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Research Article

Sugarcane Waste: Adding Value by Developing Nonwovens

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Abstract

Food, clothing and shelter are the three basic needs of human beings, and for clothing, man had been using textile fibres right from the 'Old stone age'. Textiles were indeed primarily agriculture-based until the 1960s with natural fibers such as cotton, linen and wool dominating 80 percent of the market. The agricultural waste is one of the most important problems that must be resolved for the conservation of global environment. Agricultural waste, which includes both natural (organic) and non-natural wastes, is a general term used to describe waste produced on a farm through various farming activities. In tropical regions of the world, Sugarcane represents a major crop. For every 10 tonnes of sugarcane crushed, a sugar factory produces nearly three tones of wet bagasse. Bagasse is a cellulosic residue left after sugar is extracted from sugarcane. Basically, it is a waste product that causes mills to incur additional disposal costs. It consists of water, fibers, and small amounts of soluble solids. It is often used as a fuel within the sugar milling industry. Burning of this waste bagasse, releases a variety of products into the atmosphere which is also a major cause of pollution in some cities. This research was taken up to explore the possibility of extracting fibres from waste bagasse and its product diversification. In this study attempts were made, to extract the fibre from the sugar cane bagasse waste using alkaline treatment of NaOH with varying concentration of the alkali and treatment time and optimized the suitable extraction conditions on the basis of three parameters viz. quantity of fibre, chemical composition and tensile strength. Optimized conditions for fibre extraction were found to be 0.1 N NaOH, 3 hours at 90 ∘ C. Physical and chemical properties of extracted fibre were also studied and it was found suitable for manufacturing Nonwovens. Nonwoven were prepared using Needle punched method. This paper concludes that the Nonwovens from sugarcane waste have wide potential application under the segments of technical textiles such as Geo-textiles, Agro-tech, hygiene products, agricultural end uses, animal bedding and aquaculture etc. Promoting technical textiles as a tool of value addition for survival and revival of Indian textile industry holds a high potential of success.

Keywords: Bagasse; Non-Woven; Technical Textiles; Agro-Waste

Introduction

Agricultural and food industry residues, refuse and wastes constitute a significant proportion of worldwide agricultural productivity. It has variously been estimated that these wastes can account for over 30% of world wide agricultural productivity. The Central Institute of Post-Harvest Engineering and Technology (CIPHET), Ludhiana has estimated the annual value of harvest and post-harvest losses of major agricultural produces at national level to be of the order of Rs. 92,651 Crore calculated using production data of 2012-13 at 2014 wholesale prices. Assuming that 40% of the production is available as waste and at least 10% of the waste by weight can be obtained as fibre, millions of metric tons of fibre are available every year and the amount will increase annually. These waste could be the potential resources for reinforcing materials in bio-composite applications. The utilization of such resources will not only provide the sustainable and less expensive material but at the same time will contribute the waste disposal management as well as overcoming the environmental problems.

The agricultural waste fibres are of notable economic and cultural significance all over the world are used for building materials, as a decorative product and as a versatile raw product. These fibres also have significant potential in composite due to its high strength, environment friendly nature, low cost, availability, and sustainability. The potential properties of agricultural waste fibres have sparked a lot of research to use these fibres as a material to replace man-made fibres for safe and environmentally friendly product. Agricultural waste is seen as one potential source of renewable energy. Their availability is obtained from oil palm plantations and some other agricultural industry such as rice husk, rice straw, sugarcane, pineapple, banana, and coconut. Agricultural waste produces large amounts of biomass that are classified as natural fibres which until now only 10% are used as alternative raw materials for several industry, such as bio-composites, automotive component, biomedical and others.

Sugarcane bagasse is one of the agricultural residues, produced in large quantities in several countries of the World. India has the largest area under sugarcane cultivation and is the world's second largest producer next only to Brazil. In India, Uttar Pradesh has the largest area almost 50 per cent of the cane area of the country, followed by Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh, Gujarat, Bihar, Haryana, and Punjab. These nine states are most important sugarcane producing states of India [1].

Figure 1: Sugarcane Plant Morphology [2].

Figure 2: Structure of Sugarcane Stalk [3].

