Reprinted from: Trends in new crops and new uses. 2002. J. Janick
and A. Whipkey (eds.). ASHS Press, Alexandria, VA.

Kenaf Harvesting and Processing

Charles L. Webber III, Venita K. Bledsoe, and Robert E. Bledsoe

INTRODUCTION

Kenaf (*Hibiscus cannabinus* L., Malvaceae) is a warm season annual fiber crop closely related to cotton (*Gossypium hirsutum* L., Malvaceae) and okra (*Abelmoschus esculentus* L., Malvaceae) that can be successfully produced in a large portion of the United States, particularly in the southern states. As the commercial use of kenaf continues to diversify from its historical role as a cordage crop (rope, twine, and sackcloth) to various new applications including paper products, building materials, absorbents, and livestock feed, choices will continue to increase and involve issues ranging from basic agricultural production methods to marketing of kenaf products. Management decisions will require an understanding of the many different facets of kenaf and reliance on a systems approach that will integrate the production, harvesting, processing, and utilization of kenaf.

The purpose of this review is to provide a greater understanding of kenaf harvesting and processing systems, with a goal to increase the potential use of kenaf and its products. This review includes an introduction to the crop, a short history, an overview of harvesting and processing systems, and a profile of plant components and their uses.

HISTORY

Kenaf has been used as a cordage crop to produce twine, rope, and sackcloth for over six millennia (Dempsey 1975). Kenaf was first domesticated and used in northern Africa. India has produced and used kenaf for the last 200 years, while Russia started producing kenaf in 1902 and introduced the crop to China in 1935 (Dempsey 1975). In the United States, kenaf research and production began during World War II to supply cordage material for the war effort (Wilson et al. 1965). The war not only interrupted fiber supplies from countries such as the Philippines, but the war effort also increased the use of these fibers by the US. Once it was determined that kenaf was a suitable crop for US production, research was initiated to maximize US kenaf yields. As a result, scientists successfully developed high-yielding anthracnose-resistant cultivars, cultural practices, and harvesting machinery that increased fiber yields (Nieschlag et al. 1960; Wilson et al. 1965; White et al. 1970). Then in the 1950s and early 1960s, as USDA researchers were evaluating various plant species to fulfill future fiber demands in the US, it was determined that kenaf was an excellent cellulose fiber source for a large range of paper products (newsprint, bond paper, and corrugated liner board) (White et al. 1970). It was also determined that pulping kenaf required less energy and chemical for processing than standard wood sources (Nelson et al. 1962). More recent research and development projects in the 1990s have demonstrated the plant's suitability for use in building materials (particle boards of various densities and thicknesses, with fire and insect resistance), adsorbents, textiles, livestock feed, and fibers in new and recycled plastics (injection molded and extruded) (Webber and Bledsoe 1993).

HARVESTING

The evaluation of procedures for harvesting kenaf continues to be an important aspect of commercialization. The harvest method depends on the production location, the equipment availability, processing method, and final product use.

Hand Harvesting and Retting for Cordage Fiber

Over the last 6000 years, since its first domestication, kenaf has consistently been hand-harvested for use as a cordage crop (rope, twine, and sackcloth) (Dempsey 1975). The bast fiber strands, located in the kenaf bark, are the source for these cordage products. When hand-harvested, the tall, cylindrical-shaped stalks were cut at or near ground level with a curved blade or machete (Dempsey 1975). Usually plants were still actively growing, nearing or already flowering at the time of harvest. At most of these locations, kenaf plants were usually harvested prior to a killing frost because of the plant's advanced maturity or the lack of killing frosts at their locations. The hand-harvested plants were then prepared for the retting process.

Retting is the process, usually involving moisture with bacteria or chemicals, to remove the unwanted bark material from the kenaf fiber strands within the bark. Kenaf was retted by natural processes that use primarily aerobic (air loving) bacteria, unlike water-retting of flax that is carried out primarily by anaerobic bacteria and various fungi. The whole stalk kenaf (bark and core still attached), or only the bark portions, are tied in bundles and placed in ponds, canals, or slow-moving streams to allow the bacteria to digest the plant material around the bark's fiber strands (bast fibers) (Dempsey 1975).

