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# Eco-Fibers: Product Of Agri-Bio-Waste Recycling

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**ABSTRACT:** Indian agriculture is producing very large quantity, approximately 500 million tonnes of crop residues every year (MNRE, 2016) which may either burnt in the field that produces green house gases ultimately or left in the field unutilized. Here, a review work has been done to get an eco-friendly fiber which would be the product of extraction of all possible agriculture based bio-waste, crop residues, stalks, straw etc of rice, wheat, maize, sunflower and mach more. Here all possible methods of fiber extraction like different retting processes, namely, dew, water, enzymatic, mechanical, and chemical retting, mechanical and alkali methods were comprehensively reviewed to find out suitable methodology. Chemical and Enzymatic extraction process has apparent advantages over the retting processes by having significantly shorter retting time and acceptable quality fibres, but it is quite expensive. Review paper also reveals about properties of fiber extracted from different agriculture based biowaste sources.

**Keywords:** Agriculture Based Bio-Waste, Crop Residues, Fiber Extraction Methods, Eco-Friendly

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## I. INTRODUCTION

Food security has been forced to produce more and more food grains. India produces 252.4 million tonnes of food grains in 2015-16. But this demand also contribute production of a very large quantity of crop residues, approximately 500 million tonnes of crop residues every year (Economic Survey, 2015-16, MNRE, 2016) and this may increase in future. With increased production of rice and wheat, residue production has also increased substantially. The RW system accounts for nearly one-fourth of the total CRs produced in India. (Sarkar *et al*., 1999). The surplus CRs (i.e., total residues produced minus the amount used for various purposes) are typically burned on-farm. Management of rice straw, rather than wheat straw is a serious problem, because there is very little turn-around time between rice harvest and wheat sowing and due to the lack of proper technology for recycling. Among options available to farmers for the CRM (including burning), important are baling/removal for use as feed and bedding for animals, *in situ* incorporation in the soil with tillage, and complete/partial retention on the surface as mulch using zero or reduced tillage systems.

This crop residue are one of the biggest component of all agriculture bio waste which either left in field or its large amount, 140 million tones is burnt on the field primarily to clear the remaining straw and stubble after the harvest. Burning of crop residue is resulting into emission of significant quantity of air pollutants ad green house gases like $CO_2$, $N_2O$, $CH_4$, CO, $NH_3$, $NO_x$, and $SO_2$ etc. Biomass burning from forest regions and agriculture crop residues can emit substantial amounts of particulate matter and other pollutants into the atmosphere.

Very small amount of crop residue is used as animal feed, composting, thatching for rural homes and fuel for domestic and industrial use. The field burning of CRs is a major contributor to reduced air quality (particulates, greenhouse gases), and impacts human and animal health both medically, and by traumatic road accidents due to restricted visibility in NW India. Besides, burning of CRs leads to a loss of organic matter and precious nutrients, especially N and S. The peak in asthmatic patients in hospitals in NW India coincides with the annual burning of rice residue in surrounding fields (Yadvinder-Singh *et al*. 2010b). Crop residue, a renewable resource, is an important component in ecosystem stability of the world's agricultural land. Developing techniques for effective utilization. of this vast resource is a major challenge. Almost all the leading newspapers of northern India published reports on the incidence of a thick cloud of smog that enveloped many parts of Delhi on November 2016.People experienced reduced visibility, besides irritation in the eyes and throat. This smog was attributed to the large scale burning of rice straw by farmers. The burning of the residue is not only a source of atmospheric pollution, but also leads to loss of rich renewable soil rejuvenating organic resource. Farmers opt for burning as it is a quick and easy approach for disposal of residue and enables farmers to plant the next wheat crop well on time. This is the primary reason for burning rather than incorporating the same for soil enrichment.

