Straw and Kenaf Make Inroads in Building Materials and Paper

In the United States, composite building materials are being made from straw. Straw bales are being used in the construction of buildings. Researchers are investigating straw as a raw material for paper. Uses of kenaf continue to expand. Numerous companies are producing and selling kenaf-based products.

Straw is the stalk of the plant that remains after the harvest of grains, such as wheat and rice. Most straw is incorporated back into the soil, used for animal bedding, or burned in the field. However, concern about straw burning and high wood prices has prompted interest in alternative uses of straw. Technological improvements in baling, collecting, and transporting straw during the last few decades also have made off-farm uses more economical. For example, modern balers can produce various-sized bales, with the larger sizes weighing up to a ton. A few companies in the United States have begun using straw to make composite building materials. Straw bales also are being used directly in the construction of homes and other structures as walls and insulation. Its use in paper is being investigated in the United States by government and private researchers.

Straw Is Produced in Many U.S. Regions

Numerous types of straw are available throughout the United States as residues of grain production. Most is wheat and rice, but barley, oats, rye, and grass straws also are found in some areas of the country. The amount of straw available for off-farm uses varies. How much can be removed from a field depends on the soil type and field topography. In many instances, some straw must be incorporated back into the soil to maintain soil quality and reduce wind and water erosion. Also, farmers may use some or all of their straw on-farm for livestock bedding or other uses.

Data on straw production or the amount used off-farm are not available. However, researchers have developed techniques to estimate crop residue production, including straw, and, in some instances, the percentage that can be harvested without harming soil productivity. For example, about 78.5 million tons of wheat and rice were produced on average during 1990-96 in the United States (table 5). About 123 million tons of straw was produced annually as a byproduct during the same period. North Dakota, Kansas, Oklahoma, and Washington were the leading wheat growing states, while Arkansas and California were top in rice production. In these and other major growing areas, an estimated 51 million tons out of the 101 million tons of straw produced annually could have been harvested without lasting damage to the soil. These estimates do not take into account on-farm uses, nor whether local production was concentrated enough to make straw collection and transportation feasible.

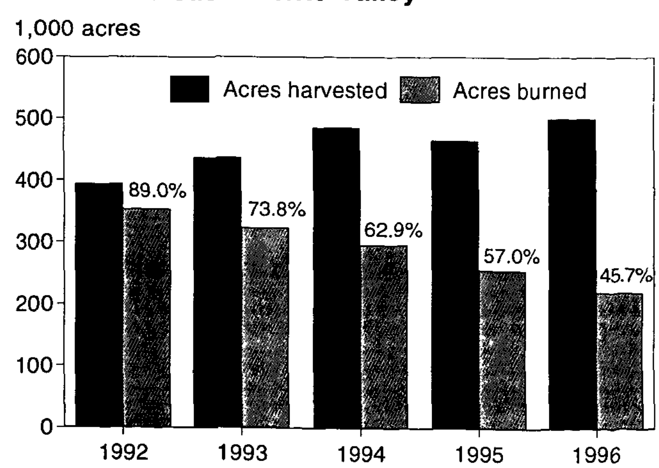
Because straw is bulky, the distance to which straw bales can be economically transported is limited. Companies using straw as a manufacturing input must decide on plant location, collection methods, and type and location of storage facilities, among other business decisions.

In California, finding off-farm uses for rice straw is becoming more important as the mandated phasedown in agricultural burning in the Sacramento Valley continues. Burning has been the standard method for clearing rice fields and disposing of the straw. However, public complaints about the effects of burning on visibility and air quality led to the passage of the Rice Straw Burning Reduction Act of 1991. The law phases down the yearly amount of rice straw that can be burned in the Sacramento Valley Air Basin from 90 percent of planted rice acreage in 1992 to 25 percent in 1998-99. In 1996, farmers burned 45.7 percent of their rice acreage (figure 6), slightly below the 50-percent level mandated by the act. To foster off-farm uses, the California Legislature passed a law in 1996 authorizing a yearly tax credit of up to $400,000 for 11 years for firms using rice straw. Businesses can claim a $15-credit for every ton of rice straw used in products and services.

In 1991, legislators in Oregon also passed a law phasing down field burning of grass-seed and cereal-grain straw in the Willamette Valley from 180,000 acres in 1991 to 40,000

Figure 6

Rice Acreage Harvested and Burned in California's Sacramento Valley



Source: California Rice Industry Association.

