pulp and its paper exhibit better or comparable kappa number, brightness and strength properties in comparison to kraft pulp (Rodra-gueza *et al.*, 2008; Han and Rymsha 1999; Nezamoleslami *et al.*, 1997; Holton, 1977) but with less complex recovery of chemicals and elimination of environmental damage caused by sulphur emission and (Jimenez *et al.*, 2009; Palmer *et al.*, 1986).

The main reactive species in soda pulping is hydroxide ion (OH^-). It reacts with lignin and causes the lignin to degrade into smaller soluble fragment. During soda pulping besides delignification, carbohydrate especially the amorphous cellulose and hemicellulose also undergo degradation. At the temperature of about 100°C , the degradation of polysaccharide chain starts through the process called peeling reaction (primary peeling).

At temperature above 140°C chains are split by alkaline hydrolysis. Thus new reducing end-groups are formed which are also subjected to endwise degradation (secondary peeling). The peeling reaction of polysaccharides involves the elimination of reducing end-groups by beta-alkoxy elimination to various carboxylic acids, thus reducing the chains by one monomeric unit at a time (Sixta, 2006a, b; Smook, 1992). The occurrence of the degradation of carbohydrate during the peeling reaction is converted to various hydroxyl acids that will consume alkali the major part of (60-70%) of the charged alkali thereby reducing the effective concentration of the pulping liquor (Sjostrom, 1993).

To avoid or at least diminish peeling reactions, the reducing aldehyde end-groups can be converted by reduction or oxidation to alcohol or carboxyl groups, respectively or substituted to yield other alkali-stable end-group. Polysaccharide stabilization, meaning increased pulp yield can be reached by the presence of the polysulfides, causing oxidation to aldonic and

metasaccharinic acids. Reduction to alditol and thioalitol groups is performed by treatment with borohydride and hydrogen sulfide, respectively. The use of AQ as catalyst in soda pulping reveals the same effect as sulfide in kraft pulping. Hence, with the absence of sulfur based compounds, soda-AQ pulping is credible as a more environmentally compatible process (Smook, 1992; Casey, 1981). The addition of small amount of AQ to soda cooking liquor will be able to improve the soda pulping performance in terms of the rate of delignification and carbohydrate stabilization. Thus, the resultant pulp imparts better yield and good strength properties especially tensile and burst indices (Hedjazi *et al.*, 2009; Akgul and Tozluoglu, 2009; Khristova *et al.*, 2002). According to Rodra-gueza *et al.* (2008) in comparison to the conventional soda pulping without AQ, the addition of 1% AQ to soda pulping of rice straw improves the pulp yield, breaking length and burst index for about 4.5, 30 and 45%, respectively.

This is because during soda-AQ pulping process, AQ is reduced to the Anathrahydroquinone (AHQ) by transferring electron from aldehyde end groups of carbohydrates to the AQ molecule, thus the loss of electrons through oxidation of the reducing sugar end-groups from an aldehyde to the alkali-stable aldonic acid groups which contributed to preserve higher pulp yield through stabilization of the carbohydrates against the peeling reaction (Sjostrom, 1993).

Furthermore, the addition of AQ also offers advantages to the kappa number and brightness. Based on the study done by Khristova *et al.* (2005), the result showed that the kappa number has dropped from 28.9- 20.7 with the addition of 0.10% AQ to soda pulping of date palm rachis which is also accompanied by a small improvement in brightness (4.8%).

The improvement in delignification is attributed to the presence of AHQ which reduces from AQ through the reaction with sugar. AHQ acts as an effective cleaving agent which reacts with quinone methides or other functional groups of reactive lignin structures. In contrast to the soda pulping, during the soda-AQ pulping, the lignin β -aryl ether linkages in free phenolic phenylpropane units is ready to be cleaved through transferring of electrons from AHQ which can participate again in the redox catalyst cycle, thereby accelerating the delignification rate during pulping process (Biermann, 1996; Sjostrom, 1993).