Burning of crop stubble has severe adverse impacts especially for those people suffering from respiratory disease, cardiovascular disease. Pregnant women and small children are also likely to suffer from the smoke produced due to stubble burning. Inhaling of fine particulate matter of less than PM2.5 μg triggers asthma and can even aggravate symptoms of bronchial attack. According to Singh et al. (2008), more than 60 % of the population in Punjab live in the rice growing areas and is exposed to air pollution due to burning of rice stubbles. As per the same study, medical records of the civil hospital of Jira, in the rice-wheat belt showed a 10 % increase in the number of patients within 20–25 days of the burning period every season.

Recently it has been scientifically focus towards extraction of fiber from all this agriculture based waste which may produce eco-friendly fiber for a different purpose. Here a review work has been made to obtain a possible best agriculture bio waste and suitable methods of extraction to fiber an eco-friendly fiber. As a kind of abundant and renewable agricultural residue, corn (Zea mays L.) Stover, that refers a combination of corn stalk (stem) and leaf, could be a low-cost and sustainable source for energy and chemicals in future. For a long time (since 1929) fibres obtained from corn waste materials have been studied and utilized for pulp and papermaking [Li 2012].

From the economic point of view it is preferable to produce fibres from locally available biomass waste in order to avoid high transport costs of the raw materials. Lignocellulosic agricultural by-products are a promising and beneficial source for cellulose fibres. Due to the chemical and physical properties, composition and sustainability agro based biofibres represent a potential for use in textile and paper industry for fibres, chemicals, enzymes and other industrial products. Annually renewable resources, e.g. corn, wheat, rice, sorghum, barley, sugarcane, pineapple, banana and coconut, etc. by-products are utilized as agro-based biofibres [Reddy 2005].

At national level there is a need to consider and address the issue of residues and by-products in the following areas like supply control; price control; technology transfer; legislation development; quality control; and agricultural research strengthening. It is essential to immediately launch a regional initiative for the improved use of crop residues and agro-industrial by-products, with the effective and sustainable involvement of relevant actors at national and regional levels.

## II. MATERIALS AND METHODS

Environmental awareness today motivates the researchers, worldwide on the studies of natural fiber extraction through residue of different plant and crops. Several research papers, journals, websites, and textbooks have been collected and thoroughly studies on different agriculture bio waste used for fiber extraction and different methods used to find best suitable methods of extraction to fiber a eco-friendly fiber. The study confirms that there is a need to extract fibre from crop residue as an alternative to crop burning.

## III. RESULTS AND DISCUSSION

**3.1 Agriculture bio waste used for fiber extraction** –

Research works of several pioneer researchers has been studied thoroughly (Table 1). Review indicates large number of agricultural bio-waste like rice husks, rice straw, rape straw, wheat straw, corn straw, cornstalk, rye straw, hemp straw, flex straw, carrot leaves, sorghum stalks and leaves, pineapple and banana leaves, sunflower straw, bean straw can be used for extraction of natural cellulose fibres which is suitable for textile, composite, and other industrial applications (Sinha, 1974; Sinha and Ghosh 1977; Doraiswamy and Chellamani, 1993; Reddy and Yang, 2005). Bio wastes from cereal crops are the stalks, made of lignified tissue. It can be easily fractioned into lignin, cellulose and hemicelluloses and is potential sources of biomaterials. Corn stalk was observed as most used agriculture bio waste for extraction of natural fibres (Kopania *et al.*, 2012; Reddy and Yang, 2005; Hassan *et al.*, 2012; Flodzz *et al.*, 2012; Thamal *et al.*, 2008; Fidelis *et al.*, 2013; Tappi, 1983). Rice husks is one of the potenial source of natural fibre extraction (Rao *et al.*, 1980; Tappi, 1983; Rosa *et al.* , 2012). Johana *et al.*, 2012 extracted nano crystal fibres from rice husks using enzymatic treatments. Wheat straw is also used by several scientist for fibre extractions (Tappi, 1983; Kopania *et al*., 2012).

Fibres obtained from hemp straw are the highest cellulose content in this group and because of high content of cellulose they express good mechanical properties. They have found, that natural cellulose fibres obtained from cornstalks have the structure and properties required for textile and other industrial applications.

