APPLICATION OF SUGARCANE BAGASSE FIBRE IN TECHNICAL TEXTILES

Synopsis of Proposed PhD. Thesis

By:

Chhavi Gangwar

Ph.D. Student

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Ph.D. Guide:
Prof. (Dr.) Madhu Sharan
Professor
Department of Clothing and Textiles
Faculty of Family and Community Sciences

Ph.D. Co-Guide :
Dr. D.P. Chattopadhyay
Retd. Professor
Department of Textile Chemistry
Faculty of Technology & Engineering

DEPARTMENT OF CLOTHING AND TEXTILES
FACULTY OF FAMILY AND COMMUNITY SCIENCES
THE MAHARAJA SAYAJIRAO UNIVERSITY OF BARODA,
VADODARA, GUJARAT,
INDIA

INTRODUCTION

Natural fibre production, processing and export are vital to the economies of many developing countries and the livelihoods of millions of small-scale farmers and low-wage workers. At present, many of those economies and livelihoods are under threat: the global financial crisis has reduced demand for natural fibres as processors, manufacturers and consumers suspend purchasing decisions or look to cheaper synthetic alternatives. Increased utility of fibre will encourage farmers and other people involved in the production and use of natural fibres. Natural fibres are obtained from plants, animals and mineral sources.

Many useful fibres have been obtained from various parts of plants including leaves, stems (bast fibres), fruits and seeds. The most used plant fibres are cotton, flax and hemp, although sisal, jute, kenaf, bamboo and coconut are also widely used. Based on the usage the fibres thus obtained are classified as Major (widely used) and Minor (limited used) fibres. Minor cellulosic fibres are hemp, sisal, kapok, ramie, coir and pina fibres. The usage of minor fibres in composite nonwovens has increased remarkably during the last few years. One reports report stated that the ratio of consumption of natural to synthetic fibres in the World was around 60:40, but today the ratio is 40:60 because of the increase of market share by synthetic fibres (1).S ome natural fibres are cheaper than conventional synthetic fibres and since they have the potential to be recycled and are eco-friendly through their biodegradability and renewability, they can be explored for their advantages.

Sugarcane Bagasse is one of the fibre which can be explored for its use in textiles. Bagasse is a fibrous residue that remains after crushing the stalks and contains short fibres (Fig. 1.1).

Fig. 1.1 Waste Bagasse after Juice Extraction

Table 1.1. Average Bagasse Composition

Content	Bagasse (%)
Moisture	49.00
Fibre	48.70
Soluble Solids	2.30

It is a waste product that causes mills to incur additional disposal costs. It consists of water, fibres and small amounts of soluble solids. Per cent contribution of each of these components varies according to the variety, maturity, method of harvesting, and the efficiency of the crushing plant. In table 1.1. (Elsunni, 1996) a typical bagasse composition is given. Fibres extracted from waste bagasse are called sugarcane bagasse fibres. The sugar cane stalk is composed of an outer rind and inner pith (Fig. 1.2)

Fig. 1.2 Billets of Sugar Cane Stalks

The inner pith of sugarcane is an abundant source of short bagasse fibres, which can be used as a raw material for wood pulp. The outer ring of sugarcane gives longer and finer fibres. They are extracted through mechanical or chemical means from the sugarcane after extraction of the juice.

Table 1.2. Chemical Constituents of Bagasse

Chemical Costituents	Content (%)
Cellulose	32-48
Hemi-cellulose	27-32
Lignin	18-26

The fibres are arranged in a random manner inside the stem and kept together using binding materials such as lignin and hemicelluloses (table 1.2.)

India has the largest area under sugarcane cultivation in the world and this is the world's second-largest producer of sugarcane next only to Brazil. The largest sugarcane-producing state of India is Uttar Pradesh, which has a 38.61% share in overall sugarcane production as per 2013-14 figures. The second and third largest states are Maharashtra and Karnataka. Other main sugarcane-producing states of India include Bihar, Assam, Haryana, Gujarat, Andhra Pradesh and Tamil Nadu. Gujarat produces only 4.99 per cent sugarcane from the 4.65 per cent area of India. Its recovery of 10.31 per cent of sugar is one of the highest among the major sugar cane-producing states of India. Surat, Bhavnagar, Rajkot, Junagadh and Jamnagar are important sugarcane-producing districts (14). The Bagasse can be explored further. Minor cellulosic fibres which are available can be modified for their use in technical textiles. Thus it is proposed to explore Sugarcane Bagasse fibre for technical textiles.

Technical textiles offer new ways, means and opportunities to the Indian textile industry to sustain the present growth and thrive shortly. It would offer not only an opportunity to augment the growth but also a new direction for the advancement of the industry. The field of technical textiles had not received adequate importance in the Indian context so far, however, it is a potential area where the textile industry can excel. Technical textile is a textile product manufactured for non-aesthetic purposes, where the function is the primary criterion. It is a large and growing sector and supports a vast array of other industries. Technical textiles include textiles for automotive applications, medical textiles (e.g., implants), geotextiles (reinforcement of embankments), geotextiles (textiles for crop protection), and protective clothing. (Kanimozhi,2012)

Technical Textiles is a high technology sunrise sector which is a necessity in India. The potential of technical textiles in India is still untapped. The global growth rate of technical textiles is about 4% per year greater than the growth of home and apparel textiles, which are growing at a rate of 1% per year. Globally, technical textiles contribute to about 27 per cent of the textile industry, in some western countries their share is even 50 per cent while in India it is 11 per cent. Currently, technical textile materials are most widely used in filtering clothing, furniture, hygiene medicals and construction material. Technical Textiles provides a new opportunity for the textile industry to have a long-term sustainable future (11).

Nonwovens are unique, high-tech, engineered fabrics made from fibres bonded together by chemical, mechanical, heat or solvent treatment. Nonwovens are innovative, versatile and indispensable. Nonwovens are used in a wide range of consumer and industrial products with diverse properties like geotextiles, medical & healthcare, agriculture and horticulture, filters, packaging, home furnishing, etc.(Dhange et al, 2012). Nonwovens present several advantages over woven and knitted fabrics such as lower cost, no edge fraying, random fibre distribution, low density, high tear strength, patternless surface appearance, high water retention capacity and good adhesion.

Needle-punched fabrics are bonded mechanically by needling. The needles punch vertically in and out of the material. The machine then transports the material and the needles come down again. This process locks the fibres together. In the needle punching process, the determination of the appropriate level of needle punching is not simple. Excessive punching results in considerable damage to the fabric layers, but insufficient punching results in minimal bridging between the fabric layers. (M Kanimozhi, 2012).