Table 5--Estimated availability of wheat and rice straw in leading U.S. production areas

Commodity and state	Average annual production, 1990-96	Grain-to-residue ratio 1/	Estimated crop residue 2/	Harvestable fraction 3/	Estimated availability
	1,000 tons		1,000 tons	Percent	1,000 tons
Winter wheat					
Kansas	10,903	1:1.7	18,535	43	7,970
Oklahoma	4,301	1:1.7	7,312	51	3,729
Washington	3,700	1:1.7	6,290	50	3,145
Texas	2,912	1:1.7	4,950	33	1,634
Colorado	2,446	1:1.7	4,158	13	541
Montana	2,285	1:1.7	3,885	20	777
Nebraska	2,168	1:1.7	3,686	34	1,253
Ohio	1,896	1:1.7	3,223	50	1,612
Illinois	1,832	1:1.7	3,114	50	1,557
Idaho	1,816	1:1.7	3,087	50	1,544
Missouri	1,676	1:1.7	2,849	50	1,425
South Dakota	1,481	1:1.7	2,518	26	655
Arkansas	1,295	1:1.7	2,202	50	1,101
Indiana	1,060	1:1.7	1,802	50	901
U.S. total	49,086	1:1.7	83,446	--	--
Spring wheat 4/					
North Dakota	10,745	1:1.3	13,969	73	10,197
Montana	3,094	1:1.3	4,022	21	845
Minnesota	2,699	1:1.3	3,509	50	1,754
South Dakota	1,789	1:1.3	2,326	36	837
U.S. total	20,930	1:1.3	27,209	--	--
Rice 5/					
Arkansas	3,505	1:1.5	5,258	100	5,258
California	1,746	1:1.5	2,619	100	2,619
Louisiana	1,327	1:1.5	1,991	100	1,991
U.S. total	8,530	1:1.5	12,795	--	--
Total	78,546	--	123,450	--	51,342

-- = Not applicable. 1/ Estimated amount of residue per unit of grain production. For example, production of 1 ton of winter wheat results in 1.7 tons of residue. Source: W.E. Larson, R.F. Holt, and C.W. Carlson, "Residues for Soil Conservation," Crop Residue Management Systems, American Society of Agronomy, Madison, WI, 1978, pp. 1-15. 2/ Grain production multiplied by the appropriate ratio. 3/ Proportion of crop residues that can be removed without significant soil damage from wind and water erosion. For wheat in the Great Plains, the rates are from W.G. Heid, Jr., Turning Great Plains Crop Residues and Other Products into Energy, AER-523, USDA, ERS, 1984. For wheat in other states, the rate is assumed to be 50 percent. For rice, 100 percent removal is assumed. 4/ Includes durum wheat. 5/ 1,000 short tons, rough basis.

acres in 1998 and thereafter. The law also authorizes state funds and burning fees be used for research and development to find alternative methods of field sanitization and uses of straw.

Companies Are Making Composite Panels From Straw

A process for producing compressed straw panels was invented in the 1930's and was used to a limited extent in Europe, Canada, and Australia in the intervening decades. Only in the last couple of years have companies in the United States started manufacturing structural and nonstructural panels and composite products made from straw. For example, Agriboard Industries, based in Fairfield, Iowa, and Coppell, Texas, began producing compressed straw panels in February 1997 at its Electra, Texas, manufacturing facility. Farmers bale straw into 1,000-pound bales, which are shipped to the factory and stored for use. The company estimates that it will initially use about 13,000 tons of straw annually and at full capacity, up to 40,000 tons per year.

A 240-foot long linear extrusion mill separates wheat or rice straw into loose strands, compresses it under intense heat, and fuses it into 3½-inch thick strawboard. No chemical binders are added. Straw fibers, when compressed under high temperatures, bond together without any adhesive. For structural applications, the strawboard is then laminated between oriented-strand board to form a stress-skin panel. Stress-skin-panel building systems, usually made with synthetic extruded polystyrene foam or paper as the core material, have become popular in applications where their high insulative properties are desired. Agriboard's panels have undergone testing by the National Association of Homebuilders Research Foundation and other testing agencies to demonstrate their fire resistance, acoustical properties, and structural and thermal performance. The company is supplying panels for several construction projects across the country, including a large retail store in Chicago, Illinois, and 200- and 300-unit apartment complexes in Austin, Texas. The company plans to open plants in California and Ohio within the next 18 months.

Other straw panel manufacturers are due to come on line in 1997. BioFab, LLC, of Redding, California, is now marketing imported prototype strawboard panels, and is planning a full-scale production facility to come on line this fall in California's Sacramento Valley. The panels are formed through an extrusion process under heat and pressure, using 100-percent rice straw and no chemical additives. The company offers two products for interior and nonload-bearing applications:

- A decorative acoustical ceiling/wall panel, which looks like a thatched ceiling, and
- A nonstructural panel covered with recycled-content linerboard, which is sold as a replacement for gypsum-board drywall and wood studs.