The plant material status prior to retting influences the water-retting efficiency for kenaf. Removing the upper, non-fibrous portion of the plant, prior to the retting process increases the retting rate by decreasing the amount of leaf and plant material to be digested. This highly nutrient-laden portion of the plant can be either used as a high quality livestock feed or returned to the soil to maintain fertility. Even if the upper portion of the plant is not removed, the retting process can be increased if the plants are allowed to dry for 24 to 48 hr after harvesting to promote defoliation. Removal of the bark from the stalk also makes the retting process more efficient. The ease of separating the bark from the core material is enhanced by the physiological makeup of the plant. The bark, which contains the bast fiber (phloem tissues), and the core that contains the core fibers (xylem tissues), are separated by meristematic tissue, the vascular cambium. The vascular cambium is responsible for secondary growth, increase in girth, by generating new phloem tissue (sieve tubes) outwardly and new xylem tissues (core fibers) inwardly. The phloem cells transport food materials (products of photosynthesis) and the xylem vessels transport water within the plant. The mature, dead xylem cells become lignified xylem fibers, which then serve as structural support for the plant. The presence of the vascular cambium interface between the kenaf bark and core results in easy separation between these two plant components as long as the plant has been recently harvested or is not fully dried.

Once drying has occurred, the bark will adhere more aggressively to the stalk core and bast fibers will also be more difficult to separate from the non-fibrous material in the bark. In addition, drying the bark while either attached to or separated from the stalk will impede the water-retting process. Dempsey (1975) reported that when kenaf bark material is retted at its ideal temperature, 34°C, dry ribbons of bark took 70 hours to ret, compared to green, moist ribbons of bark which took 29 hr.

Although the natural water-retting (bacterial) process is still used throughout many portions of the world, newer chemical retting processes have been studied, developed, and implemented to produce fibers of greater chemical and physical uniformity (Dempsey 1975; Chen et al. 1995; Ramaswamy 1999). Research determined that hand-stripped green bark ribbons and mechanically separated bark material could be successfully chemically retted using 7% and 1% sodium hydroxide, respectively, to produce good textile quality fibers from kenaf (Ramaswamy 1999).

Ribboners and Decorticators

The USDA, universities, and private industry have developed an assortment of mechanical harvesters and post-harvest equipment to separate the bark from the core material, and the bast fibers from the core fibers. As result of the USDA's initial interest in kenaf as an alternative cordage source during World War II, a tractor-drawn harvester-ribboner was developed. This machine harvested green plants, removed the leafy, low fiber top portion of the plant, ribboned the bark, bundled the ribbons, and tied the ribbon bundles (Dempsey 1975). Ribboning is the process of removing the bark from the core material. The same process is also referred to as decorticating, the removal of the core from the bark. The original objective of the ribboners/decorticators was to harvest the bark for its valuable bast fiber and discard the unwanted core material.

Newer ribboners/decorticators have been developed specifically for the kenaf industry (Chen et al. 1995) or adapted from other fiber industries (hemp and jute). Unlike the older equipment, the newer ribboner/decorticator was built specifically for kenaf and actually intended to be an in-field harvest-separator. The objective is no longer to harvest only bark ribbons, but to separate and harvest the core material for other uses (Chen et al. 1995). As with the earlier ribboners/decorticators, the newer equipment must also achieve a number of outcomes to produce positive economic advantages. These issues typically include integrating the equipment into a kenaf production, harvesting, and processing system, increasing efficiency either as a result of product quality and/or throughput, and improving equipment reliability (durability, safety, ease of use, and maintenance). The advantages of these newer ribboner/decorticator harvesters over other types of kenaf harvesters, such as sugarcane-type or forage-type harvesters, include the ability to produce a cleaner separation between the bark and core components, quicker drying of the separated components, and greater flexibility in determining the cutting length of the fiber strands (Chen et al. 1995).

Whole Stalk Harvesters

Following the successful evaluation of kenaf's bast and core fibers as a combined cellulose fiber source for paper products (newsprint, bond paper, and corrugated liner board) in the 1950s and early 1960s, the development of harvesting equipment shifted away from in-field ribboners/decorticators to whole-stalk harvesters (White et al. 1970; Dempsey 1975). The development of these whole-stalk harvesters has taken two major approaches; sugarcane-type harvesters and forage-type harvesters. In both approaches scientists and industry have concentrated on using or adapting existing equipment, rather than developing a totally unique kenaf harvester.