Oil is one of the important sources of energy in the modern industrial world. It has to be transported from the source of production to many places across the globe through oceans and inland transport. During transportation, the chance of oil spillage over the water body occurs due to accidents or deliberate action during wartime and this causes environmental pollution. An oil spill is the release of a liquid petroleum hydrocarbon into the environment, especially marine areas, due to human activity, and is a form of pollution. The term is usually applied to marine oil spills, where oil is released into the ocean or coastal waters, but spills may also occur on land. Oil spills may be due to releases of crude oil from tankers, offshore platforms, drilling rigs and wells, as well as spills of refined petroleum products (such as gasoline, and diesel) and their by-products, heavier fuels used by large ships such as bunker fuel, or the spill of any oily refuse or waste oil (10).

Oil spills can have disastrous consequences for society; economically, environmentally, and socially. Despite substantial national and international policy improvements on preventing oil spills adopted in recent decades, large oil spills keep occurring. It also disturbs the aquatic life and water cycle. Oil spills at sea are generally much more damaging than those on land since they can spread for hundreds of nautical miles in a thin oil slick which can cover beaches with a thin coating of oil. These can kill seabirds, mammals, shellfish and other organisms they coat.

Purpose of the study

- In tropical regions of the world, sugarcane represents a major crop. Because of the increasing demand for sugar, large areas in tropical and subtropical countries all around the world were allotted for sugarcane crops.
- In India, Uttar Pradesh is the largest sugarcane-producing state, which has a 38.61% share of overall sugarcane production. Besides the main product sugar juice, several by-products are available in the sugarcane extraction process. The most important is considered to be bagasse. It is an eco-friendly renewable resource available in nature. Bagasse is essentially a waste product that causes mills to incur additional disposal costs.
- From the review, it was found that sugarcane bagasse has some inherent properties of oil sorption and it’s a waste and biodegradable.
- The oil spill is the major problem in the present context. It affects not only the resource but also marine life, birds and mammals. There is a need to find a solution to this problem.
- Conventional oil removal techniques generate secondary pollution and lose the oil either due to burning or consumption by microorganisms.
- Due to the inherent property of oil sorption, Sugarcane Bagasse fibre can be explored for its use in the separation and recovery of oil from oil spills.

Hence, the study was taken up to explore the feasibility of using this waste and optimizing the treatment conditions at different stages. Keeping all the above factors into consideration the researcher decided to take up this study with the following objectives:

Objectives of the study:

1. To extract and optimize conditions for extraction of fibre.
2. To test the physical and chemical properties of extracted fibres.
3. To fabricate a machine for extraction of fibre.
4. To modify the extracted fibres for enhancing their sorption capacity through Acetylation, Cyanoethylation and enzyme treatment.
5. To test the modified fibres and optimize the treatments :

a) Oil sorption capacity

b) Recovery of sorbed oil

c) Reusability of sorbents

d) Oil retention ability

6. To study the characterization of optimized fibres: FTIR, SEM analysis.
7. To prepare oil sorbent nonwoven and test its sorption and recovery properties.

Delimitation of the study:

1. The study was limited to three modification treatments namely: Acetylation, Cyanoethylation and Enzyme treatment.
2. The study was limited to the sorption capacity of bagasse in three different viscosities of Oil.
3. The study was limited to four types of oil testing namely: Oil sorption capacity, oil retention ability, recovery of sorbed oil & reusability of sorbents.
4. The study was limited to the construction of non-woven through Needle punching.

Scope of the study:

The study aimed to use waste sugarcane bagasse fibre as a valuable natural fibre for technical textile applications. In the present scenario, it is expected that new job opportunities will be generated in the local industry. The local manufacturers will have access to new technologies for processing and production of sugarcane bagasse fibres. Because of their innovative products, they will be able to enter new markets.

One of the expected outcomes of the study is the production of high-quality natural fibres and oil sorbent materials from Sugarcane bagasse fibre with high sorption capacity. These fibres have a high potential to substitute synthetic fibres (Polypropylene) in multiple technical textile applications. The use of these natural fibres might be very beneficial for the oil sorption process because they can be substantially absorbed and recovered oil.

Utilizing these natural fibres will decrease the cost of the components considerably due to the no costs of the raw material because it’s a waste which is available in abundance. Moreover, production costs of extraction of fibres will be reduced with the help of apparatus fabricated by the researcher. Local production can have an increasing share in the future.

REVIEW OF LITERATURE

A literature review is an evaluative report of information found in the literature related to a selected area of study and it allows the reader to be updated on the state of research in a field and any contraindications that may exist those challenge findings of other research studies. In this chapter, the researcher attempted to discover specific literature materials relevant to the study and integrate the new readings into it.

This chapter deals with the theoretical and research knowledge of natural fibres. The investigator visited and collected the literature through books, journals and thesis from various libraries in different universities of India such as the Central Library of Delhi University, Lady Irwin College Library, Delhi University, Central Library, Indian Institute of Technology (IIT), Delhi College Library, Avinashilingam Institute for Home Science and higher education for Women, and Smt. Hansa Mehta Library (Central Library), T.K. Gajjar library at Faculty of Technology and Engineering, and the library of Department of Clothing and Textiles, Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda, Vadodara.

The Researcher also visited various centres of excellence for collecting literature viz. SITRA (South India Textile Research Association), Coimbatore, BTRA (Bombay Textile Research Association) Mumbai, ATIRA (Ahmadabad Textile Industry’s Research Association), ICAR-CIRCOT (Central Institute for Research on Cotton Technology) Mumbai, DKTE Central Library, Icchalkaranji, DKTE centre of excellence in nonwovens, Ichalkaranji, Maharashtra, CICT(Central Institute of Coir Technology), Bangalore, Sugarcane Research Station, Navsari Agricultural University, Gujarat, Indian Institute of Sugarcane Research (ICAR), Lucknow, Uttar Pradesh. Another important secondary source of collecting information was Shodh Ganga, e-books and various online web sources.

Keeping in mind the objectives of the study, the review of literature of relevance concerning the present study is arranged in this chapter under the following subheadings:

2.1 Theoretical Review: It has been discussed under the following sub-heads:

2.1.1. Agro-Waste

2.1.2. Technical Textiles

2.1.3. Structural modification of fibre

2.1.4. Oil Spill and its environmental hazardous

2.2. Research Review: The research review has been discussed under the following sub-heads:

2.2.1. Cellulosic Minor Fibres

2.2.2. Chemical modification treatments

2.2.3. Sorbents for specific end-use

2.2.4. Sugarcane Bagasse fibre

Structurally sugar cane (Saccharum Officinarum) stalk is composed of an outer rind and an inner pith. According to Paturau (1989), the majority of sucrose together with bundles of small fibres is found in the inner pith. The outer rind contains longer and finer fibres, in a random arrangement throughout the stem and is bound together by lignin and hemicellulose. Previous studies on the extraction of the fibres from sugar cane rind demonstrated that controlled amounts of lignin and hemicellulose could be removed through alkaline and mechanical treatments, resulting in bundles of relatively thin fibres (Collier *et al*, 1992).