Pierce International of Englewood, Colorado, and Stramtech of Rupert, Idaho, are planning to open a production facility in Rupert this fall. Construction is underway. A similar facility in Virginia's eastern shore is scheduled to open in the fall of 1998. Once in operation, these plants will compress straw under heat and pressure in an extrusion process to produce straw panels. Plants in Europe and Australia have been using the same technology to manufacture straw panels since the late 1940's. The panels will be used for interior and nonload-bearing walls and partitions.

Cereal straws are also being used for the production of particleboard and plywood substitutes. For instance, PrimeBoard, Inc., is making an industrial-grade particleboard from wheat straw at its new $15-million plant in Wahpeton, North Dakota, which opened in August 1995. The particleboard is made from wheat straw and a formaldehyde-free binder made from methylene diphenyl diisocyanate (MDI). The absence of urea formaldehyde, a common substance in wood particleboard, is seen as a plus because formaldehyde-containing adhesives give off toxic fumes. PrimeBoard's composite panel has been independently tested and mill certified to meet or exceed all specifications for industrial-grade particleboard and can be used in the same applications as wood particleboard. One of PrimeBoard's primary customers is PrimeWood, Inc., a kitchen cabinet/furniture/architectural millwork component manufacturer also located in Wahpeton. A major impetus for forming PrimeBoard came from PrimeWood's concern about long-term supplies of wood for building materials.

Naturall Fibre Boards, LC, of Minneapolis, Kansas, began manufacturing strawboard on a limited scale in June 1995. The equipment chops up the straw, mixes it with a MDI resin, and presses it into panels. A new press is on order for delivery in 1998 that will increase production eight-fold. The panels are being marketed as floor underlay (a material that is often under carpeting, vinyl flooring, and other floor coverings). According to the company, the panels meet the requirements for fiberboard and particleboard underlay and comply with all building codes.

Eleven farmer cooperatives in central Kansas formed CenKan Enterprises to produce straw-based particleboard. The manufacturing facility in Hutchinson, Kansas, is scheduled to come on line this summer. The production system was purchased from a British firm, which is marketing the technology worldwide. As with similar systems, chopped straw is mixed with a MDI binder and pressed into panels. CenKan has signed a 5-year contract with a Canadian-based distributor to market the straw-based particleboard in ready-to-assemble furniture applications in the United States. These companies are just a few examples of the firms that are using straw or are planning straw-based enterprises in the near future.

According to an analysis of alternative construction materials made from cellulosic wastes (straw, urban wood waste, and recycled paper) by the Institute for Local Self-Reliance, the short-term acceptance of alternative building systems or products depends not only on customer acceptance but also on whether the systems comply with building codes. Construction products made from cellulosic sources will likely have the most success when used with pre-existing construction techniques (8).

Straw Bales Are Used Directly in Construction

In addition to using straw to manufacture building materials, straw bales are being used directly in construction. The bales are used to make the walls of houses, garages, storage sheds, and other structures. Two types of smaller bales are used:

- Two-string bales, which are roughly 35-40 inches long, 18 inches wide, and 14 inches high and tied together with two pieces of polypropylene twine, or
- Three-string bales, which are usually 32-47 inches long, 23-24 inches wide, and 14-17 inches high and tied together with three pieces of polypropylene twine.

Any type of straw can be used. Bale size, density, and the number of strings will vary with the type of straw and the type of baler used.

Bale walls can be built on top of any type of foundation, and can be load-bearing or used as infill with post-and-beam construction. If the walls are load-bearing, which means they are the structural support for the roof, the bales are stacked in staggered courses like big bricks, then rebar (steel reinforcement bars used in concrete structures), bamboo, or wooden dowels are driven down through the bales for vertical reinforcement. Load-bearing structures are usually one-story, square, or rectangular buildings.

With post-and-beam construction, a wood, metal, or masonry structural frame supports the roof, and bales are stacked in between the posts to make the walls. Post-and-beam construction offers greater flexibility than load-bearing designs, allowing for a wider variety of floor plans, roof designs, and building heights. Hybrid systems, with some load-bearing walls and some post and beam, also exist. As one of the final steps in construction, the walls are covered with some sort of finish. Commonly, stucco is applied to the exterior and plaster to the interior, although various other wall finishes have been used.

In the United States, building with bales can be traced to the Sand Hills of Nebraska around the turn of the century. Few trees were available for timber, and the soil was too sandy for sod homes. The advent of baling equipment allowed settlers to use prairie hay as a building material. From about 1890 to 1935, bales were used to build load-bearing homes, farm buildings, churches, schools, offices, and grocery stores.

Recent interest in straw bale construction began in the late 1970's after an article by a Nebraska historian on the bale homes in that state was published in 1974. Using straw bales appeals to future home owners, architects, and builders who are concerned about the impact of traditional building systems on the world's resources. They view straw as an abundant renewable resource. In the southwestern United States, straw bales also were found to be a cheap substitute for labor-intensive double-wall adobe.