Sugarcane-type Harvesters. The unmodified or slightly modified sugarcane harvesters use rotating knives or circular cutting blades to sever the base of the kenaf stalk and to cut off the low fiber, high foliage, top portion of the plants. These long stalks then pass through the equipment in an upright fashion (soldier-type harvester) and then are laid down in long windrow piles to field-dry. Once these stalks have been field-dried on the ground other sugarcane equipment with articulating claws can be used to pick up the kenaf stalks and place then in sugarcane wagons. This type of system can be used to harvest both live and dead kenaf stalks. If the kenaf stalks are already dry at harvest, the harvesting system can be reconfigured to immediately transfer the long cut stalks to in-field wagons traveling with the harvesting equipment or existing sugarcane harvesters could be adapted to cut the kenaf stalks in smaller segments (e.g. 30-cm segments) prior to transferring them to in-field collection wagons.

One important consideration for all harvesting and processing systems is the moisture content of the kenaf plant material. The moisture content of actively growing plants at harvest is normally about 75%. Sugarcane-type harvesters encounter an easier cutting process with growing, high moisture kenaf plants, but allowances must be made in the harvesting and processing systems for either drying the plant material or handling and storing high moisture material. If dry, dead kenaf stalks are harvested, the harvesting equipment will encounter tougher stalks with a greater likelihood that the long, twine-like, fiber strands in the bark will wrap around rotating equipment parts.

Another important consideration is the density of the kenaf plant material and the potential limitations and disadvantages that low bulk density plant material may have on storage and transportation. Drawbacks of the sugarcane-type harvesting systems include the transport and storage of the low density stalks or stalk segments. This limitation is often mentioned as requiring the growing and processing the kenaf to occur within a limited geographical location, for example within a 50 to 100 km range of the processing facility, such as a pulp mill.

Forage-type Harvesters and Baling Equipment. Forage-type harvesting and baling systems have been widely evaluated for use in kenaf production, harvesting, and processing systems. It has been demonstrated that standard forage cutting (Fig. 1), chopping (Fig. 2), and baling equipment can be used for harvesting kenaf as either a forage or fiber crop (Webber and Bledsoe 1993). Kenaf can be baled in both small and large square bales or large round bales. In cotton growing regions, cotton modules (Fig. 3) have been used for field-side storage of chopped kenaf (Fuller and Doler 1994). Compressing of kenaf in cotton modules or baling kenaf serves to increase the bulk density of the kenaf for storage and transportation purposes.

Factors Affecting Harvesting

A dry kenaf stalk without leaves is a lightweight material with a low density, 0.31 g/cm^3. Chopped uncompressed kenaf fiber will have an even lower density of approximately 0.1g/cm^3. The low bulk density of either the individual kenaf stalk or the chopped kenaf stalk will affect management decisions concerning the economic transportation and storage of the kenaf material. Industry and the USDA have cooperated to develop methods to increase the density of the kenaf material for increased transportation and storage efficiency. Webber and Bledsoe (1993) reported that pelletizing kenaf increased the kenaf material density by approximately 390%, to 1.21 g/cm^3. They produced kenaf pellets over a range of 0.5 to 1.9 cm in diameter (Fig. 4). The same researchers successfully cubed bast fibers to a density of 0.89 g/cm^3, core fiber to a density of 1.22 g/cm^3, and whole stalk (bast and core) to a density of 0.93 g/cm^3. The kenaf cubes produced were 3 × 3 cm square with lengths ranging from 3 to 13 cm. Although these kenaf pellet and cube densities refer to average densities of the items produced rather than total bulk densities, the advantages of compressing the kenaf material would also translate into advantages in bulk transportation or storage of these materials compared to unprocessed kenaf stalks or non-compressed chopped kenaf.

It may be economically advantageous to use available commercial harvesting and processing equipment rather than investing in the development and production of kenaf-specific equipment. Appropriate harvesting, pelletizing, and cubing equipment is readily available throughout the United States.