Research at Louisiana State University (LSU) has been conducted to determine the feasibility of sugar cane rind fibres for textile and geotextile applications (Elsunni & Collier, 1996). One product is a nonwoven mat formed by suspending the fibre bundles on a screen in water, then dewatering and drying. The mats have been tested as geotextiles for soil erosion control in civil engineering applications (Romanoschi, 1998). A suitable nonwoven mat for geotextiles should sustain, or at least, prevent erosion. At the same time, it should be penetrable by growing plants, be capable of permitting interaction between air and soil, and allow rain to penetrate the soil and drain excess water (Collier *et al*, 1995). Thus, a low-cost, biodegradable geotextile can be produced in local sugar cane mills, providing an economic benefit to both the transportation industry and the sugar cane industry.

Industrial textiles are now more often viewed as a subgroup of a wider category of technical textiles, referring specifically to those textile products used in the course of manufacturing operations (such as filters, machine clothing, conveyor belts and abrasive substrates) which are incorporated into other industrial products (such as electrical components and cables, flexible seals and diaphragms or acoustic and thermal insulation of domestic and industrial appliances) state Horrocks and Anand (2004).

Sun.X.F et al (2004) conducted a study on “Acetylation of sugarcane bagasse using NBS as a catalyst under mild reaction conditions for the production of oil sorption-active materials”. In this study, Sugarcane bagasse was esterified with acetic anhydride using N-bromosuccinimide as a catalyst under mild conditions in a solvent-free system. The extent of acetylation was measured by weight per cent gain, which varied from 2.1% to 24.7% by changing the reaction temperature (25–130○C) and duration (0.5–6.0 h). N-Bromosuccinimide was found to be a novel and highly effective catalyst for the acetylation of hydroxyl groups in bagasse. At a concentration of 1% of the catalyst in acetic anhydride, a weight per cent gain of 24.7% was achieved at 120○C for 1 h, compared with 5.1% for the un-catalyst reaction under the same reaction condition. FT-IR and CP-MAS13C-NMR studies produced evidence for acetylation. The thermal stability of the products decreased slightly upon chemical modification, but no significant decrease in thermal stability was observed for WPG ≥ 24.7%. The oil sorption capacity of the acetylated bagasse obtained at 80○C for 6 h, was 1.9 times higher than the commercial synthetic oil sorbents such as polypropylene fibres. The results revealed that the acetylation significantly increased the hydrophobic properties of the bagasse.

They concluded from their research that the acetylated SCB can be used as a natural sorbent in oil spill cleanup, and its oil sorption capacity was much higher than that of the synthetic sorbents, indicating that a total or partial substitution of commercial synthetic oil sorbents by acetylated SCB could be beneficial in oil spill cleanup operations by improving the efficiency of oil sorption and by incorporation other advantages such as biodegradability.

According to Reddy *et al* (2005), 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 bio fibres represent a potential for use in the 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 bio fibres.

Bayat *et al* (2005) studied the performance of three sorbents to determine their potential for oil spill cleanup. The sorbents were selected from natural and synthetic categories. Bagasse and rice hull as natural materials and polypropylene nonwoven web as synthetic sorbents were used. The results obtained that polypropylene can sorb almost 7 to 9 times its weight from different oils. Bagasse, 18 to 45 mesh size, follows polypropylene as the second sorbent oil spill cleanup.

Bagasse, 14 to 18 mesh size, and rice hull have comparable oil sorption capacities, which are lower than those of the two former sorbents. It was found that oil viscosity plays an important role in oil sorption by sorbents. Bagasse and rice hull was agricultural wastes and pose disposal problems, but they are biodegradable and of low price. Also, they both are usually burned as fuels and, have been used as oil sorbents.

Tserki, V. & N.Z. (2005) Conducted a study on "A study of the effect of acetylation and propionylation surface treatments on natural fibres". In this study, two fibre pre-treatment methods, acetylation and propionylation, were applied on flax, hemp and wood fibres. The effect of esterification between the acetyl/propionyl groups and the hydroxyl groups of the fibre was examined by attenuated total reflectance-Fourier transform infrared (ATR-FTIR) and X-ray photoelectron spectroscopy (XPS), while its extent was assessed by titration. X-ray diffraction (XRD) and scanning electron microscopy (SEM) were used to characterize the crystallinity and the surface morphology of the untreated and esterified fibres. The highest extent of the esterification reaction was achieved for the wood fibres due to their high lignin/hemicellulose content. XPS and FTIR experiments revealed the presence of acetyl/propionyl groups that are involved in an ester bond with the fibre constituents for the treated fibres. Esterification decreased the hydrophilicity of the materials as indicated by the moisture adsorption reduction, while the fibre crystallinity was slightly decreased, as a result of the increase of the amorphous portion due to the esterification reaction. The SEM results revealed that both treatments resulted in a removal of non-crystalline constituents of the fibres, possibly waxy substances, and alter the characteristics of the surface topography. It was found through SEM and XPS analyses that the surface of the untreated fibres is rich in compounds that are of hydrocarbon nature, such as waxes and wax-like substances, and that the treatments altered the fibre surface characteristics, by removing the outer surface layer and producing a smoother fibre surface.

Bledzki A. K. *et al* (2008) conducted a study on " The effects of acetylation on properties of flax fibre and its polypropylene composites". Flax fibre was modified with acetylation. The influence of the acetylation on the structure and properties of flax fibre was investigated as well as modified flax fibre reinforced polypropylene composites were also prepared. The catalyst was used to accelerate the acetylation reaction rate. Flax fibre was characterised after modification. Surface morphology, moisture absorption property, components content, degree of polymerisation, the crystallinity of cellulose and thermal stability of flax fibres were studied. Due to acetylation, the flax fibre surface morphology and moisture resistance properties improved remarkably. Flax fibre (modified and unmodified) reinforced polypropylene composites were fabricated with 30 wt% fibre loading. The mechanical properties were investigated for those composites. Tensile and flexural strengths of composites were found to increase with increasing degree of acetylation up to 18% and then decreased. Charpy impact strengths of composites were found to decrease with an increasing degree of acetylation. Owing to the addition of a coupling agent (maleated polypropylene -MAH), the tensile and flexural strength properties were found to increase between 20 to 35% depending on the degree of acetylation.