In tropical regions of the world sugarcane represents a major crop. In India Uttar Pradesh is the largest sugarcane producing state, which has 38.61% share in overall sugarcane production. In Gujarat, Surat, Bhavnagar, Rajkot, Junagadh and Jamnagar are the important sugarcane producing districts. Sugarcane Bagasse fibre is one of such fibre which can be explored for its use in textiles. Bagasse is a fibrous residue that remains after crushing the stalks and contains short fibers. Basically, it is a waste product that causes mills to incur additional disposal costs. There are numerous application possibilities used as fibre, powder and pulp form. This can be used for making non-wovens used in geotextile applications, hygiene products, agricultural end uses, animal bedding, aquaculture etc.

India has tremendous potential for production, consumption and export of technical textile. The latest developments in textiles and their industrial uses have lead to the birth and development in technical textile. Technical textile goods are mostly manufactured for non-aesthetic purpose where the function is its criteria. This is a very vast and rapidly developing sector as it supports many industries. Exploration of this waste bagasse will add to the technical textiles.

Objectives

This study is planned with the following objectives

- To extract the fibre from sugarcane bagasse waste.
- To test the properties of extracted fibre and optimize the extraction conditions.
- To manufacture a nonwoven fabric.

Material and Methods

For present study, waste bagasse was procured from local sugarcane juice extraction vendors of Vadodara city, Gujarat. After procurement of wet bagasse, it was kept under sun for proper drying. The bagasse is composed of an outer rind and inner pith. The outer rind of cane contains bundle of fibres. By mechanical means, outer rind were separated from inner pith for extraction of fibre. The outer rind was subjected to boiling for removal of color and loosening of fibres. Fibres were extracted at different alkaline conditions viz. 0.1 (N), 0.2 (N), 0.3 (N) with varying time. Physical and chemical properties viz. microscopic appearance, length, diameter, fineness, moisture regain, chemical composition and tensile strength of the extracted fibre were studied. On the basis of chemical composition, tensile strength and fibre quantity, fibre extraction conditions were optimized. Nonwovens were prepared using Needle-punched method.

Results and Discussions

Extraction of fibre from waste bagasse

The fibres were extracted from waste bagasse through mechanical and chemical treatment. First, wet bagasse were dried under sun-light. After drying, nodes were removed. Outer rind were separated from the inner pith mechanically. The seperated outer rind were subjected to 60 minutes of boiling for easy opening of fibres. After boiling, the outer rind was treated with alkaline treatment under the presence of heat with mild stirring conditions. Sodium Hydroxide (NaOH) was used for alkaline treatment in different concentrations viz. 0.1 (N), 0.2 (N), 0.3 (N) for 1hour, 2hour, 3hour and 4hour respectively at 90^0 C. After treatment, the fibres were taken out and washed with hot and then cold water to neutralize and then dried in sun light.

Figure 3: Extraction Process: From Waste Bagasse to Fibre.

Optimization of extraction conditions

The prepared material (baggase) was subjected to NaOH solution in three different concentrations viz 0.1 (N), 0.2 (N) and 0.3 (N) for 1hour, 2hour, 3hour and 4hours for each concentration at 900 C. There were three parameters for optimization of extraction process:

- Fibre quantity
- Chemical composition
- Tensile strength

NaOH Conc. and duration	Fibre Quantity (%)	Stress (g/den)	Chemical composition (%)	
			Cellulose	Lignin
0.1 (N) (3 hour)	55.00	2.02	69.50	13.50
0.1 (N) (4 hour)	61.00	1.91	66.50	13.50
0.2 (N) (3 hour)	55.00	1.87	67.00	11.50
0.2 (N) (4 hour)	50.00	1.84	66.00	9.50
0.3 (N) (1 hour)	51.00	1.50	70.00	11.50
0.3 (N) (2 hour)	46.00	1.23	70.00	9.50

Table 1: Optimization of extraction conditions.

From the table 1, it is seen that fibres extracted with 0.1 N NaOH concentration, for 3 hours contains 69.50% cellulose with 13.50% lignin which was the good chemical composition found than the fibres extracted in other conditions. The tensile strength of fibre was 2.02g/den and the 55% was the fibre quantity obtained. Thus, for fibre extraction, 0.1 N NaOH, 3 hours at 90^0 C was the optimized treatment condition.