When harvesting kenaf for fiber use, moisture content and equipment availability are important considerations. Kenaf can be harvested for fiber when it is dead, due to a killing frost or herbicides, or when it is actively growing. The dry standing kenaf can be cut and then chopped, baled, or transported as full-length stalks. If the kenaf drying and defoliation process is dependent on a killing frost, the harvest date will vary according to the environmental conditions of the area, including the time of the killing frost and the time required for the kenaf to dry. Soil type and seasonal weather may delay harvesting and drying, especially on high clay soils in areas that receive excessive rainfall during harvest. Actively growing kenaf can be cut and then allowed to dry in the field. Once dried, the kenaf can then be chopped, baled, or transported as full-length stalks. The availability of in-field harvester/separators will add to the harvesting options.

Fig. 1. Kenaf plants being cut and crimped with forage equipment at Ladonia, Texas.

Fig. 2. Frost killed kenaf being harvested with forage chopper at Lane, Oklahoma.

Fig. 3. Chopped kenaf stored in a large module field-side in Arkansas.

Fig. 4. Whole stalk kenaf compressed into small pellets (right), range pellets (center), and square cubes (left).

PROCESSING

Initial processing methods and equipment will be dependent on many factors, including the production location, equipment availability, the economic variables involved, and the available commercial markets. One of the first processing decisions is whether the whole stalk, either as an unmodified stalk or as a chopped stalk, will be separated into its bast and fiber components or left unseparated for use as a combined fiber source. For example, kenaf used in some paper products or processes can be pulped using a mixed fiber supply (unseparated bast and core), while certain processing applications involve separating the bast and core components.

Several existing commercial kenaf facilities mechanically separate the two fiber components by different methods with distinct processing efficiencies, using a range of equipment with varying rates of throughput resulting in varying degrees of fiber separation. Each separation system also has unique economic ramifications based on their integrated production, harvesting, processing, and utilization systems.

One method of fiber separation adapts unused cotton gin facilities, which are scattered throughout the southern region of the United States, to process the kenaf fibers. The modified gin equipment and facilities provide excellent machinery for separating the kenaf core material from the bast fibers, similar to the method that cotton gins process separates cottonseed from cotton fibers. Since the number of active cotton gin facilities is decreasing with the decline in cotton production, unused gin facilities are available for converting to kenaf separation facilities.

Kenaf Plant Components and Composition

The diversity and usefulness of kenaf plant components provides both a wide spectrum of potential commercial products and the necessity to understand the distinct and diverse harvesting and processing options to produce these products. It was the diversity and usefulness of this plant which lead to kenaf's domestication over 6000 years ago and the continued commercial interest today. The useful kenaf plant components include the stalks/stems, leaves, flowers, and seeds. Depending on the component under discussion it may contain such useful substances as bast and core fibers, proteins, and essential oils.

Plant Components

Research has evaluated the components of the kenaf plant and the composition of these components. Yield component research with five kenaf cultivars in Oklahoma over a two year period produced plants at harvest (161 days after planting) which averaged 26% leaves and 74% stalks by dry weight (Webber 1993b). The kenaf stalk's average composition was 35% bark and 65% woody core by weight. The bark of the kenaf stalk contains a long fiber called bast fiber, while the woody core contains short core fibers. Whole stalk kenaf (bast and core fibers) has been identified as a promising fiber source for paper pulp (Nieschlag et al. 1960; White et al. 1970). The kenaf fibers, bast, and core, can be pulped as a whole stalk or separated and pulped individually (Kaldor et al. 1990).

Whole Stalk. Whole stalk kenaf can be pulped by kraft, soda, neutral-sulfite, sulfate, mechanical, chemimechanical, thermomechanical, and chemithermomechanical processes (Clark and Wolff 1962; Bagby 1989). Whole stalk kenaf pulps have been processed into high quality bond, surface sized, coated rawstock, and newsprint papers (Clark et al. 1971; Bagby et al. 1979; Bagby 1989). Commercial presses have printed on kenaf paper using letterpress, offset, rotogravure, flexograph, and intaglio techniques (Bagby 1989). The combined (bast and core) bleached fiber yield from chemical pulping is about 46% by weight (Kaldor et al. 1990). Whole stalk kenaf can also be used in corrugated medium (Kugler 1988), in building materials such as particleboard (Fig. 5) (Webber et al. 1999a), and for reinforcement in injection molded and extruded plastics (Fig. 6) (Webber and Bledsoe 1993).