Besides the improvement in pulp yield and strength properties, the addition of AQ as a catalyst in soda pulping liquor will also reduce the consumption of cooking chemicals. As reported Khristova *et al.* (1998) noted that with the addition of AQ as low as 0.13%, the

active alkali charge can be reduced by 2% resulting in an increase of the yield by 2.2% with lower reject content and similar level of kappa number. This is mainly due to the enhancement of delignification where most of the aldehyde end-group of carbohydrates is converted to alkali stable aldonic acid groups and thus less alkali charge is needed to neutralize the degradation product of hydroxy acids that arise from the degradation of carbohydrate during peeling reaction (Sjostrom, 1993).

In the case of kenaf fiber for chemical pulping Kraft, soda and soda-AQ processes have been the most frequently used for kenaf pulping (Dutt *et al.*, 2009; Villar *et al.*, 2009; Khristova *et al.*, 1998, 2002; Ohtani *et al.*, 2001). In comparison to kraft pulping, soda-AQ process has higher yield at the same Kappa level and better delignification (Ohtani *et al.*, 2001) without environmental damage due to the absence of sulphur emissions (Jimenez *et al.*, 2009; Holton, 1977). The use of soda-AQ for Kenaf whole stem entails the utilization of less chemical, it also ensures higher pulp yield than soda pulping (Khristova *et al.*, 1998).

Hybrid pulping: Hybrid pulping process is a combination of chemical and mechanical treatment and thus, its pulp has intermediate properties. The dosage of chemical used in the treatment is much less than that in the full chemical pulping. The purpose of applying the chemical treatment prior to mechanical action is to pre-soften the wood chips thus making the fibers more refined.

This treatment indirectly reduces the consumption of energy and refining temperature during the mechanical refining process. Hybrid pulping can be further categorized into Chemical Pulping (CMP) and semi-chemical pulping.

The yield of CMP pulp is in the range of 85-95% with better strength than those mechanical pulping. The bulk of the yield loss basically associates with the removal of the extractives and hemicellulose, with small amount of lignin been removed in the process. The most commonly used CMP is cold soda, Chemithermomechanical Pulping (CTMP) and Alkaline Peroxide Mechanical Pulping (APMP). The major advantage of the APMP is that it can produce high brightness pulp from a variety of non-wood lignocellulosic materials (Xu, 2001; Biermann, 1996). According to Xu (2001), kenaf APMP pulp exhibit a good potential to be used for applications similar to aspen APMP pulp or market Bleached Chemithermomechanical Pulp (BCTMP) which are normally used for printing or writing paper, tissue and high brightness paperboard grades. Also, Myers and Bagby (1994) found that linerboard using kenaf whole stem CTMP alone was not comparable to linerboard prepared from 100% loblolly pine

kraft. The linerboard with acceptable strength can be made from blending 30-50% of the kenaf CTMP with loblolly pine kraft pulp. Besides, the kenaf CTMP addition could enhance compressive strength. On the other hand, the yield of semichemical pulp is in the range of 65-80% which is less than those given by mechanical pulping and even the chemimechanical pulp but higher in strength properties. The most commonly used semi-chemical pulping processes are the Neutral Sulphite Semi-chemical (NSSC), softwood bisulfite high-yield pulp and softwood sulfate pulping for linerboard production. The NSSC mostly used for hardwood species (Aravamuthan *et al.*, 2002; Biermann, 1996). The NSSC hardwood pulp contributes to an important part of packaging market, especially for corrugating medium where strength and fiber length are less critical than stiffness.

CONCLUSION

An increase in world wide consumption of wood-based products and a decrease in forest resources have raised potential demands for supplemental non-wood fibers resources. Kenaf as an annual plant grown in many parts of the tropics and some sub-tropical and warm temperature area has been considered as alternative fibrous crop to wood-based products, partially in pulp and paper ma-king industries. The sucessess of kenaf in papermaking has relied on its high yield per hectare and quality of its fibrous especially bast fiber with low lignin content that can be cooked under mild cooking condition through environmental friendly process and produce paper with strength exceeding that of paper from wood fibers.

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