Coir is a coarse, short fibre extracted from the outer shell of coconuts. There are two types of coir namely brown fibre which is obtained from mature coconuts and finer white fibre which is extracted from immature green coconuts. Coir fibres measure up to 35cm in length with a diameter of 12-25 microns. It has one of the highest concentrations of lignin making it stronger but it has good resistance to microbial action and saltwater damage. It is used in ropes, mattresses, brushes, geotextiles and automobile seats. (Kanimozhi,2012)

Automotive textile is an integral aspect of technical textiles. Since it cannot be classified as apparel textiles, it is more of a techno-mechanical application of textiles. Automotive textile means all types of textile components such as fibres, filaments, yarns and fabrics used in automobiles. Some of these components are visible while others are concealed. Examples are Truck covers (polyvinyl-coated polyester fabrics), car trunk coverings (often needle felts), seat covers (knitted materials), seat belts, nonwovens for cabin air filtration (also covered in indutech) and airbags. (Kanimozhi,2012)

Asagekar and Joshi (2013) studied the characteristics of Sugarcane fibres produced from different varieties cultivated in the western part of Maharashtra, India. Sugarcane fibres have been extracted from bagasse by 0.1 N NaOH treatment and their characteristics are evaluated. They found that there is a difference in properties of fibres between varieties as well as between maturity levels and as such no specific trend was observed. The properties of Sugarcane fibres are closer to the properties of cellulosic coir fibres. Hence, this fibre can be used for making nonwoven mats. The nonwoven can be impregnated in resins for making composites for various applications.

Behnood *et al* (2013) stated that natural sorbents are applied as a single solution for oil spills since this technique is effective, rapid and cost-saving for cleaning these pollutions and reducing environmental effects. Thus, for their study, they selected raw sugarcane bagasse as a natural organic sorbent. This sorbent was used in different particle sizes and the effect of contact time and the existence of water was studied. The results of their study show that the bagasse can be applied to effectively remove crude oil in crude oil layer pollution from marine environments. The maximum adsorption capacity of raw bagasse for the dry system was obtained at about 8 g for raw bagasse mesh number 60. The particle size effect was evaluated and it was shown that the sorption capacity improved with decreasing particle size, due to increased surface area. The maximum adsorption capacity of raw bagasse for the crude oil layer was about 6.6 g crude oil per g sorbent.

Chattopadhyay, D & Umrigar, K (2017) studied the possibility of the use of waste cotton linters as oil sorbents by chemical modification such as acetylation and cyanoethylation. Both the chemical modification processes were optimized based on the oil absorption capacity of the chemically modified cotton fibre with the help of MATLAB software. The modified samples were tested for their oleophilicity in terms of oil absorption capacity, oil retention capacity, oil recovery capacity, reusability of sample and water uptake and buoyancy as oil sorbent. The results show that Cotton waste linters were successfully acetylated using acetic anhydride in presence of either H2SO4 or HClO4 as catalysts and cyanoethylated using acrylonitrile. The modification was characterized by the FTIR spectra and SEM analysis. Maximum oil absorption was achieved at around 39.6% for cotton fibre acetylated using 3% H2SO4 at room temperature for 60 min. Cyanoethylation treatment resulted in about 35% oil absorption for cotton samples pre-treated with 2% NaOH and cyanoethylated at room temperature for 60 min. The recovery of oil from the acetylated and cyanoethylated cotton samples was about 85–90% and 80–85% respectively. It was found that the chemically modified samples can also be reused conveniently at least 3 times. In addition to oil absorption, the higher sinking time of chemically modified fibres in the water further confirmed the chemical modification. Acetylated or cyanoethylated waste cotton linters, therefore, can be suitably used for oil spill cleanup applications.

According to the New policy to make technical textiles must for ministries “As many as 92 categories of technical textiles including fire-resistant curtains, geo-grids for railways, bulletproof jackets, leno bags for transporting Agri commodities, and architectural membranes for tents, have been identified for mandatory use, according to senior government sources. Seven ministries that undertake major infrastructure and public works will lead the initiative. These are the railways, road transport, Jal shakti, agriculture, urban development, health and defence.

Technical textiles are functional fabrics used in multiple industries such as automobiles, construction and agriculture. The sector has been on the government's policy for 10 years for its high growth potential and capacity for job creation and is divided into 12 industries.

Among these, medical textiles such as implants, geo-textiles used in the reinforcement of river embankments and rocky cliff sides and agro-textiles for crop protection have been earmarked by the government as major growth creators, an official said. (2019)

RESEARCH DESIGN AND METHODOLOGY

The Research was an experimental and exploratory study. The study was conducted to construct nonwoven from extracted sugarcane fibres under optimized extraction conditions which can be used as a material for oil sorption and recovery from the oil spill. This chapter deals with the materials used and methods followed for conducting the present investigation.

It was divided into three major phases explained as follows:

The different methodological procedures adopted for the study have been described under the following heads:

3.1 Procurement and extraction of fibre from waste Sugarcane bagasse

3.2 Optimization of fibre extraction conditions

3.3 Preliminary Testing

  3.3.1 Physical properties of extracted fibre

  3.3.2 Chemical properties of extracted fibre

3.4 Fabrication of Sugarcane Fibre Extractor

3.5 Modification of fibre through chemical and enzymatic treatments

3.6 Optimization of treatments through Response Surface Design of experiment.

3.6.1 Acetylation Treatment

3.6.2 Cyanoethylation Treatment

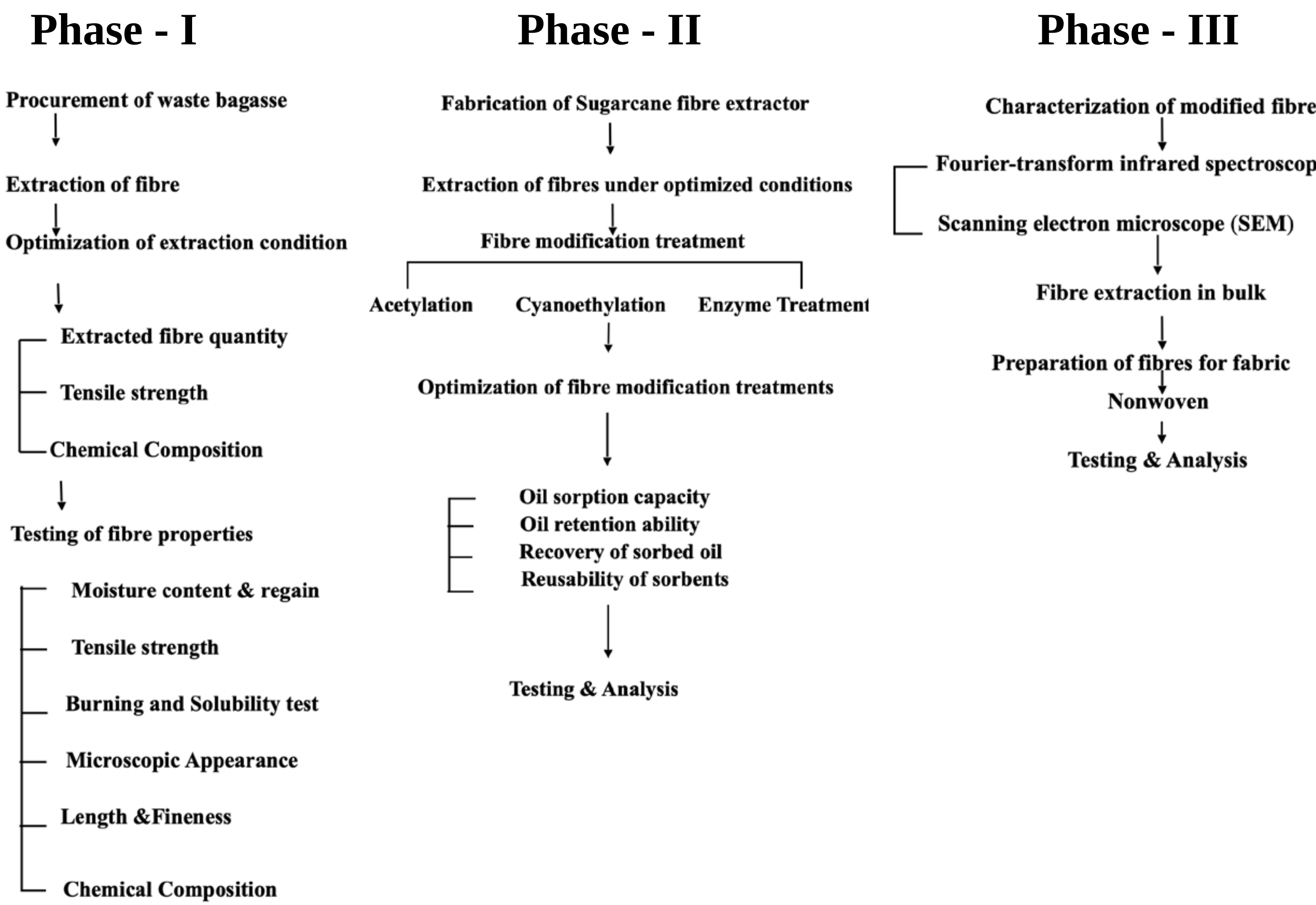
3.6.3 Enzyme Treatment

3.7 Optimized fibre Characterization through FTIR

3.8 Optimized fibre Characterization through SEM

3.9 Manufacturing of Nonwoven

3.10 Testing of Nonwoven


Phase - I
Procurement of waste bagasse
Extraction of fibre
Optimization of extraction condition
Extracted fibre quantity
Tensile strength
Chemical Composition
Testing of fibre properties
Moisture content & regain
Tensile strength
Burning and Solubility test
Microscopic Appearance
Length &Fineness
Chemical Composition
Phase - II
Fabrication of Sugarcane fibre extractor
Extraction of fibres under optimized conditions
Fibre modification treatment
Acetylation
Cyanoethylation
Enzyme Treatment
Optimization of fibre modification treatments
Oil sorption capacity
Oil retention ability
Recovery of sorbed oil
Reusability of sorbents
Testing & Analysis
Phase - III
Characterization of modified fibre
Fourier-transform infrared spectroscop
Scanning electron microscope (SEM)
Fibre extraction in bulk
Preparation of fibres for fabric
Nonwoven
Testing & Analysis

3.1 Procurement of waste Sugarcane bagasse

In this study, waste sugarcane bagasse was procured from Main Sugarcane Research Station, Navsari Agricultural University, Navsari, Gujarat.

3.1.1 Extraction of fibre

The fibres were extracted from waste sugarcane (bagasse) through mechanical and chemical treatment. The wet bagasse was dried under the sunlight for two days. After drying, nodes were removed. The outer rind was separated from the inner pith mechanically/manually. The separated outer rind was subjected to an hour of hot water treatment keeping material: liquor ratio 1:50, for loosening of fibres and removal of colouring matters and sugar traces. Then, further treated with alkali-keeping material: liquor ratio 1:100 under the presence of heat with vigorous stirring. 0.1N Sodium Hydroxide (NaOH) at 90^0C for 4 hours was used for alkaline treatment[6]. After treatment, the fibres were taken out, washed followed by neutralization by acetic acid and then dried under sunlight. Extraction of fibres was carried out in the Textile Chemistry Laboratory, Department of Clothing and Textiles, The Maharaja Sayajirao University of Baroda, Vadodara.

3.2 Optimization of fibre extraction conditions

To optimize conditions (chemical concentration and time) for the fibre extraction process: NaOH solution in three different concentrations of 0.1 N, 0.2N and 0.3 N was taken with the time duration of 1 hour, 2 hours, 3 hours and 4 hours for each concentration respectively. The following three parameters were analyzed for optimization of the extraction process:

3.3.1 Extracted fibre quantity

3.3.2 Chemical composition

3.3.3. Tensile strength

3.3 Preliminary testing

3.3.1 Physical properties of extracted fibre

3.3.1.1 Burning test

For the burning test, the fibre was moved slowly towards a small flame and the reaction to heat was observed. One end of the sample fibre was put directly into the flame to determine its burning rate and characteristics. The burning odour was also noticed.

3.3.1.2 Fibre Morphology

The longitudinal & cross-sectional characteristics of fibre were studied by microscopic analysis. The longitudinal section of the fibre was observed under a polarized light microscope with a magnification of 45 X power. The cross-sectional view of the fibre was observed under a polarized light microscope with a magnification of 45 X power as well as under a Scanning Electron microscope (SEM) with a magnification of 50 X to 2500 X power, at Bombay Textile Research Association (BTRA), Laboratory, Mumbai.

3.3.1.3. Fibre Length

Fibre length was taken using a steel ruler. Each fibre was gently kept on the ruler and the readings between both ends were recorded. A total number of 50 readings were taken and the average was calculated to determine the length of the fibre.

3.3.1.4. Fibre Diameter

Fibre diameter was viewed under a polarized microscope by using a micrometre lens. A total number of 50 readings were taken and the average was calculated to determine the diameter of the fibre.