Bast Fiber Pulping and Alternative Uses. When the bark material was chemically pulped separately, it produced a 57% yield of bast fiber (Karlgren et al. 1991). On a whole-stalk dry weight basis, the bark comprises 17.4% to 28.6% (Karlgren et al. 1991; Nieschlag et al. 1961). Bast fibers are up to 5.0 mm long (Clark and Wolff 1965) averaging 2.6 mm in length and 20 m in width (Nieschlag et al. 1961). Chemical bast pulp is well-suited for specialty papers. Compared to softwood pulp, bast pulp has a similar tensile strength, but greater tear strength and bulk fiber; thus it could serve as a replacement for softwood pulp (Kaldor et al.

1990). Pulping kenaf fibers (bast and core) can benefit the environment because the process requires fewer chemicals and less energy compared to standard pulping processes for wood fibers (Nelson et al. 1962). The kenaf fibers can also serve as a virgin fiber for increasing recycled paper quality and paper strength.

The kenaf bast fiber can be used as a domestic supply of cordage fiber in the manufacture of rope, twine, carpet backing, and burlap (Wilson et al. 1965). Additional potential uses in manufactured products include automobile dashboards, carpet padding, corrugated medium (Kugler 1988), as a "substitute for fiberglass and other synthetic fibers" (Scott and Taylor 1988), textiles (Ramaswamy and Boyd 1994), and as fibers for injected molded and extruded plastics (Webber and Bledsoe 1993). Kenaf bast fibers are presently in commercial use in other environmental friendly products such as fiber lawn mats impregnated with grass seed, and spray-on soil mulches to prevent soil erosion from water and wind along highway rights-of-way or at construction sites.

Core Fiber Pulping and Alternative Uses. Chemical pulping of the woody core will yield about 41% core fiber from the original woody portion of a kenaf stalk (Karlgren et al. 1991). The core fibers make up from 20% to 40% of the entire stalk by weight (Nieschlag et al. 1961). The average length of the core fibers ranges from 0.49 to 0.78 mm (Nieschlag et al. 1961; Adamson and Bagby 1975; Kaldor et al. 1990) with a mean length of 0.6 mm and an average diameter of 37.4 m (Nieschlag et al. 1961). Compared to hardwood pulps, core pulp has a lower tear strength but greater tensile and burst strength (Kaldor et al. 1990).

Due to the high absorbency of the core material, researchers have investigated the use of kenaf as an absorbent (Goforth 1994), as a poultry litter and animal bedding (Tilmon et al. 1988), as a bulking agent for sewage sludge composting (Webber 1994), and as a potting soil amendment (Laiche and Newman 1994; Webber et al. 1999b). In addition to the above core products, which are all now available in the market place, several kenaf core products have been successfully used for toxic waste cleanup, including oil spills on water, and the remediation of chemically contaminated soils.

Livestock Feed. Although kenaf is usually considered a fiber crop, the entire kenaf plant, stalk (core and bark) and leaves, can be used as a livestock feed. Research indicates that it has high protein content (Clark and Wolff 1969; Killinger 1969). Crude protein in kenaf leaves ranged from 14% to 34% (Killinger 1969; Suriyajantratong et al. 1973; Swingle et al. 1978; Webber 1993a), stalk crude protein ranged from 2 to 12% (Swingle et al. 1978; Webber 1993a), and whole-plant crude protein ranged from 6% to 23% (Killinger 1969; Swingle et al. 1978; Webber 1993a). Kenaf can be ensilaged effectively, and it has satisfactory digestibility with a high percentage of digestible protein (Wing 1967). Digestibility of dry matter and crude proteins in kenaf feeds ranged from 53% to 58% and 59% to 71%, respectively (Wing 1967; Suriyajantratong et al. 1973; Swingle et al. 1978). Kenaf meal, used as a supplement in a rice ration for sheep, compared favorably with a ration containing alfalfa meal (Suriyajantratong et al. 1973). It has also been determined that chopped kenaf

Fig. 5. Different types of building materials containing whole-stalk kenaf.