Physical and chemical properties

- **Microscopic Appearance:** The longitudinal and cross sectional characteristics of fibre was studied by microscopic analysis. The fibre was observed under the Scanning Electron microscope (SEM) at BTRA Laboratory, Mumbai.
  The SEM photographs reveals that the cross section of fibre similar to most of the lignocellulosic fiber (Jute), fiber shows irregular shape and diameter variations. It is observed that there is more encrusting material between the ultimate cells revealed in the cross - sectional view of the fibre. Thick walls, irregular lumen (visible in 45X with polorized light microscope).
- **Physical properties:** Physical properties of extracted fibres: length, fineness, diameter, length to breadth ratio, Moisture regain and Tensile strength were tested by using standard (ASTM D 3822) testing methods (Table 2).

S. No.	Properties	Value (%)
1	Fibre Length (cm)	9.5 (5-12)
2	Fibre Fineness (denier)	288
3	Fibre Diameter (μm)	25 (18-35)
4	Fibre length to breadth ratio	1:3800
5	Tensile Strength (g/den)	2.05 (1.92-2.31)
6	Moisture Regain (%)	13-18

Table 2: Physical properties of fibre.

Fibre tensile strength

From the above table, the result indicates that the tensile strength of extracted fibre was found in terms of stress% i.e., 2.02 gm/den followed by 1.06% strain. The tensile strength describes the response of a textile material when an external force is exerted on it until it breaks.

Fibre	Denier	Maximum Load (gf)	Max Extension (mm)	Stress (gm/den)	% Strain
Tensile Strength	345.60	738.84	1.06	2.02	1.06

Table 3: Tensile strength of extracted fibre.

Fibre Fineness and Evenness

In Direct system, the fibre fineness value obtained was 228 denier. Fibre evenness was obtained by plotting a graph by taking 100 readings of fibre diameter through microscopic observation.

Figure 4: (a) Longitudinal view 45X, (b) Cross-sectional view 45X, (c) Cross-sectional view 100X.

Large variation was observed in the diameter of the fibre along its length between different fibres (Figure 5) The graph shows that most of the readings lies between 10-25 μm. The mean and standard deviation for fibre diameter were calculated as 22.41 μm and 7.23 respectively. Therefore, it can be concluded that sugarcane fibre is very uneven.

- **Chemical Composition:** Chemical composition of fibre were tested, using the method given by Turner and Doree [6-13] using Soxhlet Apparatus (Table 4).
- **Manufacturing of Nonwoven:** Fibres extracted from optimized treatment conditions found suitable for preparing nonwovens. Needle punched method was used to preparing Nonwoven. The nonwoven prepared in two different GSM i.e., 800g/m2 and 1000g/m2 of 100% sugarcane fibre.

S. No.	Constituents	Composition (%)
1	Water Soluable	12.0
2	Fat and Waxes	2.5
3	Pectin	1.0
4	Hemicellulose	1.5
5	Lignin	13.5
6	Cellulose	69.5

Table 4: Chemical composition of fibre.

Figure 5: Fibre Evenness graph.

Figure 6: Nonwoven.

Figure 7: Needle Punching machine.

Conclusion

Waste bagasse is considered as a type of unconventional fiber because of its very limited applicability in textile industry. Fibres are to be modified chemically for specific end use. Agricultural waste can be a source for producing technical textiles which will help in reducing waste as well. Technical textiles in the form of shelter, protection, transportation etc. are most suitable from the point of logistics for the victims of cyclone, draught, flood, earthquake, fire etc., which are rather frequent events in our country every year. In digenisation of technical textiles will not only contain import and achieve strategic self sufficiency in sensitive and emerging areas of applications like defence, aerospace, sustainable development, waste management etc. but also provide new avenues of value-added exports. Promoting technical textiles as a tool of value addition for survival and revival of Indian textile industry holds a high potential of success. The following conclusions are drawn

- The tenacity of fibres extracted under optimized condition, was found 2.02g/den. Fibre quantity was obtained 55%. Chemical composition was found 69.15% cellulose and 14.5% lignin, respectively.
- The morphological characteristics of fibre revealed irregular shape and variations in diameter. More encrusting material between the ultimate cells was observed in the cross - sectional view of the fibre. Presence of numerous voids around lumen indicates its multi-fibrillar structure.
- Fibres extracted with optimized conditions found suitable for preparing Nonwovens. The nonwoven were prepared in two different GSM i.e., 800g/m2 and 1000g/m2 of 100% sugarcane fibre.
- The reason for limited use of these fibers is attributed to its difficult extraction, processing and also limited knowledge of these fibers to be used as textile fiber among the people. Proper extraction method will contribute to the maximum utilization of the agricultural waste.

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