**Tables 1- Possible agricultural bio-waste used for fiber extraction**

| **Researchers** | **Agri bio waste used** | **Cellulose** | **Lignin (%)** |
|---|---|---|---|
| Rao *et al.*, 1980 | Rice husks | 38 | 22 |
| Tappi, 1983 | Rice straw | 36 | 16 |
| Johana *et al.*, 2012 | Rice husk | 35 | 18 |
| Rosa *et al.* , 2012 | Rice husk | 37 | 20 |
| Kopania *et al.*, 2012 | Rape straw | 41 | 19 |
| Tappi, 1983 | Wheat straw | 46 | 9 |
| Kopania *et al.*, 2012 | Wheat straw | 41 | 22 |
| Kopania *et al.*, 2012 | Corn straw | 39 | 20 |
| Reddy and Yang, 2005 | Cornstalk | 40 | 8 |
| Hassan *et al.*, 2012 | Cornstalk | 28 | 21 |
| Flodzz *et al.*, 2012 | Cornstalk | 40 | 21 |
| Thamal *et al.*, 2008 | Cornstalk | 28 | 21 |
| Fidelis *et.al.*, 2013 | Cornstalk | 37 | 23 |
| Tappi, 1983 | Cornstalk | 44 | 21 |
| Kopania *et al.*, 2012 | Rye straw | 45 | 22 |
| Kopania *et al.*, 2012 | Hemp straw | 60 | 12 |
| Kopania *et al.*, 2012 | Retted flax straw | 51 | 18 |
| Kopania *et al.*, 2012 | Flax straw oil variety | 42 | 23 |
| Kopania *et al.*, 2012 | Carrot leaves | 32 | 19 |
| Kopania *et al.*, 2012 | Sunflower straw | 41 | 19 |
| Kopania *et al.*, 2012 | Bean straw | 40 | 18 |

### 3.2 Methods applied for fiber extraction from agricultural bio wastes -

In the present work research works of several pioneer researchers has been studied thoroughly that are shown in Table 2 and 3. Review works indicates natural cellulose fibers are extracted from lignocellulosic byproducts using a process called retting using microbes, enzymes and chemical methods.

#### 3.2.1 Retting

Retting is sometimes termed degumming. It is a chemical process for removing non-cellulosic material attached to fibres to release individual fibres**.** After harvesting, the stems are usually kept either in the field or under water for 2 to 3 weeks, during which the pectinous substances that bind the fibre with other plant tissues are softened and degraded by micro-organisms. A quality of fibre is largely determined by the retting condition and duration. Table 2 compares five types of retting processes, namely, dew, water, enzymatic, mechanical, and chemical retting, which are normally applied to hemp, jute, flax, and kenaf. Apparently, there is no single method that can give optimum results in terms of retting period, fibre strength, environmental pollution, and cost. Dew retting largely relies on indigenous soil fungi to colonise the stem/bast and to degrade pectin and hemicellulose by releasing polygalacturunase (PGase) and xylanase. The resulting fibres are often coarse and of variable quality. Conversely, water retting is performed in an aqueous environment, and anaerobic, pectinolytic bacteria are responsible for the decomposition of pectic substances and the subsequent release of fibre (Akin et al. 2002).

Chemical and enzyme retting offer substantially more control compared with dew and water retting. Paridah et al. (2009) used 5% sodium hydroxide and 5% sodium benzoate during retting of kenaf bast fibre and found that both methods produced fibres of relatively lower tensile strength than those obtained with water alone.

To extract the fibre strands from other plant tissues the natural gum binding them must be removed by retting. The traditional methods for separating the long bast fibres are by dew and water retting. Both methods require 14 to 28 days to degrade the pectic materials, hemicellulose, and lignin. Even though the fibres produced from water retting can be of high quality, the long duration and polluted water have made this method less attractive. A number of other alternative methods such as mechanical decortication, chemical, heat, and enzymatic treatments have been reported for this purpose with mixed findings.