3.3.1.5 Fibre Fineness

Fineness (Denier) of the fibre was determined using (ASTM D 7025-09) test method, an average of 20 observations of 100 mm length of fibre was taken and then calculations were done using the formula given below:

$$\text{Denier} = \frac{W \times l}{L}$$

Where, W = Weight of the fibre

L = length of the sample

l = the unit length of the system

3.3.1.6. Fibre Moisture Content and Regain

To determine the moisture content and regain, the fibres of known weight were conditioned at 65±2 % RH at 27±2 ˚C temperature. The samples were weighed in a conditioned state (W). The samples were then dried at 110 ˚C in the oven. After an hour sample was taken out from the oven and weighted (D). The difference in weight, moisture content and moisture regain were calculated using the following equation: (Booth, 1996).

$$\text{Moisture Content (M) (\%)} = \frac{100\ W}{D+W}$$

$$\text{Moisture Regain (R) (\%)} = \frac{100\ W}{D}$$

Where D = Oven dry weight

W = Weight of Water

M = Moisture Content

R = Regain

3.3.1.7. Fibre Tensile Strength

Single fibre strength tests for Sugarcane fibre specimens were carried out on Llyod Instron tensile testing Instrument (ASTM D 3822) in the Textile Testing Laboratory, Department of Textile Engineering, Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda, Vadodara. Test Specimens having gauge lengths of 100 mm were kept an average of 50 readings were taken.

3.3.2. Chemical properties of extracted fibre

3.3.2.1. Chemical Solubility

The fibres were subjected to different alkali and acids in both cold and hot conditions to examine the solubility of fibre.

3.3.2.2 Chemical Composition

The chemical composition of the fibre was determined as per the scheme suggested by Turner and Doree, with the help of Soxhlet Apparatus. The procedure was carried out in the following sequence:

a) **Estimation of water-soluble components**

A weighted sample of untreated fibres was boiled with distilled water for five hours, using a material liquor ratio of 1:30. Samples were then filtered in sintered glass crucible of No. 1 porosity, oven dried at 100℃ for 30 minutes, and then weight was taken on an electronic balance. The water-soluble component was calculated with oven dry weight and using the formula given below:

$$\text{Water soluble components (\%)} = W_1\text{-}W_2 \,/\, W_1 \times 100 \qquad ....(1)$$

Where W_1 = Initial weight of the sample

W_2 = Weight of the sample after the procedure

b) **Estimation of Fats and Waxes content**

After the removal of the water-soluble component from the sample, it was extracted in the Soxhlet apparatus with 2:1 alcohol (methanol)/ benzene solution for 4 hours. The sample was then washed with alcohol dried and weighted (W_3). The result was expressed as a percentage of the oven dry weight of the original sample.

$$\text{Fats and waxes (\%)} = W_2\text{-}W_3 \,/\, W_1 \times 100 \qquad ....(2)$$

Where W_2 = Initial weight of the sample

W_3 = Weight of the sample after the procedure

c) **Estimation of Pectin Content**

The fibre samples were further extracted by boiling for 1 hour in 1% ammonium oxalate solution and then washed with distilled water until the washing was free from oxalate. The loss in weight owing to the removal of pectineus material was recorded as a percentage of the oven dry weight of the original sample using the equation:

$$\text{Pectin content (\%)} = W_3\text{-}W_4 \,/\, W_1 \times 100 \qquad ....(3)$$

Where W_3 = Initial weight of the sample

W_4 = Weight of the sample after the pectin removal

d) Estimation of Hemicellulose Content

After the pectin removal, the fibres were extracted in the Soxhlet apparatus with 2% Caustic soda solution for 1 hour and then washed thoroughly with distilled water. The loss in weight due to the removal of hemicellulose was estimated as a percentage of oven dry weight of the original sample using the equation:

$$\text{Hemicellulose content (\%)} = W_4\text{-}W_5 / W_1 \times 100 \quad ....(4)$$

Where W_4 = Initial weight of the sample

W_5 = Weight of the sample after this procedure.

e) Estimation of Lignin Content

After the hemicellulose removal, fibres were subjected for 2 hours under reflux boiling in a water bath with a 50:1 material liquor ratio of 0.7% Sodium Chlorite solution, at 4 pH using acetic acid. Then these fibres were filtered in a sintered glass crucible of No. 1 porosity. Later the samples were washed with 750ml of distilled water then with 250ml of 2% sodium bisulphate solution, and then finally with 1000ml of distilled water. Later the samples were dried at 105 ̊C. The lignin content as a percentage of oven dry weight of the original sample was calculated by:

$$\text{Lignin content (\%)} = W_5\text{-}W_6/ W_1 \times 100 \quad ....(5)$$

Where W_5 = Initial weight of the sample

W_6 = Weight of the sample after the lignin removal.

f) Estimation of Cellulose Content

After the removal of non-cellulosic components, cellulose was measured by weight differences using the equation:

$$\text{Cellulose content (\%)} = W_6/ W_1 \times 100 \quad ....(6)$$

Where W_6 = Weight of the sample after the lignin removal.

W_1 = Initial weight of the sample

3.4 Fabrication of Sugarcane Fibre Extractor

An important factor for the extraction of fibre is continuous heating with stirring. First, the researcher experimented with a laboratory stirrer which lead to entanglement and crushing of material and consequently stopped the stirring operation. Therefore, the researcher fabricated an instrument for the extraction of fibres. (Patent Application No: 202121017962)

3.5 Modification of fibre through chemical and enzymatic treatments

Sugarcane bagasse fibre has been modified using Acetylation, Cyanoethylation & Enzyme treatments, for enhancing its oil sorption capacity. The hydrophilicity of cellulose can be reduced in other words, its oleophilic can be improved by these chemical modifications.

3.5.1. Acetylation: Acetylation refers to the process of introducing an acetyl group (CH3CO) into a compound, namely the substitution of an acetyl group for an active hydrogen atom. Acetylation significantly increased the hydrophobic properties of the bagasse.

In acetylation treatment, three different input variables were taken viz. Chemical concentration (1%,3% & 5%), time (30 mins , 60 mins & 90 mins) & temperature (Room 30 ^{0} C 50 ^{0} C & 70 ^{0} C) for modification of fibre.

3.5.2. Cyanoethylation: It is an etherification treatment which is done in two steps. The fibre is first pre-treated with sodium hydroxide and then the pre-treated sample is reacted with acrylonitrile (C_3H_3N), called Cyanoethylation.

In Cyanoethylation treatment, three different input variables were taken viz. Pretreatment with sodium hydroxide (NaOH) concentration (1%,5% & 10%), time (30 mins , 60 mins & 90 mins) & temperature (Room 30 ^{0} C, 50 ^{0} C & 70 ^{0} C) for modification of fibre.