One facet of straw bale building often mentioned in the popular press is its affordability. However, walls typically represent only 15 to 20 percent of the overall cost of most houses, and building costs can vary depending on the climate, the characteristics of the site, building-code and permit requirements, and labor and raw-material costs. Using salvaged materials and labor donated by the owner/builder, friends, relatives, and straw bale workshop participants are frequently mentioned as ways owner/builders can reduce construction costs. Structures built by architects and contractors are only marginally less expensive than conventional construction, given that labor accounts for 60 percent of the cost of a contracted home (6). Nevertheless, lower energy and maintenance costs over the life of the structure are often cited as a benefit of straw bale buildings.

Straw Bale Buildings Can Be Found In Many Locations

All types of buildings have been erected with straw—homes, cabins, storage sheds, barns, and other out buildings. Initially, most structures were built in rural areas, where complying with building codes was not a problem. The first straw bale house to have a building permit was constructed in Tesuque, New Mexico, in 1991. This post-and-beam structure was considered a breakthrough by the industry, as it was the first permitted, contractor-built, bank-financed, straw bale house in the United States (4).

The first load-bearing house to receive a building permit was constructed in Tucson, Arizona, in 1993. Approval was made possible as the result of structural tests conducted at the University of Arizona, in cooperation with city and county building officials (5). Since then, load-bearing houses have been approved in other Arizona jurisdictions, California, Colorado, Florida, Maine, Oregon, and Washington State. An estimated 20 states have straw bale structures built with building permits and another 23 have straw bale buildings erected since 1940 (figure 7).

Applying for and receiving building permits is a local process. Unlike Canada and most European countries, the United States does not have a national building code. Building codes are usually adopted as municipal or county ordinances or by state legislatures in the case of statewide codes. These codes often are based on one of three model building codes:

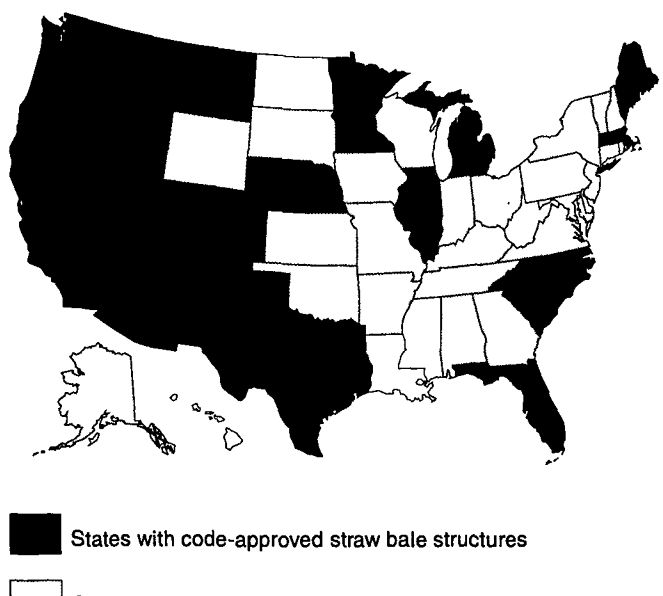
- the Uniform Building Code, which is common west of the Mississippi River,
- the Basic Building Code, which is used primarily in the Northeast and Midwest, and
- the Standard Building Code, which is usually found in the Southeast (3).

All three model codes contain sections that address the use of alternative building materials, such as straw bale, adobe, and rammed earth. Building officials may approve any such alternative, provided that the proposed design of the structure is satisfactory and complies with the provisions of the local code and that the material is, for the purpose intended, at least equivalent to that prescribed in the code in terms of suitability, strength, effectiveness, fire resistance, durability, safety, and sanitation (3).

A few jurisdictions have approved building codes specifically for straw bale construction. In January 1996, New Mexico adopted the post-and-beam code that the state had

Figure 7

Estimated Locations of Straw Bale Structures



States with code-approved straw bale structures

Other states with straw bale structures

been using as guidelines to issue building permits. Also, in January 1996, the City of Tucson and Pima County, Arizona, adopted standards for load-bearing and nonload-bearing straw bale construction.

In the fall of 1995, the California legislature enacted a bill, which became effective January 1, 1996, that amends the state building standards law to establish safety guidelines for the construction of structures that use baled rice straw as a load-bearing or nonload-bearing material. California cities and counties must adopt the guidelines for them to become part of local building codes. Individual jurisdictions may modify the guidelines as deemed necessary. Several counties, including Glenn, Napa, Trinity, and Yolo, have adopted the straw bale guidelines as part of their building codes. Also in 1995, a law was passed in Nevada specifying that local jurisdictions amend their building codes to permit the use of straw and other materials that are renewable or conserve scarce natural resources.