Fig. 6. Different plastic and resin products containing kenaf fibers.

(29% dry matter, 15.5% crude protein, and 25% acid detergent fiber) is a suitable feed source for Spanish (meat-type) goats (Wildeus et al. 1995).

SUMMARY

The diversity of kenaf's useful plant components is paralleled by even a greater diversity of harvesting and processing systems that can produce an increasing number of potential commercial products. Understanding the crop's composition and the desired end products is key to selecting the optimum harvest and processing system. Sufficient technology and equipment is already available or easily adapted for use with kenaf. Using existing equipment, which is also utilized with other local cropping systems, can be economically advantageous by spreading the capital expanse over a greater number of crops and uses. Increased kenaf commercialization does not seem to be limited by either agronomic production or the availability of suitable harvesting and processing systems, but understanding the harvesting and production systems in relationship to kenaf production and products will enhance the management of this crop as it continues to compete in the marketplace.

REFERENCES

Adamson, W.C. and M.O. Bagby. 1975. Woody core fiber length, cellulose percentage, and yield components of kenaf. Agron. J. 67:57–59.

Bagby, M.O. 1989. Kenaf: The papermaking fiber. Proc. Assn. Adv. Ind. Crops. Peoria. IL. p. 1.

Bagby, M.O., R.L. Cunningham, F.G. Touzinsky, G.E. Hamerstrand, E.L. Curtis, and B.T. Hofreiter. 1979. Kenaf thermomechanical pulp in newsprint. TAPPI/NPFP Committee Prog. Rpt. 10. Atlanta, GA.

Chen, L., E.P. Columbus, J.W. Pote, M.J. Fuller, and J.G. Black. 1995. Kenaf bast and core separation. Proc. Int. Kenaf Assoc. Conf. Irving, TX. 7:15–23.

Clark, T.F., R.L. Cunningham, and I.A. Wolff. 1971. A search for new fiber crops. TAPPI 54:63–65.

Clark, T.F. and I.A. Wolff. 1962. A search for new fiber crops, VI. Kenaf and wood pulp blends. TAPPI 45:786–789.

Clark, T.F. and I.A. Wolff. 1965. A search for new fiber crops, VIII. Sulfate pulping of kenaf (*Hibiscus cannabinus*). TAPPI 48:381–384.

Clark, T.F. and I.A. Wolff. 1969. A search for new fiber crops, XI. Compositional characteristics of Illinois kenaf at several population densities and maturities. TAPPI 52:211–216.

Dempsey, J.M. 1975. Fiber crops. The Univ. Presses of Florida, Gainesville.

Fuller, M.J. and J.C. Doler. 1994. An economic analysis of kenaf separation. p. 21–22. In: C.E. Goforth, and M.J. Fuller (eds.), A summary of kenaf production and product development research. Mississippi State Univ. Bul. 1011.

Goforth, C.E. 1994. The evaluation of kenaf as an oil sorbent. p. 25. In: C.E. Goforth, and M.J. Fuller (eds.), A summary of kenaf production and product development research. Mississippi State Univ. Bul. 1011.

Kaldor, A.F., C. Karlgren, and H. Verwest. 1990. Kenaf—a fast growing fiber source for papermaking. TAPPI 73:(11)205–208.

Karlgren, C., H. Verwest, and A. Kaldor. 1991. Kenaf—a fast growing fiber source for papermaking. TAPPI Nonwood Plant Fiber Pulping Prog. Rpt. 19:159–172.

Killinger, G.B. 1969. Kenaf (*Hibiscus cannabinus* L.), a multi-use crop. Agron. J. 61:734–736.

Kugler, D.E. 1988. Non-wood fiber crops: Commercialization of kenaf for newsprint. p. 289–292. In: J. Janick and J.E. Simon (eds.), Advances in new crops. Timber Press, Portland, OR.

Laiche, A.J. and S.E. Newman. 1994. Kenaf core as a container media component for woody landscape plants and greenhouse bedding plants. p. 30. In: C.E. Goforth, and M.J. Fuller (eds.), A summary of kenaf production and product development research. Mississippi State Univ. Bul. 1011.

Nelson, G.H., H.J. Nieschlag, and I.A. Wolff. 1962. A search for new fiber crops, V. Pulping studies on kenaf. TAPPI 45:780–786.

