

PAPER FROM AGRICULTURAL RESIDUES

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Paper from Agricultural Residues

Summary

Crop residues have been used as a source of papermaking fiber for centuries and were extensively used for this purpose within the United States for several decades following the onset of World War II. Today, the use of agricultural residues in paper manufacturing is growing slowly worldwide, and there is renewed interest in North America in industrial use of these materials. Significant quantities of agricultural residues are available in North America. Conservative estimates indicate that the current availability of agricultural residues could expand the supply of papermaking fiber in the U.S. by 7-10 percent if only cereal straws (stalks of wheat, barley, and oats) are considered, and by up to 40 percent if corn stalks also prove to be a viable source of industrial fiber.

It is today technically possible to produce pulp from agricultural residues using either chemical or mechanical processes, although technology development in both areas is needed to improve prospects for technology adoption. However, from an economic perspective, there is some evidence to suggest that near-term investment in dedicated agricultural residue-based pulping facilities is unlikely because of projections of unacceptably low financial rates of return. What does appear to have promise is co-pulping of agricultural residues (up to 10 to 15 percent by volume) along with wood chips in existing chemical pulp mills.

The environmental benefits of the use of agricultural residues as a source of fiber in papermaking are dependent on the specific region and situation. Some regions dealing with excess straw find disposal to be a problem requiring annual burning, and thus development of alternative uses for straw is both environmentally and economically attractive. Additionally, in chemical pulping processes straw can be pulped using smaller quantities of pulping and bleaching chemicals than when pulping wood. On the flip side, agricultural residues require relatively high primary energy demands in processing, greater energy consumption in transporting bulky raw materials, and there are difficulties in economically recovering pulping chemicals from the waste stream and treating resulting emissions.



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Agriculture is a major activity in the United States. Among the most important crops in terms of average total acres planted from 1995 to 1997 are:

- Corn, 77 million acres,
- Wheat, 72 million acres,
- Soybeans, 65 million acres,
- Hay, 60.5 million acres,
- Cotton, 15 million acres,
- Grain sorghum, 10 million acres,
- Barley, 7 million acres,
- Oats, 5 million acres,
- Rice, 3 million acres, and
- Rye, 1.5 million acres

U.S. Department of Agriculture, National Agricultural Statistical Service, Crop Production Summary, Washington, DC, January 1998b.

Introduction

Crop residues such as bagasse (sugarcane residue) have long been used in making paper in China, India, Pakistan, Mexico, Brazil, and a number of other countries. Today, production of paper and paperboard from crop residues is on the rise, with the percentage of pulp capacity accounted for by non-wood fiber globally now close to 12 percent; this compares to an estimated 6.7 percent non-wood fiber in 1970. Wheat straw is currently estimated to account for over 40 percent of non-wood fibers used to make paper, with bagasse and bamboo together accounting for another 25 percent.



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American papermakers began experimenting with alternative raw materials as early as the 1790's, and many mills tested local sources of fiber as substitutes for rag pulp, including tree bark, bagasse (sugarcane waste), straw, and cornstalks. The first US newspaper to be printed on paper made from ground wood pulp was the edition of the Boston Weekly Journal that appeared on January 14, 1863.

*-The Robert C. Williams American Museum of Papermaking
www.ipst.gatech.edu/amp/collection/museum_pm_usa.htm*

To say that non-wood fiber has been used for a long time in making paper is something of an understatement. In fact, non-wood fiber has been used in papermaking for almost two thousand years! Chemical pulping of wheat straw, using a process similar to that used today for pulping of wood, was accomplished over 175 years ago. U.S. research examining potential uses of crop residues as a papermaking raw material dates back to at least World War II. In the 1940s, 25 mills in the Midwest produced almost 1 million tons of corrugating medium annually from straw. Momentum in the non-wood fiber industry was lost following the war because of the high costs of gathering and processing straw, and the return to pulping of hardwoods on the part of the paper industry. The last straw mill in the United States closed in 1960.

Today, interest in straw-based paper is reemerging. For instance, a mill in Alberta, Canada is commercially producing market pulp from flax, and the Weyerhaeuser Company, a giant in the forest products industry, is operating a pilot pulping plant in Oregon that uses steam explosion technology and is designed for processing of rye straw. In addition, current research at the University of Minnesota, North Carolina State University, the University of Washington, and elsewhere is focused on the use of agricultural residues as a source of fiber in the manufacture of paper and paperboard.