Bale Wall Systems Have Various Attributes

One of the most often cited benefits of building with straw bales is the increased insulation the thick bales provide. Results of two studies conducted in 1993 and 1994 indicate that straw bales have an average R-value (resistance to heat flow) of 2.5 to 3 per inch, compared with 1 for wood, 0.2 for brick, and 3 for fiberglass batts. Thus, depending on the thickness of the bale, R-values can range from 35 to 55. Plaster, stucco, or other finishes also can add to the R-value of completed walls.

While loose straw burns, once it is packed into bales it is remarkably fire resistant. The dense bales limit the oxygen available for combustion. Fire-resistance tests were conducted in December 1993 for New Mexico on test straw bale walls. A 1994 report from the New Mexico State Construction Industries Division on straw bale construction states that the results of the fire-resistance tests demonstrate that a straw bale infill wall assembly is a far greater fire-resistive assembly than a wood frame wall assembly using the same finishes.

Moisture is a concern with straw bale buildings as it is with wood structures. Fungus (dry rot) can occur in straw at humidity levels above 20 percent of the dry weight. However, for significant damage to occur, these humidity levels must be maintained over a period of time. To keep obvious sources of moisture at bay, those familiar with straw bale construction recommend that the bales be elevated above the surrounding soil and a moisture barrier used in areas subject to direct wetting. Historical experience suggests that the best way to avoid sustained high-moisture concentrations is to permit finished bales to transpire any accumulated moisture back into the environment. Common finishes, like lime and adobe plaster and cement stucco, do allow vapor transmission.

More Testing Needed on Straw Bale Construction

For straw bale construction to become more widely accepted, particularly by building code officials, more research and testing is needed on topics such as building methods and parameters and long-term durability in various climates. Some testing has been done in the last few years. For example, structural and thermal tests have been performed in Tucson, Arizona, and fire, wind-loading, and compression tests have been conducted by a certified laboratory in Sante Fe, New Mexico.

In addition, during the early 1990's, the Navajo Nation, in cooperation with the U.S. Department of Energy (DOE) and U.S. Department of Housing and Urban Development, initiated a search for more energy-efficient, affordable housing that could be built on the reservation with local materials and would fit the Navajo lifestyle. The result was a demonstration home, using a combination of adobe walls and load-bearing straw bale walls, constructed near Ganado, Arizona. On behalf of DOE, Lawrence Berkeley Laboratory analyzed the thermal characteristics of the various wall materials and projected energy savings for the prototype home. In its final report, the laboratory concluded that straw bale building offered the best energy performance of any of the new construction types being considered, with a 15-percent improvement in overall building energy efficiency in heating for the climates on the Navajo reservation.

In 1995, the City of Tucson's Community Services Department was awarded a $73,000 grant to measure and evaluate the affordability and energy efficiency of straw bale housing and site/resource utilization. The funding came from DOE and was administered by the Urban Consortium Energy Task Force. In 1996, Habitat for Humanity Tucson and the Tucson Urban League, in conjunction with the city, each built a straw bale house on city-owned land. The buildings were designed for low-energy and resource use and will be monitored for energy use for a minimum of 1 year. The structures, now private homes, are open to the public on a limited basis for 1 year for educational and informational purposes. The information gathered during construction and monitoring of the two houses will be documented and analyzed to determine costs and energy and resource savings.

The nonprofit Aprovecho Research Center of Cottage Grove, Oregon, will soon complete a 2-story straw bale dormitory. The post-and-beam structure complies with Lane County Building Codes and has 350 rye grass straw bales as infill. Part of the funding for the project came from the Oregon Department of Agriculture for construction of a straw-bale home that could be studied for practicality and durability. A portion of the money, from a state fund for finding alternatives to burning straw on Willamette Valley grass-seed fields, goes to the university for monitoring the dormitory with moisture-detecting sensors imbedded in the walls.

