The 1th International and The 4th National Congress on
Recycling of Organic Waste in Agriculture
26 – 27 April 2012 in Isfahan, Iran

# USE OF AGRICULTURAL WASTE IN THE PULP AND PAPER INDUSTRY

Moghadase akbari[1]
Akbari_moghadase@yahoo.com

Hussein resalati[2]
hnresalati@yahoo.com

## ABSTRACT

Non-wood fiber is one of the major sources for the pulp and paper industry in developing countries due to their abundance and cost-effectiveness. These non-wood materials have considerable potential to be used as alternative choices in many paper grades, including writing and printing papers. This paper provides an overview of how agricultural fibers can be used for this purpose. Fibrous materials that are discussed include bagasse, cereal straw, cotton stalks, kenaf, canola, and rice straw.

## 1. INTRODUCTION

There has been an increase in paper and board production and consumption in recent decades. Due to the strong growth in demand in recent years, it is predicted that the forecasted demand for wood materials may exceed the potential supply. Production of pulp from non-wood resources has several advantages compared with wood, such as easy pulping capability, excellent fibers for special types of paper and high-quality bleached pulp (Atchison, 1995).
Over the years, an increasing preoccupation regarding forest preservation and rational use of forest and agricultural residues has occurred. This fact is mainly motivated by the increasing consumption of wood fibre-based products, such as panel, paper and boards. Annual plants could also be a new source of cellulosic fibres for papermaking and/or composite materials.
Formerly, paper was made from non-wood plant materials such as flax, cotton, mulberry, bamboo or cereal straw. The increasing demand for paper and the invention of the printer raised the need for low-cost raw materials such as wood species and also to develop automatic processes in order to boost production. As a result, wood species have accounted for 90–95% of all raw materials used to obtain cellulose pulp for more than a century. The world production of wood pulp in 2003 was estimated to be 170 358 000 tons; by contrast, that of non-wood pulp amounted to only 18 695 000 tons. Such a marked increase has been the result of the use of wood species as the main raw material leading to massive deforestation and replantation, which has altered the ecological balance and contributed to the climate change. Based on the foregoing, we undertook a study aimed at comparing the effectiveness of non-wood raw materials including bagasse, cereal straw, cotton stalks, kenaf, canola, and rice straw for pulp and paper manufacturing purposes (Hurter & Robert., 2001).

### 1.1.Bagasse

Bagasse is the residue fiber remaining when sugar cane is pressed to extract the sugar. Some bagasse is burned to supply heat to the sugar refining operation; some is returned to the fields; some finds its way into various panel products. Bagasse is composed of fiber and pith. The fiber is thick walled and relatively long (1 to 4 mm). It is obtained from the rind and fibrovascular bundles dispersed throughout the interior of the stalk. The chemical composition of bagasse as follows: 52.42% cellulose, 21.69% lignin, 73.92% holocellulose, 45.3% α-cellulose, 2.73% ash and, 1.66% ethanol/dichloromethane extractable, on an oven-dry weight basis. (Peng & Simonson 1992). In spite of the many studies in other non-woods organosolv pulping, so far, limited research has been conducted on the pulping of bagasse by organic solvents. Organosolv processes have been applied with varying success to hard and soft wood and also, to a lesser extent, to non-wood materials (Atchison 1998).

### 1.2.Canola

Canola has been vastly cultivated for edible oil production. The average yield of canola straw reaches to approximately 3 dry ton/ha. It was estimated that 500,000 tons of canola straw are annually produced in Iran. Due to the governmental policy, it was predicted that the canola production will grow in the future. After harvesting, the canola straw remains in the field and is burnt. Recently, the potential application of canola straw on medium density fiberboard (MDF) has shown promising results. Also, the pulps produced from soda pulping of canola straw were comparable with those of bagasse and other cereal straws. However, the CMP pulping of canola straw has not yet been investigated (Yousefi, 2009).