Potential Availability of Agricultural Fiber

Although a wide variety of crops might provide fiber for production of paper, those that appear to be most compatible with current technologies are wheat, barley, and oats. Global production of these three crops alone totaled 724 million metric tons (mt) in 2003, with over 39 percent of production concentrated in China, the United States, India, and the Russian Federation. Total production is likely to increase significantly in the coming decades, and perhaps as much as 40 to 60 percent to meet the needs of the rising population.

North America (United States, Canada, and Mexico) together produced 117.5 million mt of wheat, barley, and oats in 2003, accounting for about 16 percent of world production; approximately 92 million mt, or 78 percent, of North American production of these three grains was accounted for by wheat.

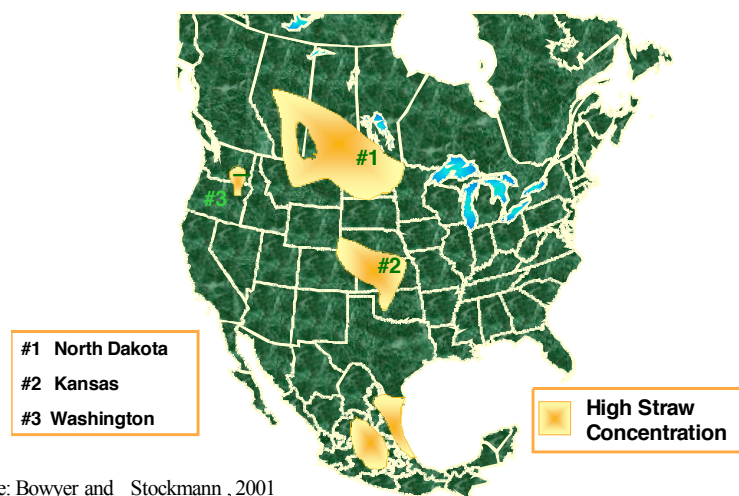
	Wheat	Barley	Oats	Total
China	86,100,250	3,115,000	465,000	89,680,250
United States	65,589,820	6,011,080	2,099,570	73,700,470
India	65,129,300	1,405,800	--	66,535,100
Russian Fed.	34,062,260	17,967,900	5,174,890	57,205,050
Canada	23,552,000	12,327,600	3,691,000	39,570,600
Australia	24,900,000	8,525,000	1,596,000	35,021,000
UK	14,288,000	6,370,000	749,000	21,407,000
Argentina	14,530,000	548,530	500,940	15,579,470
Poland	7,858,160	2,831,485	1,181,888	11,871,533
Mexico	3,000,000	1,109,424	147,474	4,256,898
World	556,348,627	141,503,090	26,268,713	724,120,430

World Production of Cereal Straws – 2003

Source: FAO 2004.

Production of grains is concentrated in the Great Plains and westward, extending northward into Canada and southwest through east central Mexico. Pockets within this region are extraordinarily productive, with consistent production of straw beyond needs for conservation tillage. These are known as straw-rich regions.

Straw-Rich Regions in North America



Source: Bowyer and Stockmann, 2001

The ratio of wheat straw to grain production has been the subject of several studies in recent years. Findings indicate from 0.7 to 1.6 tons of dry straw production per ton of grain for the principal cereal crops, with an average of about 1.1 to 1.2. Using a conservative value of 1.0 ton of dry straw for each 1.0 ton of grain production suggests a total production of over 117 million metric tons of straw in North America in 2003. Adding corn stalks to the mix of potential fiber sources almost quadruples agricultural fiber availability.

Obviously, much or even most of the volume of crop residues is not available for use in producing pulp and paper. In North America, about one-half of the straw produced is left on the field for soil conservation purposes. In addition, some is harvested, baled, and used to feed livestock. In other cases, livestock is grazed on fields in the several months directly following the grain harvest. In straw-rich regions, soil conservation and various agricultural uses together may account for about 60 percent of the total straw produced, leaving a surplus of 40 percent on average. However, in dry producing regions, such as much of Colorado, soil conservation concerns may dictate no straw harvest. Moreover, straw yields vary by growing season, with markedly lower production in abnormally dry years. For example, one recent report indicates that straw production in Montana is less than one-half of average about 30 percent of the time. Therefore average surplus straw figures cannot be used to determine the optimum capacity for a straw-based paper mill. Even considering these caveats, there is a significant volume of available straw. A simple calculation reveals the magnitude of the potential resource. Conservatively assuming a straw surplus of 15 to 20 percent (instead of 40 percent in order to allow for cyclical variation in straw production), but also assuming that surplus straw could be gleaned from all of the area on which wheat is produced in North America, yields an estimate of 11 to 15 million metric tons of straw. This is roughly equivalent to 7 to 10 percent of the annual virgin fiber requirement in U.S. paper and paperboard manufacture.