Other Countries Are Using Straw For Paper And Paperboard

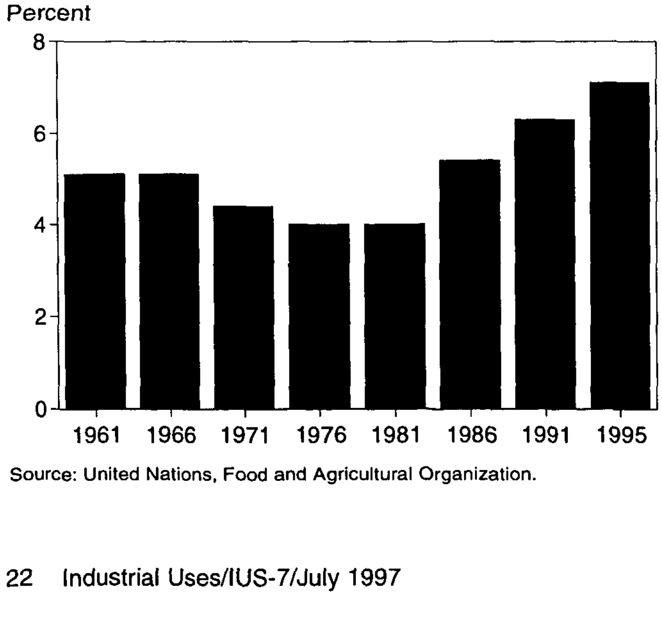
During the 1800's, straw was widely used in the United States and other countries to make paper and paperboard, but the advent of wood pulping technology in the mid-1800's displaced straw from many paper grades. Straw pulping for paperboard continued to expand and peaked in the 1940's. During the next couple of decades, demand for paperboard increased substantially as corrugated cardboard boxes began to displace wooden crates as packing and shipping containers. However, declining economic returns caused many paperboard manufacturers to switch from straw to hardwoods and waste paper. The last U.S. mills stopped using straw in the 1960's.

Nevertheless, cereal straws and other nonwood fibers continue to be important in many countries where supplies of pulpwood are limited. In developing countries, many of which are located in areas with limited forest resources, nonwood fibers accounted for about 35 percent of the raw materials used for pulp production during the 1990's. In contrast, during the 1990's, nonwood fibers made up less than 0.5 percent of pulp production in developed countries, which often have greater forest resources. In 1995, nonwood fibers accounted for 7 percent of total world pulp production, up from roughly 4 percent in the 1970's and early 1980's (figure 8).

Straw, sugar cane bagasse, and bamboo are the leading nonwood fibers countries use for general paper production (table 6). Other nonwood fibers, such as abaca and sisal, have unique characteristics and are used in specialty applications. China and India are major producers of nonwood fibers (table 7). As for straw, China accounted for 88 percent of straw pulp capacity in 1993, with another 22 countries holding the remainder (2).

Figure 8

Nonwood Pulp as a Share of Total World Pulp Production



Source: United Nations, Food and Agricultural Organization.

For straw to again become a raw material for paper and paperboard in the United States, industry experts cite a number of issues that must be addressed:

- Certainty of supply over the long run at a competitive price. For an industry accustomed to using trees, relying on a byproduct of annual grain production raises concerns about availability and price.
- Raw material bulkiness. Straw is bulky, which means collection, transportation, and storage costs will be higher than for wood over similar distances. Pulping procedures also must be adjusted to account for straw's bulkiness.

Table 6—World nonwood-pulp production capacity, by type of raw material

Raw material	Pulp production capacity 1985	1990	1993
	1,000 metric tons		
Straw	6,166	6,787	9,566
Sugar cane bagasse	2,339	2,739	2,984
Bamboo	1,545	987	1,316
Other	3,302	5,049	6,870
Total	13,352	15,562	20,736

Source: Joseph Atchison, "Present Status and Future Prospects for Use of Non-Wood Plant Fibers for Paper Grade Pulps," paper presented at the AF&PA 1994 Pulp and Fiber Fall Seminar, Tucson, AZ, November 14-16, 1994.

Table 7—World production of nonwood pulps, selected years 1/

Country	1961	1971	1981	1991	1995
	1,000 metric tons				
China	1,640.0	2,270.0	3,466.0	12,232.0	17,551.0
India	290.0	660.0	457.0	1,009.0	920.0
United States	400.0	580.0	670.0	240.0	240.0
Pakistan	21.0	42.0	56.0	159.0	160.0
Colombia	16.6	70.0	88.0	101.0	142.0
Thailand	2.6	22.0	37.0	148.0	134.0
Italy	53.6	400.0	215.0	97.0	130.0
Mexico	45.7	165.0	285.0	237.0	117.0
South Africa	25.0	30.0	84.0	99.0	99.0
Argentina	50.0	39.0	44.0	78.0	98.0
Brazil	25.0	56.9	122.0	125.0	75.0
Indonesia	6.0	17.0	65.0	84.0	74.0
Vietnam	0.0	7.0	5.0	69.7	74.0
Venezuela	5.4	23.0	42.0	67.0	66.0
Egypt	2.0	67.0	80.0	47.0	60.0
Cuba	23.0	36.0	31.6	52.0	52.0
North Korea	3.0	30.0	50.0	50.0	50.0
Peru	27.0	78.0	120.0	116.0	48.0
Iran	2.4	24.0	50.0	62.0	45.0
Canada	15.0	40.0	40.0	40.0	40.0
Bangladesh	0.0	20.0	50.5	33.0	38.0
Turkey	6.3	12.3	75.0	87.0	35.0
Denmark	12.6	37.0	45.0	34.0	34.0
Philippines	10.0	33.0	31.0	22.0	27.0
Algeria	23.0	16.0	31.0	21.0	21.0
Hungary	5.5	18.8	22.0	5.0	20.0
Other	1,233.3	1,164.3	841.8	690.8	132.2
World	3,944.0	5,958.3	7,103.9	16,005.5	20,482.2

1/ Includes pulp made from cereal straws, bagasse, bamboo, cotton fibers and linters, flax, abaca, jute, sisal, hemp, reeds, and grasses.