Table 1. Dimensional properties of canola straw and of some other non-wood materials reported in the literature.

| Fiber source | Fiber length, mm | Fiber width, µm | Lumen width, µm | Fiber wall thickness, µm | Reference |
|---|---|---|---|---|---|
| **Canola straw** | 1.31 | 31 | 19.5 | 5.75 | Yousefi (2009) |
| **Canola straw** | 1.21 | 28 | 11.9 | 7.43 | Yousefi (2009) |
| **Wheat straw** | 1.17 | 15.9 | 10.24 | 2.83 | Moradian and Latibari (2001) |
| **Wheat straw** | 1.2 | 13 | | | Garg and Singh (2004a) |
| **Bagasse** | 1.9 | 28.9 | 19.55 | 4.77 | Yousefi (2009) |
| **Bagasse** | 1.7 | 23 | | | Garg and Singh (2004a) |

### 1.3.Cotton stalks

Cotton is cultivated primarily for its fiber; little use is made of the plant stalk. Stalk harvest yields tend to be low and storage can be a problem. cotton stalks can be an excellent source of fiber. With regards to structure and dimensions, cotton stalk fiber is similar to common species of hardwood fibe. As such, de barked cotton stalks can be used to make high grades of paper. The stalk is about 33 percent bark and quite fibrous. Newsprint quality paper can be made from whole cotton stalk (Mobarak & Nada., 1975).

### 1.4.Cereal straw

cereal straw is meant to include straw from wheat, rye, barley, oats, and rice. Straw, like bagasse, is an agricultural residue. Unlike bagasse, large quantities are generally not available at one location. Straw has a high ash content (Table 2) and they tend to fill up fire boxes in boilers and increase the wear rate on cutting tools. Their high silica content tends to make them naturally fire resistant (Opel, L. 1992).

Table 2. Chemical composition of selected lignocellulosic fibers.

| Composition% | | | | |
|---|---|---|---|---|
| Fiber type | Alpha celluse | lignin | Ash | Silica |
| Rice straw[b] | 28 to 36 | 12 to 16 | 15 to 20 | 9 to 14 |
| Wheat straw[b] | 38 to 46 | 16 to 21 | 5 to 9 | 3 to 7 |
| Oat straw[b] | 31 to 37 | 16 to 19 | 6 to 8 | 4 to 7 |
| Bagasse[b] | 32 to 44 | 19 to 24 | 2 to 5 | 1 to 4 |
| Kenaf[b] | 31 to 39 | 14 to 19 | 2 to 5 | NA |
| Rice husks[c] | 38 | 22 | 20 | 19 |
| Softwoods[c] | 40 to 45 | 26 to 34 | <1 | .. |
| Hardwoods[c] | 38 to 48 | 23 to 30 | <1 | .. |

[a] NA= not available
[b] Source: Gonzalo et al., 1998
[c] Source: Ward et al., 2008

### 1.5.Kenaf

Kenaf is a plant that is similar to jute or hemp. It has a pithy stem surrounded by fibers. The fibers represent 20 to 25 percent of the dry weight of the plant. Mature kenaf plants can be 5 m tall. Historically, kenaf fibers first found use as cordage. Industry is exploring the use of kenaf in papermaking and nonwoven textiles. Kenaf fiber can be used to make letterhead quality paper. Whole kenaf stalks can be used to make newsprint grade paper (Lamahieu, et al 1991).

### 1.6.Rice straw

Rice straw was reported to contain 25.4–35.5% of cellulose, 32.3–37.1% of hemicellulose, and 6.4–10.4% of lignin. The problems encountered in biogasification of rice straw are mainly related with high C/N ratio or low hydrolysis performance and digestibility because of high lignin content and its complex, stable and recalcitrant lignocellulosic structure, which needs a further balance of nutrients and destructive pretreatments if rice straw is used as substrate for biogasification.