3.5.3. Enzyme Treatment: Two enzymes were used in the study i.e., Cellulase and Pectinase which were procured from Rossari Biotech Ltd., Ahmadabad, Gujarat. Cellulase and pectinase both enzymes were both used in an equal ratio (1:1).

In the Enzyme treatment, three different input variables were taken viz. Enzyme Concentration (1%,5% & 10%), time (30 mins , 60 mins & 90 mins) & temperature (Room 30 ^{0} C, 50 ^{0} C & 70 ^{0} C) for modification of fibre.

After each treatment modification, the modified fibre samples were tested for their oil sorption capacity (ASTM F726-99), recovery of oil, oil retention and reusability of the sample and the average readings were recorded for further optimization of treatment parameters.

3.6 Optimization of treatments through Response Surface Design of experiment.

All three modification treatments were optimized with the help of the Response surface design of experiment. A response surface design is a set of advanced design of experiments (DOE) techniques which provide better understanding and optimize conditions for a response.

3.7 Optimized fibre Characterization through FTIR

The FTIR analyses of the samples were carried out in Borex Alpha – IR Spectroscopy over the wavelength of 400 to 4000 cm–1. The test was carried out in the Department of Chemistry, Faculty of Science, The Maharaja Sayajirao University of Baroda, Vadodara. The sample was prepared by freezing the chopped untreated and optimized fibres in liquid nitrogen and pulverizing it to yield a fine powder capable of being cast into traditional KBr pellets for IR analysis. For the analysis, the scanning range was from 400 to 4000 cm-1. The spectrum was recorded in transmittance mode by using the ATR sampling technique.

3.8 Optimized fibre Characterization through SEM

The surface morphology of the control and optimized fibre samples were analysed using a scanning electron microscope, SEM Joel JSM- 5610V. The test was conducted under the supervision of Dr. Vandana Rao, an expert in SEM from the Department of Metallurgical and Material Engineering, Faculty of Technology and Engineering, (DST, PURSE, New Delhi), The Maharaja Sayajirao University of Baroda, Vadodara.

3.9 Manufacturing of Nonwoven

Nonwoven structures were created using a minimum level of technology. The technological process used involved extraction, cleaning and carding for the preparation of the fibre web and needle-punching as the bonding of the fibres. The Nonwoven were prepared in random laid direction through DILO- Needle Punching Machine, at the Department of Textile Technology, Indian Institute of Technology(IIT), Delhi.

3.9.1 Determination of Fabric weight per unit area (GSM):

Specimen of Nonwoven 5 × 5 cm was cut and weighted. An average of five observations were taken. Using ASTM Test Method D3776-96, GSM was calculated with the following formula:

$$GSM = \frac{\text{Weight in grams of sample} \times 100 \times 100}{5 \times 5}$$

3.10. Testing of prepared Nonwoven:

The prepared nonwoven was tested for its Oil sorption capacity, recovery of oil, oil retention ability and Reusability of the sample, in three different viscosities of oil viz. Motor oil, Light viscosity crude oil, Heavy viscosity crude oil.

RESULTS AND DISCUSSION

The Results of the study were discussed under the following sub-heads:

4.1 Procurement and extraction of fibre from waste Sugarcane bagasse

4.2 Optimization of fibre extraction conditions

4.3 Preliminary Testing

4.3.1 Physical properties of extracted fibre

4.3.2 Chemical properties of extracted fibre

4.4 Fabrication of Sugarcane Fibre Extractor

4.5 Modification of fibre through chemical and enzymatic treatments

4.6 Optimization of treatments through Response Surface Design of experiment.

4.6.1 Acetylation Treatment

4.6.2 Cyanoethylation Treatment

4.6.3 Enzyme Treatment

4.7 Optimized fibre Characterization through FTIR

4.8 Optimized fibre Characterization through SEM

4.9 Manufacturing of Nonwoven

4.10 Testing of Nonwoven

4.1 Procurement and extraction of fibre from waste Sugarcane bagasse fibre

4.1 Extraction of Fibre

To obtain the fibres from waste sugarcane bagasse following steps were followed:

4.1.1 Preparation of Raw material

Bagasse is mainly composed of an outer rind and an inner pith. The softcore pith was removed from the bagasse manually. The outer rind was then cut across the length, nodes were removed and separated all the pithy material from the rind.

4.1.2 Removal of Coloring matters and sugar traces

Under this step, the cut outer rind was subjected to hot water (material: liquor ratio1:50) treatment for 60 minutes at 90^o temperature. This process helps to remove the colouring matters, sugar traces and other dust particles.

4.1.3 Chemical Treatment

The separated outer rind was subjected to NaOH solution in conc. of 0.1 N (material: liquor ratio 1: 100). Treatment time was kept at 180 mins and the temperature was 90^0 C. This process was carried out in a fabricated instrument with continuous vigorous stirring which pertains to the good separation of fibres.

4.1.4 Neutralization of fibres

After chemical treatment, fibres were taken out and washed with hot water. Then the fibres were kept for 15 mins (room temperature) in diluted Hydrochloric acid (HCl) solution obtaining 4-5 pH, for neutralization followed by a hot water rinse and cold water rinse respectively. After the Neutralization process, the fibres were kept for drying at room temperature.

4.2 Optimization of fibre extraction conditions

Under this section of the study, the researcher aimed to evaluate and optimize conditions for fibre extraction. To enhance extraction efficiency, it is essential to work under optimized conditions. Therefore, to select optimal extraction conditions, the effect of two independent variables viz. chemical concentration and time were observed based on the response variable viz. extracted fibre quantity, tensile strength and chemical composition of the fibre.

Table.4.1. Optimization of fibre extraction conditions

Chemical Conc. and time	Fibre Quantity(%)	Stress (g/den)	Chemical composition(%)	
			Cellulose	Lignin
0.1 N (3 hour)	55.00	2.05	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

From table 4.1, it was observed that fibres extracted with 0.1 N NaOH concentration, for 3 hours have 69.50 % cellulose with 13.50 % lignin which was a good chemical composition found as compared to other fibres extracted in other conditions. The tensile strength of fibre was 2.05 g/den and 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.

4.3 Preliminary Testing

4.3.1 Physical properties of extracted fibre

4.3.1.1. Burning test

The fibre catches fire quickly, when approaching to flame and propagates faster. The residue is in the form of ash and after the burn, the odour was like burning paper, so the cellulosic nature of fibre was confirmed.