Source: United Nations, Food and Agricultural Organization.

- Extended storage. After harvest, straw must be collected and stored for year-around availability, without significant deterioration of fiber quality.
- Silica content. (Silica is a common mineral; its most familiar form is sand.) Depending on the type, straw can contain 4- to 15-percent silica, which interferes with conventional recovery of pulping chemicals.
- Pulp drainage characteristics. Straw pulp contains high amounts of short fibers (less than 1 millimeter in length) and hemicellulose, which combine to slow the drainage of water from the pulp. Fast drainage is important when using high-speed papermaking machines, which have been key in increasing industry productivity.

A few universities and other organizations are researching the feasibility of using straw for paper and paperboard. For example, Weyerhaeuser Company, Oregon State University, and the Oregon Department of Agriculture initiated a project in 1993 to investigate new technologies for processing ryegrass straw. The project has progressed to tests in a 50-tons-per-day pilot plant using a steam-explosion process. The straw pulp would be used with wood pulp to make linerboard for corrugated containers. Also, the University of Washington and Washington State University are cooperating on a project to assess pulping options for wheat straw and to select wheat varieties with improved fiber properties. The project hopes to receive a grant to assess the feasibility of a straw pulp mill in eastern Washington.

University of Minnesota researchers are working with Blandin Paper Company of Grand Rapids, Minnesota, and local wheat and barley growers to investigate the use of straw for paper. In preliminary tests, researchers found that mixing straw and wood pulps yielded the same type and quality of paper Blandin was making for glossy newspaper inserts. Up to 30 percent of straw pulp could be used without a loss in quality. The group is now planning to conduct a feasibility study of producing straw from farmer-owned mills in the upper Midwest.

One company, Arbokem of Vancouver, Canada, is already producing limited amounts of straw pulp. It's demonstration-scale pulp mill in Vulcan, Alberta, can make up to 2,000 tons of pulp per year using a proprietary potassium-based process. The company plans to build a rice straw-based pulp mill in California's Sacramento Valley. In collaboration with different paper mills, the company has produced various grades of paper for test commercial sale, principally in California. Its white photocopy paper is made from 45-percent wheat straw, 43-percent post-consumer recycled paper, and 12-percent calcium carbonate.

Kenaf Production and Products Continue To Expand

Development and commercialization of kenaf and various kenaf-based products in the United States have been ongoing since the 1940's. Research and development efforts, initiated by the U.S. Department of Agriculture (USDA) when U.S. jute imports were interrupted during World War II, received a boost in the 1950's when researchers identified kenaf as the most promising nonwood fiber for pulp and paper making. More recent USDA research and industry interest was triggered by high newsprint prices in the late 1970's.

Like jute and flax, kenaf stems consist of two distinct fibers. The outer bark of bast fibers comprises 30 to 40 percent of the total dry weight of the stalk. The inner core of short balsa-wood-like fibers accounts for the remainder.

Kenaf can be grown in many parts of the United States and the world, but it generally needs a long growing season to produce the necessary yield to make it a profitable crop. With a long growing season, like that found in the southern United States, kenaf can reach a height of 12 to 18 feet and produce 5 to 10 tons of dry fiber per acre annually. An estimated 8,000 acres of kenaf currently are being grown in the United States (1), up from roughly 4,000 acres in 1992 and 1993 (see the June and December 1993 issues of this report). Primary production areas are Texas, Mississippi, Georgia, Delaware, and Louisiana.

Numerous companies are producing and selling kenaf-based products. Kenaf International, headquartered in McAllen, Texas, has been producing kenaf since 1981 (1). The kenaf is grown in southern Texas and processed locally to separate the bast and core fibers. The fibers are used in moldable fiber mats and oil-absorbent pillows for cleaning up oil spills. The fiber mats, which are made from the bast fibers, are being used in European automobiles as interior door panels. The company also is evaluating other products that can be made from the bast and core fibers. Company President, Charles Taylor, has identified many current and potential types of kenaf-based products, including:

- Pulp, paper, and paperboard produced by wet processing;
- Fiberboard produced by dry processing using moldable fiber mats;
- Absorbing media;
- Packing materials;
- Composite products;
- Livestock forage and feed; and
- Traditional cordage uses.