Microbial retting is not a new process. This traditional method is mainly achieved by the pectic enzymes produced by bacteria. During retting, the bacteria multiply and produce extracellular pectinases, which release the bast fibre from the surrounding cortex by dissolving the pectin. Nowadays, with the advancement of biotechnology tools, such enzymes can be commercially produced, thus making enzymatic retting a more popular choice for the production of long fibres. In microbial retting, Uses of microbes like bacteria and fungi for retting is traditional process to extract fibers. Bacteria such as *Bacillus* and *Clostridium* has been used in water retting, and fungi such as *Rhizomucor pusillus* and *Fusarium lateritium* has been used in dew retting most effectively for fibers extraction (Mukherjee, 1972; Henriksson, *et al*., 1997). Based on review works it is found that this method is suitable for corn stalks and flex.

Van Sumere (1992) reported that the bacterial method is relatively better than chemical, because it gives better fibre quality and lower pollution, whilst chemical retting requires high energy and generates costly wastes.

Yu and Yu (2007) removed 91.3% of pectin from kenaf bast fibre by subjecting the bast fibres with enzyme from fungal strain isolated from the river where the kenaf was retted. The optimal retting conditions used were: culture temperature 32ºC, initial pH 6.0 of the culture medium, cultivation time 24 h, retting time 21 h, and inoculation size 25%.

### 3.2.2 Chemical extraction

In review works of different research papers, it is found that chemicals as alkalis, mild acids and enzymes are used for fiber extraction from natural agricultural bio-wastes. Sodium hydroxide is found to be most commonly used chemical for fiber extraction (Henriksson, *et al.*, 1997; Majumdar and Chanda, 2001). Acids such as sulphuric acid and oxalic acid in combination with a detergent have also been used for fiber extraction. Chemical concentration, temperature and duration of treatment are the main factors determining the quality of chemically extracted fibers (Henriksson, *et al.*, 1997). Yilmaz, 2013 extracted fibres from corn husks by alkalisation using NaOH. Yilmaz (2012) also extracted corn husks fibres by enzymatic treatments.

Paridah et al. (2009) used 5% sodium hydroxide and 5% sodium benzoate during retting of kenaf bast fibre and found that both methods produced fibres of relatively lower tensile strength than those obtained with water alone. The colors of chemically-treated bast fibre were also darker

### 3.2.3 Extraction by enzymatic hydrolysis treatment-

A combination of enzymes such as pectinases, hemicellulases and cellulases can be used for fiber extraction with a pre- or post chemical treatment. Recently, Sejr, 2004 found multienzyme complexes that can express 10–15 enzyme activities and provide better fiber quality have been devel

**Table 2 -Various Types of Retting Processes Used for the Production of Long Bast Fbers**

| Retting types | Description | Advantages | Disadvantages | Duration of retting | Types of bast fiber | Referen-ces |
|---|---|---|---|---|---|---|
| Dew retting | Plant stems are cut or pulled out and left in the field to rot | Pectin material could easily be removed by bacteria. | Reduced strength, low and inconsistent quality; restriction to certain climatic change and product contaminated with soil. | 2-3 weeks | Flax, jute | 1, 2 |
| Water retting | Plant stems are immersed in water (rivers, ponds, or tanks) and monitored frequently (microbial retting) | Produces fiber of greater uniformity and higher quality | Extensive stench and pollution arising from anaerobic bacterial fermentation of the plant, high cost and putrid odor, environmental problems and low-grade fiber. Requires high water treatment maintenance. | 7-14 days | Flax, Hemp, kenaf, jute | 1, 3, 4, 5, 6, 7 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Enzymatic retting | Enzymes such as pectinase, xylanases etc. are used to attack the gum and pectin material in the bast. The process is carried out under controlled conditions based on the type of enzyme. | Easier refining particularly for pulping purposes that degrades and provides selective properties for different applications. The enzymatic reactions cause a partial degradation of the components separating the cellulosic fiber from non-fiber tissues. The process is faster and cleaner. | Lower fiber strength | 12-24 hours | flax | 1,8 |
| Chemical retting | Boiling and applying chemicals normally sodium hydroxide, sodium | It is more efficient and can produce clean and consistent long and smooth surface bast fiber | The fiber retted in more than 1% NaOH the tensile strength decreases. Unfavorable color and high processing cost. | 1 hour | Kenaf, jute, flax | 9, 10 |
| Mechanical retting | Hammering or fibers are separated by hammermill or decorticatore | Produces massive quantities of short fiber in short time | High cost and lower fiber quality. | | Kenaf | 11 |