Nieschlag, H.J., G.H. Nelson, and I.A. Wolff. 1961. A search for new fiber crops, VI. Kenaf composition. TAPPI 44:515–516.

Nieschlag, H.J., G.H. Nelson, I.A. Wolff, and R.E. Perdue, Jr. 1960. A search for new fiber crops. TAPPI 43:193–201.

Ramaswamy, G.N. 1999. Processing kenaf bast fibers: Chemical retting. p. 91–96. In: T. Sellers Jr., N.A. Reichert, E.P. Columbus, M.J. Fuller, and K. Williams (eds.), Kenaf properties, processing, and products. Mississippi State Univ., Mississippi State.

Ramaswamy, G.N. and C.R. Boyd. 1994. Kenaf as a textile fiber: Processing, fiber quality, and product development. p. 31–33. In: C.E. Goforth, and M.J. Fuller (eds.), A summary of kenaf production and product development research. Mississippi State Univ. Bul. 1011.

Scott, A.W. Jr. and C.S. Taylor. 1988. Economics of kenaf production in the lower Rio Grande Valley of Texas. p. 292–297. In: J. Janick and J.E. Simon (eds.), Advances in new crops. Timber Press, Portland, OR.

Suriyajantratong, W., R.E. Tucker, R.E. Sigafus, and G.E. Mitchell Jr. 1973. Kenaf and rice straw for sheep. J. Anim. Sci. 37:1251–1254.

Swingle, R.S., A.R. Urias, J.C. Doyle, and R.L. Voigt. 1978. Chemical composition of kenaf forage and its digestibility by lambs and in vitro. J. Anim. Sci. 46:1346–1350.

Tilmon, H.D., R. Taylor, and G. Malone. 1988. Kenaf: An alternative crop for Delaware. p. 301–302. In: J. Janick and J.E. Simon (eds.), Advances in new crops. Timber Press, Portland, OR.

Webber, C.L. III. 1993a. Crude protein and yield components of six kenaf cultivars as affected by crop maturity. Ind. Crops Prod. J. 2:27–31.

Webber, C.L. III. 1993b. Yield components of five kenaf cultivars. Agron. J. 85:533–535.

Webber, C.L. III. 1994. Kenaf (*Hibiscus cannabinus* L.) yield components as affected by sewage sludge applications. Nonwood Plant Fibers. Prog. Rpt. 21:19–24.

Webber, C.L. III and R.E. Bledsoe. 1993. Kenaf: Production, harvesting, and products. p. 416–421. In: J. Janick and J.E. Simon (eds.), New crops. Wiley, New York.

Webber, C.L. III, C.D. Ray, R.E. Bledsoe, and J.L. Blalock. 1999a. Production properties of industrial-grade kenaf particleboard. p. 360–365. In: T. Sellers, N.A. Reichert, E.P. Columbus, M.J. Fuller, and K. Williams (eds.), Kenaf properties, processing, and products. Mississippi State Univ., Mississippi State.

Webber, C.L. III., J. Whitworth, and J. Dole. 1999b. Kenaf (*Hibiscus cannabinus* L.) core as a containerized growth medium component. Ind. Crops Prod. J. 10:97–105.

White, G.A., D.G. Cummins, E.L. Whiteley, W.T. Fike, J.K. Greig, J.A. Martin, G.B. Killinger, J.J. Higgins, and T.F. Clark. 1970. Cultural and harvesting methods for kenaf. USDA Prod. Res. Rpt. 113. Washington, DC.

Wildeus, S., H.L. Bhardwaj, M. Rangappa, and C.L. Webber III. 1995. Consumption of chopped kenaf by Spanish goats. Proc. Int. Kenaf Assoc. Conf. Irving, TX. 7:161–164.

Wilson, F.D., T.E. Summers, J.F. Joyner, D.W. Fishler, and C.C. Seale. 1965. 'Everglades 41' and 'Everglades 71', two new varieties of kenaf (*Hibiscus cannabinus* L.) for the fiber and seed. Florida Agr. Expt. Sta. Cir. S-168.

Wing, J.M. 1967. Ensilability, acceptability and digestibility of kenaf. Feedstuffs 39:26.