In February 1997, Canadian-based Kafus Capital Corporation announced that its subsidiary, Kenaf Paper Manufacturing (KPM), had acquired an option to purchase 50 acres of land in Willacy County, Texas, on which the company plans to construct a newsprint mill (7). The facility will be the first commercial pulp mill in North America to use whole-stalk kenaf as its sole fiber source. The announcement indicated that KPM is in the final stages of concluding long-term sales agreements for its newsprint with leading newspaper publishers, primarily in Texas. Newspapers reportedly are interested in newsprint from kenaf because it has the potential to be an additional source of newsprint at a reasonable price. Long-term contracts for supplying kenaf fiber also are expected soon with Kenaf International, which is a minority owner of KPM.

The KPM plant is estimated to cost slightly over $100 million to build and will be capable of producing between 70,000 and 90,000 tons of high-quality newsprint annually. Although this plant is somewhat smaller than most conventional newsprint facilities constructed in North America during the past 10 years, the company claims it is designed to be one of the lowest cost producers of newsprint on the continent.

First Farm Fibers, a Delaware-based corporation comprised of farmers and investors, and researchers from the University of Delaware have worked with Curtis Paper Mill, a division of James River Paper, in Newark, Delaware, to produce kenaf paper, which can be bleached or unbleached, coated or uncoated. They also have collaborated with Crane Paper Company of Dalton, Massachusetts. Crane, looking for ways to expand market options, has placed an order for 10 tons of kenaf fiber to be used in its fine stationery. In 1996, First Farm Fibers contracted with farmers to produce 250 acres of kenaf in Delaware, and has 750 acres under contract this year.

Another commercial producer of kenaf paper is KP Products of Albuquerque, New Mexico. According to the company, kenaf paper is stronger, whiter, longer lasting, more resistant to yellowing, and has better ink adherence than wood-based paper. The firm has produced about 200 tons of kenaf-based paper since 1992.

Examples of other businesses that sell kenaf-based paper products and the types of items they offer include:

- Acorn Design, stationery sets;
- Dancing Kenafs, kenaf spiral journals;
- Don Mickey Designs, letterhead stationery, envelopes, and business cards;
- Eco Specialties, specialty advertising products;
- Everything Earthly, notepads, writing tablets, and envelope sets;
- Grass Roots Paper Company, soft-covered journal paper;
- Okina Sales, spiral notebooks;
- Simple Thoughts, coloring books and calendars; and
- Soundings of the Planet, cassette tape and compact disk inserts and posters.

Ankal, Inc., based in Atlanta, Georgia, also has developed technology to separate the bast and core fibers. The primary product advertised by the firm is a kenaf-core-based cat litter, which is described as biodegradable, dust free, and environmentally friendly. Other products mentioned in company literature, but not advertised for sale, include kenaf paper, building materials, pressure sensitive labels, and pelletized fiber and feed.

During the early 1990's, the Mississippi Delta Fiber Cooperative of Charleston, Mississippi, attempted to produce 2,000 to 3,000 acres of kenaf annually. However, due to various problems, much of the crop was not harvested and, in 1995, the business was taken over by Lumus Gin Company. About 1,600 acres were grown in 1996. The company hopes to produce about the same volume of kenaf this year on less, but more productive, land.

Kenaf Research Also Continues

While significant progress has been made on commercialization of kenaf, much research and development remains to be accomplished before kenaf becomes a major U.S. crop. The largest and most comprehensive U.S. research effort on kenaf is located at Mississippi State University (MSU). MSU has had over 20 scientists from more than 15 disciplines evaluating various aspects of kenaf, including product development. Much of the financial support was Federal funding provided through USDA's Agricultural Research Service, but this funding is being phased out in 1997. The types of research MSU staff have been conducting include:

- Varietal selection and breeding;
- Evaluating planting date, row spacing, plant density, and other yield determinants;
- Production practices;
- Control of nematodes and other kenaf pests;
- Fertility;
- Weed control;
- Plant desiccation for harvest;
- In-field separation of fibers;
- Economic analysis of fiber separation;
- Using kenaf as bedding for horses, broilers, and laboratory animals;
- Evaluating kenaf as an oil sorbent;
- Kenaf core as a bioremediation enhancer, a feedstock for composite materials, and a component in landscape and greenhouse bedding media; and
- Use as a textile fiber, including processing, fiber characteristics, and product development.

University of Delaware researchers have been evaluating kenaf as an alternative crop for their area. Farmers like to use kenaf in rotation with soybeans because it helps to break the life cycle of the soybean cyst nematode. In addition to on-going kenaf production research, scientists are conducting product development work such as using kenaf fibers in composite materials and kenaf core in cat litter, animal bedding, and as a growing medium for plants. [Straw: Lewrene Glaser, ERS, (202) 219-0091, lkglaser@econ.ag.gov. Kenaf: Donald Van Dyne, University of Missouri, (573) 882-0141, ssvandyn@muccmail.missouri.edu]

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