In 1994, about 146.5 million hectares of rice were harvested in 107 countries, producing approximately 534.7 million tons of paddy. In order to feed the increasing global population, the world's annual paddy rice production must increase from the present level to 690 million tons by the year 2010 (or 27.6 percent) (FAO, 1993). Asia accounts for 90% of the world's production and consumption of rice because of its favourable warm and humid climate[Ward et al., 2008]). Huang and Shi (1986) studied rice straw pulping kinetics and mechanisms and suggested that delignification during soda-based cooking in the presence of anthraquinone could be divided into three phases: (1) a bulk phase of delignification at less than 90 °C, in which 72% delignification was attained, (2) a supplementary phase between 90 °C to 150 °C, in which 20% delignification occurred, and (3) a final phase at 150 °C. The delignification reaction of rice straw was a first-order reaction, with an activation energy of 49.7 kJ/mol. Gonzalo et al. (1998) found that about 90% of the lignin was dissolved in the rapid initial phase. The delignification reaction was first order with respect to residual lignin, and the activation energy for the bulk delignification was found to be 93 kJ/mol.

## 2. CONCLUSION

Production of pulp from non-wood resources has many advantages such as easy pulping capability, excellent fibers for the special types of paper and high-quality bleached pulp and they can be used perpetually as an effective substitute where forest wood resources are being decreased. Current pulp output is inadequate to meet the increasing demand, particularly in developing countries and this is leading to an increasing shortage of wood raw materials and to gradual deforestation of some areas in the world. This makes non-wood materials such as bagasse and various other agricultural residues abundant in Iran especially attractive alternatives for pulp making. Packaging and corrugating medium are two paper grades that have a high potential to be manufactured with non-wood raw materials. However, the mechanical strengths of these paper grades are not adequately high owing to a high lignin content in unbleached pulps. Tutus and Eroglu described the necessity of silica precipitation on fibers in non-wood pulping extensively. However, this precipitation would further impair the dry strength of papers, and stress the application of non-wood materials in paper making applications. Non-wood raw materials account for 5–7% of the total pulp and paper production worldwide (Ward et al,. 2008).

## REFERENCES

Atchison “twenty _five years of global progress in non-wood plant fiber pulping Historical highlights present status, and future prospects,”proc.1995 pulping conference (Atlanta:TAPPI press, 1995), p.97.

Atchison, J.E.”Progress in the Global Use of Nonwood Fibers and Prospects for Their Greater Use in the Future,”in Paper International, Apr-Jun 1998, Pg21.

Gonzalo, C. Lindgren and M. Lindstrom, Kinetics of wheat straw delignification in soda and kraft pulping, J. Wood Chem. Technol. 18 (1998) (1), pp. 69–82.

Hurter, Robert W.2001.”Nonwood Plant Fiber Uses in Papermaking “Extracted from” Agricultural Residues “, TAPPI 1997 Non wood Fibers Course Notes, updated and expanded September 2001.

Mobarak, F. and A.M.Nada. 1975. Fiberboard from exotic raw materials-2. Hardbord from undebarked cotton stalks. J. Applied Chem. And Biotech. 25 (9): 659-665.

Lamahieu, P.J., E.S. Oplinger, and D.H. Putman. 1991. AJ. Ternative Field Crops Manual: Kenef. Univ. of Wisconsin- Madison Ext. Publ. April.

Opel, L. 1992. Personal communication. Meadowood Industries, Inc, Albany, Oreg.

Peng and Simonson, 1992 F. Peng and R. Simonson, High-yield chemimechanical pulping of bagasse. Part 4. Baggase CMP with sodium hydroxide/hydrogen peroxide pretreatment, Appita J. 45 (2) (1992), pp. 104–108.

Ward et al., 2008 A.J. Ward, P.J. Hobbs, P.J. Holliman and D.L. Jones, Optimisation of the anaerobic digestion of agricultural resources, Bioresource Technology 99 (2008), pp. 7928–7940. Article | PDF (293 K) | View Record in Scopus | Cited By in Scopus (30)

Yousefi, Canola straw as a bio-waste resource for medium density fiberboard (MDF) manufacture, Waste Manage. 29 (2009), pp. 2644–2648. Article | PDF (370 K)  View Record in Scopus | Cited By in Scopus (2).