**Source-** [1]Van Sharma 1992; [2]Sharma and Faughey 1999; [3] Sharma 1987a; [4] Hongqin and Chongwen 2007; [5] Cochran, et al. 2000; [6] Banik et al. 2003;[7] Rome 1998; [8] Akin et al. 2007; [9] Kawahara et al. 2005; [10] Mooney et al. 2001;[11] Paridah and Khalina 200

**Table 3- Extraction of fibers from agricultural bio wastes**

| **Researchers** | **Methods** | **Details** | **Agriculture bio waste used** |
|---|---|---|---|
| Mukherjee, 1972 | Microbial retting | Bacteria such as *Bacillus* and *Clostridium* has been used | Corn stalks |
| Henriksson, *et al*., 1997 | Microbial retting | fungi such as *Rhizomucor pusillus* and *Fusarium lateritium* has been used | Dew retted flex |
| Collier and Collier, 1998 | Mechanical separation | Tilby process; Separated fibres from plant components without disintegrating their constituents | Corn and sorghum stalks |
| Focher *et al*., 1998 | Mechanical separation | Tilby process and steam explosion; cellulose fibres extracted | Wheat straw and rind of sugarcane |
| Henriksson *et al.*, 1997 | Chemical retting | Alkalinization using Sodium hydroxide | Flex |
| Majumdar and Chanda, 2001 | Chemical retting | Alkalinization using Sodium hydroxide; Usings Acids like Sulphuric acid and oxalic acid | Flex |
| Yilmaz, 2013 | Chemical retting | Alkalisation using NaOH | Corn stalks |
| Reddy and Yang, 2005 | Chemical retting | Chromic acids | Switchgrass leaves |

**3.2.4 Mechanical separation of fibers** –

Review works finding state natural fibers are also separated mechanically by using decorticating machines, steam explosion (STEX), ammonia fiber extraction, Tilby process etc. Collier and Collier, 1998 used the Tilby process for extracting fibres from corn, sorghum and other lignocellulosic plant stalks. This process offers the advantage of separating the plant components without disintegrating their constituents, which can be further treated to extract fibers and other bioproducts. Focher *et al.*, 1998 found Tilby process and steam explosion as suitable mechanical method for extracting cellulose fibres from wheat straw and rind of sugarcane which is suitable for textile, paper and composite use.

## IV. FIBER PROPERTIES

Fibers from the switch grass leaves and stems have very similar width of single cell but the switch grass leaves have slightly longer single cell then stem. Natural cellulose fibers obtained from cotton stalks are coarser than that of linen as given in Table 4.The presence of short single cells and the formation of the fibers by a bundle of single cells results in relatively coarser fibers from cotton stalks compared to linen fibers.

The soybean straw technical fibers have deniers of about 65 and in the range of about 30–90 as given in Table 1.4.Technical fibers obtained from soybean straw are much coarser than the cotton mainly because soybean straw technical fibers are a bundle of single cells whereas cotton is a single cell fiber. However, finer denier soybean straw technical fibers have fineness similar to that of jute fibers and the coarser soybean straw fibers are similar to that of cornhusk, cornstalk and sorghum stem and leaf fibers. The soybean straw technical fibers have longer lengths than cotton and similar to the lengths of fibers obtained from sorghum and cornstalks and the length of the fibers being suitable for processing on the long staple spinning system with fibers such as linen. However, the soybean straw can be cut to obtain technical fibers with the desired length to process on the short staple system with fibers such as cotton. Lower % crystallinity, poor crystal orientation and presence of a bundle of single cells are some of the factors that contribute to the lower strength of cotton stalk fibers compared to linen.