Estimated surplus straw in the United States - 2003:

		<u>(Million metric tons)</u>
Wheat, barley, oats (100%) ^{a/}		73.7
Soil conservation (50%)		36.8
<u>Agricultural uses (30-35%)</u>		<u>22.1-25.8</u>
Surplus (15-20%)		11.1-14.8

^{a/} assuming 1mt of straw for each mt of grain produced.

While even very conservative assumptions suggest that the quantity of crop residues potentially available for use in papermaking is currently large, potential competition for this resource from other industries is very likely. It is specifically important to recognize that use of surplus residues by the composite panels industry is a growing reality, and that the U.S. Department of Energy and others are actively considering such material as a potential biofuel.

Technical, Economic, and Environmental Aspects of Paper Manufacture from Straw

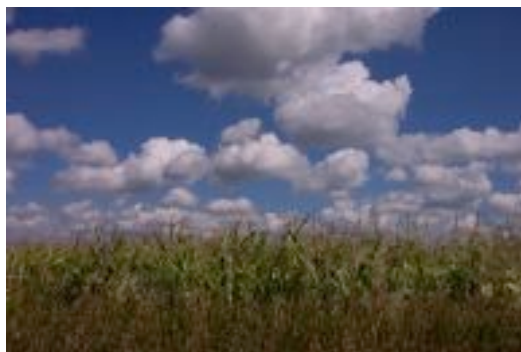
There are literally thousands of straw-based paper mills in operation worldwide, with most of these in China and India. Relatively few of these agri-fiber based paper mills are located outside of these two countries. Nonetheless, such mills operate today in at least 15 other nations. The fact that agri-fiber based paper mills are currently in operation around the world would seem to suggest that there is no question about technical and economic feasibility. However, the vast majority of such mills are of very small scale and ill equipped to meet environmental requirements common to most developed countries.



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In 1996, the Paper Task Force, a group of paper industry experts convened under the auspices of the Environmental Defense Fund and Duke University and funded by several large U.S. corporations issued a report that included examination of the potential for commercial paper production from non-wood fiber. Cereal straws were among the fiber sources examined. It was concluded that 1) straw can be satisfactorily pulped, 2) technology improvements are likely to improve pulp properties and reduce pulping costs, 3) transport and storage of straw are factors likely to limit plant capacity (and thus perhaps to inhibit achievement of optimum economies of scale), and 4) the most likely use of straw pulp was as an additive to wood pulp. Overall, the outlook regarding use of straw pulp was determined to be positive.

A recent agricultural fiber-based pulp mill preliminary feasibility study conducted by the University of Minnesota examined technical and economic issues related to potential development of cereal straw market pulp mill in the Red River Valley region of northwestern Minnesota. Initial findings were that an agricultural residue-based pulp mill was sufficiently promising as to justify further evaluation. This work resulted in an in-depth study of potential feasibility (Kellogg Brown & Root/University of Minnesota 2001) that concluded with the finding that although the project was technically feasible, this was not the case regarding economics; analysis showed likely internal rates of return of less than 6% (pre-tax) for all scenarios considered, well below the threshold of 15% considered necessary for commercial financing. This conclusion has shifted the attention of University of Minnesota researchers to the possibility of co-pulping wood and agricultural residues in existing pulp mill operations, with the percentage of agri-fiber in the range of 10 to 15 percent. This approach, if successful, will focus early development of agricultural residue-based papermaking in regions where straw-rich cereal straw production and pulpwood harvesting exist in close proximity. Using this guideline, the most likely areas for near-term development are Minnesota and eastern Washington and Oregon. Should corn prove to be a viable papermaking fiber, the potential for paper production from crop residues would widen considerably.



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Possible uses for corn stover include: animal feed, animal bedding, fuel for a boiler furnace, composite products such as fiberboard, pulp and paper, chemicals, and liquid fuels. In addition to Ethanol production, pulp and paper, fiberboard, and chemicals are currently believed to be the only applications for which corn stover may be needed in any substantial quantity. To achieve an ethanol production potential of 3 billion gallons per year (a target level for a non-niche feedstock), about 40% of the harvestable corn stover is needed.

