Agricultural Residues in Pulp and Paper
Discussion Paper

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Overview

All plants contain cellulose, and any plant can be made into paper. This article is written from the perspective of environmental, technical and economic efficiency, and the desire to replace trees as a main source of virgin raw material for pulp and paper on a commercial scale. The vast majority of collectable agricultural residues, in tons, in the US are made up of straw – primarily from wheat and rice production, and corn stalks. Because of the volume of biomass per acre that these crops generate and the resulting lower cost of collection, they are the most frequently considered for commercial scale pulping in an effort to substitute or supplement wood fiber. Because any viable pulping operation will require a physically consistent and reliable supply of similar raw material, many other types of agricultural residues from significant crops are not considered in this discussion (cotton stalks, sorghum stalks, soy stalks, etc.)

Straw Fiber Characteristics

Short Weak Fibers

Fibers from wheat and rice straw are short (0.5 – 1.5mm[1]) and weak when compared to wood fiber. On their own, they cannot provide the technical properties demanded by modern pulp and paper manufacturers, nor can they meet the demands of the printing and packaging industries. While straw fibers could supplement wood fiber in some of the less demanding grades of paper and packaging (such as the corrugated section of a cardboard box), and when used in small percentages, could be incorporated into higher quality applications, they do not possess the necessary physical attributes to replace tree fiber in the majority of paper applications.

Negative effect on commercial recycling

When paper and cardboard containing straw fiber is mixed with wood based paper and cardboard in waste collection systems, then processed under the same conditions as the wood content waste in a recycling mill, the weaker straw fibers break down more easily than wood fiber, and act as a contaminant, slowing the drainage time of the pulp, and producing weaker products. This aspect of straw is seemingly not understood by the proponents of straw for pulp and paper. All fibers become shorter in the recycling process. Since straw fibers are short to begin with, recycling them will make them too short to be retained in the process, and the shortest will pass through screens along with other process rejects. This will result in a lower yield for a recycling mill, which will have negative economic impacts. There has been no study of this issue by any US or

Canadian research group, to my knowledge. The only published data that I have seen is about recycling straw paper in isolation, (not mixed waste) in Russia. I believe this is one area of study that needs to be performed before people promote straws as a paper making material. My experience and intuition tells me the results will not be positive.

Silica content environmentally and economically negative

Straw contains significant amounts of silica, ranging approximately from 3-14%[2], and ash depending on type and regional growing conditions. In the process of pulping, silica is separated from the fiber and appears in the black liquor (waste stream) in the form of sodium silicate and/or other complex siliceous compounds. The black liquor also contains the noncellulose portion of the straw (lignin, pentosans and other degradable carbohydrates), and the process chemicals and water. Heat is used to reduce the water content. Upon evaporation, the resulting fluid is quite thick and difficult to process in a chemical recovery system. This silica accumulates and causes scaling in evaporator tubes and other parts of the recovery system, reducing their efficiency and adding to maintenance costs. Most mills that process straw are located n countries where environmental protection laws are either weak or poorly enforced. These mills expel effluent onto land or into waterways in concentrations that would not be allowed under most European or US environmental regulations.

Harvest, collection and storage issues

Straw must be harvested in a time frame consistent with the harvest of the grain. Depending on regional practices, the straw may be cut and baled at the same time as the grain crop, or it may be harvested in a subsequent operation. The storage conditions and moisture content of straw are important because it is susceptible to molds and rot, and subject to spontaneous combustion. Weathered straw consumes more chemicals for pulping and yields less pulp of relatively lower strength.[3]

Historically used then abandoned

The use of straw for pulp and paper is common in fiber poor third world countries. Straw has historically been used for pulp and paper production in the US. One of the first pulp mills in the US was based on straw (1827, Hollywell, PA[4]). Its use was abandon when higher quality fibers from trees could be obtained using more advanced pulping methods. Straw is still available in abundance in the US and could be obtained for a very low cost, basically the cost of collection. The US paper industry is always interested in low cost raw materials supplies. While aware of the availability of straw, and its low price, the industry still does not utilize it. The above is a summary of some of the major reasons for its nonuse.

Corn Stalks Characteristics

Less published information exists regarding the use of corn stalks in pulp and paper making. There is no readily available evidence of current commercial use in the world. Historically, corn stalks were used to produce low grade wrapping paper and board in Austria around 1880.

Low cellulose/high lignin content

Corn stalks cellulose content (35-45%[5]) ranges significantly depending on variety and regional conditions. Combined with the high lignin content (14-34%[6]) and nodes and pith, pulp yields of 30-40% are optimistically misleading, because the resulting pulp is dominated by non-fibrous elements (epiderma, pith, barrel type vessels). Such a low pulp yield indicates a high cost of processing. The environmental compliance characteristics are challenging because there will be roughly two tons of waste stream solids for every one ton of pulp produced. Even if the raw material were delivered to a mill at no cost, the economics of a corn pulp mill would be very disadvantaged.

Short Fibers

Fibers from corn are short (1.2 – 1.4mm) and would be roughly comparable to a hardwood fiber in length and width. The strength properties reported are poor, and there seems to be no technical property of corn pulp that justify the expense of pulping it. Many of the characteristics of straw fibers would apply to corn, except it seems that during refining, the freeness decreases quickly and the drainage rate decreases even faster.[7]

Negative effect on commercial recycling

While there is currently no corn paper to test or even to speak of, the known fiber characteristics indicate that it would be less favorable in recycling than straw.

Harvest, collection and storage issues

Corn stalks, like straws, would probably be harvested in a time frame consistent with the harvest of the grain, depending on specific harvesting methods. The moisture content of corn stalks would be higher at harvest time than straw and therefore more problematic. Some sort of energy consuming drying system would probably be required prior to storage due to the same mold, rot and combustion issues as with straw.

Little to no historic use

The lack of historic use of corn, and the limited amount of published data on its use in pulp and paper making are probably due to the ease with which one can logically eliminate it as a viable raw material source for pulp and paper. It may be possible to genetically alter corn to produce better fiber quality, and higher usable cellulose content, but at present, conversion to ethanol or another form of biofuel seems a more logical development path for this material.

[1] Joseph E. Atchison – Data on Nonwood Plant Fibers - Pulp and Paper Manufacture Volume 3 – Secondary Fibers and Nonwood Pulping – TAPPI Joint Textbook Committee of the Paper Industry

[2] Joseph E. Atchison – Data on Nonwood Plant Fibers - and DK Misra – Cereal Straw – Pulp and Paper

Manufacture Volume 3 – Secondary Fibers and Nonwood Pulping – TAPPI Joint Textbook Committee of the Paper Industry

[3] DK Misra – Cereal Straw – Pulp and Paper Manufacture Volume 3 – Secondary Fibers and Nonwood Pulping – TAPPI Joint Textbook Committee of the Paper Industry

[4] Atchison and McGovern – History of Paper and the Importance of Nonwood Plant Fibers - Pulp and Paper Manufacture Volume 3 – Secondary Fibers and Nonwood Pulping – TAPPI Joint Textbook Committee of the Paper Industry

[5] McGovern, Coffelt, et al – Other Fibers – Pulp and Paper Manufacture Volume 3 – Secondary Fibers and Nonwood Pulping – TAPPI Joint Textbook Committee of the Paper Industry

[6] ibid

[7] ibid