**Table 4 -**Mechanical properties of extracted fiber from different agro bio wastes

| **Publisher Year** | **Bio waste** | **Strength( g per denier)** | **Crystali-nity (%)** | **Moisture regain(%)** | **Elongation(%)** |
|---|---|---|---|---|---|
| Narendra Reddy and Yiqi Yang 2007 | Switchgrass leaf | 5.5±**1.2** | 51 | 10 | 2.2± .7 |
| Narendra Reddy and Yiqi Yang 2007 | Switchgrass stem | 2.7± .8 | 46 | 9.3 | 66.8± 2.1 |
| Narendra Reddy and Yiqi Yang 2008 | Soybean straw | 2.7± 1.4 | 47± .4 | 11.2 | 3± 1.8 |
| Narendra Reddy and Yiqi Yang 2009 | Cotton stalk fibre | 2.9±**1.4** | 47± .2 | 8.8± 2.2 | 3.9± 1.4 |
| Batra 1998 | Linen | 4.6 6.1 | 65 70 | 12 14 | 1.6 3.3 |

Although fibre properties of corn stover have been studied for decades, the first systematic investigation of cell morphology and fibre quality of different corn stover fractions was performed by Li et al. [Li 2012]. Individual fibres were connected in bundles by middle lamella with the highest lignin concentration. Obvious differences in cell morphologies and chemical compositions between four different plant fractions, i.e. stalk rind and stalk pith, and leaf blade and leaf sheath were observed. Fibres were shorter and finer in stalk pith and parenchyma,and vessel content was the highest in this part of the plant. Therefore it was not suitable for papermaking, while morphological characteristics of fibres from corn stalk rind were appropriate as papermaking materials. There were also differences in lignification and hemicellulose content. Sclerenchyma cells in stalk rind were more lignified than those in other tissues. The lowest hemicellulose content was observed in stalk rind [Li 2012].

Natural fibres are currently attracting a lot of attention for reinforcement. Fibre reinforced composites consists of fibre as reinforcement and a polymer as a matrix. Their special advantage is their low cost, low density, good mechanical properties, biodegradability, etc. The advantage of natural fibre composites includes lack of health hazards and non-abrasive nature [Sreenivasan 2012]. Natural fibres provide stiffness and strength to the composite and are easily recyclable. Natural fibres from conventional and unconventional source are considered as potential replacement for man-made fibres in composite materials for their reinforcement. They are a renewable material. In addition to, an important advantage of these materials is their biodegradability and low toxicity. It was confirmed by many researchers that properties of natural fibres of different origin improve composites properties, e.g. the mechanical properties of natural fibres - polymer composites are superior to those of the unreinforced materials

## V. CONCLUSION

In this review works, It is found that several agricultural bio-waste like rice husks, rice straw, rape straw, wheat straw, corn straw, cornstalk, rye straw, hemp straw, flex straw, carrot leaves, sorghum stalks and leaves, pineapple and banana leaves, sunflower straw, bean straw can be used for extraction of natural cellulose fibres which is suitable for textile, composite, and other industrial applications. Several fibre extraction methods has been reviewed which includes different extraction processes namely enzymatic, alkaline and retting. The retting method is the predominant challenge in the application of bast fibres. The selection of retting method is most important if the fibres are to be used in textiles. Studies have shown that the most efficient method is by combining chemical and enzymatic retting. Sodium hydroxide is found to be most commonly used chemical for fiber extraction. Based on different review studies mechanical properties of extracted fiber from different agro bio wastes were also analyzed. The main indicators of these properties are length, strength, fineness, crystallity and elongation. The future of use of agro bio waste for fibre extraction also depends on the end uses of the fibres.

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