<http://www.bioproducts-bioenergy.gov/pdfs/bcota/abstracts/31/z263.pdf>

From a technical point of view, the pulping of straw is both attractive and unattractive when compared to pulping of wood. The primary advantage of straw is that it has low lignin content. The lignin content of wood is approximately 26 to 35%, while the lignin content of straw is approximately 16%. This is an advantage in that lignin is removed in chemical pulping processes, and lower lignin translates to reduced chemical use and effluent generation in the pulping process. Straw can also be pulped with simple chemical systems without the use of sulfur.

A disadvantage of straw is that chemical recovery following pulping is difficult due to ash and silica contents that are higher than wood. Secondly, chemical recovery and effluent treatment is expensive for small scale non-wood mills – a problem arising from the high bulk and associated high shipping costs for straw, costs that in turn provide an incentive for construction of small-scale

pulping facilities. Third, the advantageous low lignin content of straw becomes a disadvantage with respect to energy requirements in pulping since it is lignin that is typically burned for power in traditional pulping operations, making domestic paper production largely energy self-sufficient; without as much lignin available for internal energy generation requires the use of more energy from the regional energy grid. Another disadvantage is related to the short time frame available for annual harvests of crop residues. The possibility of crop failure or adverse weather through the harvest period, or alternatively the inability to leave fiber in the field should paper markets be soft, provide an element of risk to agri-fiber papermaking that does not exist when using wood.

Environmental implications of agricultural residue use are mostly positive. In some regions that consistently produce high crop yields, straw is produced in quantities above that required for maintenance of soil productivity. In these regions, dealing with excess straw can represent a disposal problem, and development of alternative uses for straw is both economically and environmentally attractive. Pulping of straw can also generally be accomplished with use of a smaller volume of pulping and bleaching chemicals than if pulping wood. Downsides to straw use are that shipping of straw is more energy intensive, that primary energy requirements in pulping and papermaking are greater, and that recovery of chemicals used in pulping and effluent treatment are more difficult.

The Straw Storage Issue

Because agricultural residues are produced over a 1-to 3-month period each year, storage of this material is a concern when volumes of the magnitude needed for paper manufacturing are considered. Very large volumes need storage in order for processing facilities to be able to operate at a sufficient capacity to achieve economies of scale.

A number of sources report that straw bales must be relatively dry to prevent degradation, as bales with higher moisture are reportedly susceptible to rot and spontaneous combustion. Evidence indicates that losses as high as 22 to 23 percent could be expected in straw stored uncovered directly on the ground compared to losses of 1 to 8 percent with indoor storage or covered storage on a gravel base. A study of opportunities in grass straw utilization in the Pacific Northwest concluded that covered storage was necessary in order to ensure an uninterrupted supply to a mill, a reality that would require considerable investment. Others have pointed out that covered storage does not necessarily translate to construction of an expensive storage facility. Realistically, storage options include: 1) storage of all annual supply at the mill; 2) storage of a portion of the annual supply at regional storage facilities owned by a mill, with the rest stored at the mill; and 3) storage of a small portion of straw at the mill as a buffer supply with the rest stored at nearby farms. These options include storage within buildings, tarp-covered storage in farm fields or elsewhere, and uncovered storage at a farm, regional storage site, or mill.



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Costs of storing grass seed and straw under a roof in western Oregon were estimated at \$13.22 to \$14.23 per ton (\$14.54/mt to \$15.65/mt), assuming an average 6-month storage period, and including costs of construction, interest, repairs, insurance, and straw losses in storage. A similar estimate of storage costs (\$14 to \$15 per short ton), which included the cost of working capital tied up in stored fiber, resulted from a recent study of papermaking from kenaf. These costs can be reduced by one-half or more by storing straw outside, but under tarps, a savings that will likely be reduced after higher straw losses are taken into consideration. In general, costs of storing straw would be from \$2.50, to as much as \$12-13, higher per ton than those associated with storing wood.

The Bottom Line

Today, paper can be made using fiber from agricultural residues, and this is a modern reality in many parts of the world. Interest in agricultural residues as a source of papermaking fiber is growing in North America and significant research and development efforts are dedicated to solving technical problems that could improve the economic prospects for technology adoption as well as the environmental performance of agri-fiber pulping systems. Co-pulping of wood and agricultural residues may represent the greatest near-term opportunity for significant North American paper production from agricultural residues.

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