4.3.1.2. Fibre Morphology (Longitudinal and Cross-sectional view)

The longitudinal view of fibre shows the appearance of fibre similar to sugarcane. Fibres in bundles are visible with striations and to some extent single strand of fibre is also observed. The cross-sectional characteristics of fibre were studied by microscopic analysis. The SEM photographs revealed that the cross-section of fibre was similar to most of the lingo-cellulosic fibre. Fibre showed irregular shape and variations in diameter. More encrusting material between the ultimate cells was observed in the cross-sectional view of the fibre. The presence of numerous voids around the lumen indicates its multi-fibrillar structure. Thick walls and irregular lumen were visible in 45 X with a polarized light microscope (Fig.4.1.)

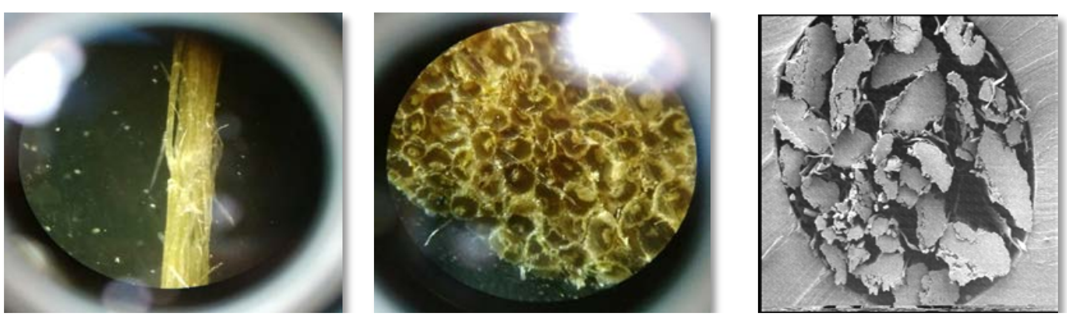


Fig.4.1. Longitudinal view 45X Cross-sectional view 45X Cross-sectional view 100X

4.3.1.3. Fibre length

Sugarcane fibre is a staple length fibre. The length of fibre depends on the length between the nodes of the sugarcane. The length of fibre was observed between 4.5 cm – 12.5cm and the average length was 9.5 cm.

4.3.1.4. Fibre Diameter

It was observed that Fibre has a large variation in diameter. Fibre diameter ranges from 20-35 μm and the average diameter was 25 μm. It was observed that the fibre length to breadth ratio was 3800:1. As the fact associated with the aspect ratio the higher the ratio, the finer the fibre. Therefore, sugarcane fibres are not under the class of finer fibres.

4.3.1.5. Fibre Fineness and Evenness

In the 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.

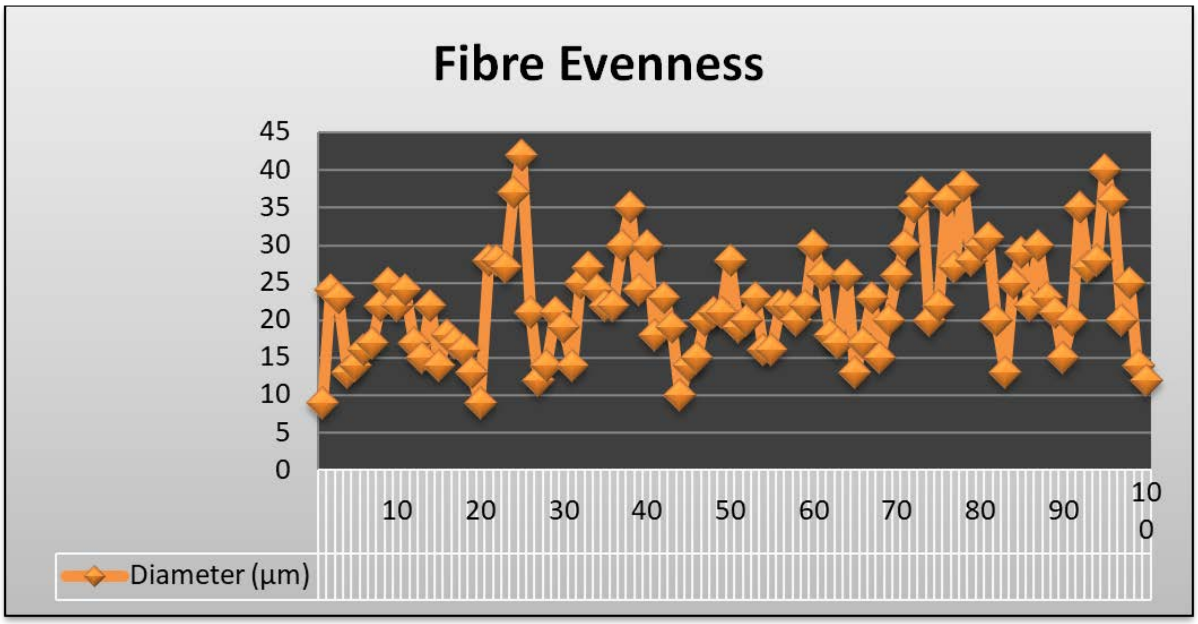


Fig.4.2. Fibre fineness and evenness

From the above graph (Fig.4.2.), fibre diameter revealed a large variation between the fibres. The graph shows that most of the readings lie between 10-25 µm. The mean and standard deviation for fibre diameter was calculated as 22.41 µm and 7.23 respectively. Therefore, it can be concluded that sugarcane fibre is uneven.

4.3.1.6 Fibre Moisture Content and Regain

From the above-specified method fibre moisture content and regain were calculated. The Value obtained for moisture content and regain was 7.76% and 8.4 % respectively which is almost similar to coir fibre[7] (regain: 8-12.5%).

4.3.1.7. Fibre tensile Strength

Table.4.2. Tensile strength of extracted fibre

Fibre	Denier	Maximum Load (gf)	Extension At Max (mm)	Stress in gm/den	% Strain
Tensile Strength	345.60	738.84	1.06	2.16	21.27
Standard Deviation	184.06	366.77	0.23	0.23	4.66
Coefficient of Variance	53.25	49.64	21.90	10.81	21.90

From table 4.2, the results indicate the tensile strength of the extracted fibre in terms of stress % i.e 2.16 gm/den followed by 21.27 % strain.

4.3.2 Chemical properties of extracted fibre

4.3.2.1 Chemical Solubility test

The solubility test of extracted fibre was done. The fibres were subjected to different alkaline and acids in both cold and hot conditions. The results revealed that the fibre dissolve in 99% of concentrated Sulphuric acid (H_2SO_4) when subjected to heat for 5 minutes confirming the cellulosic nature of the fibre

4.3.2.2. Fibre chemical composition

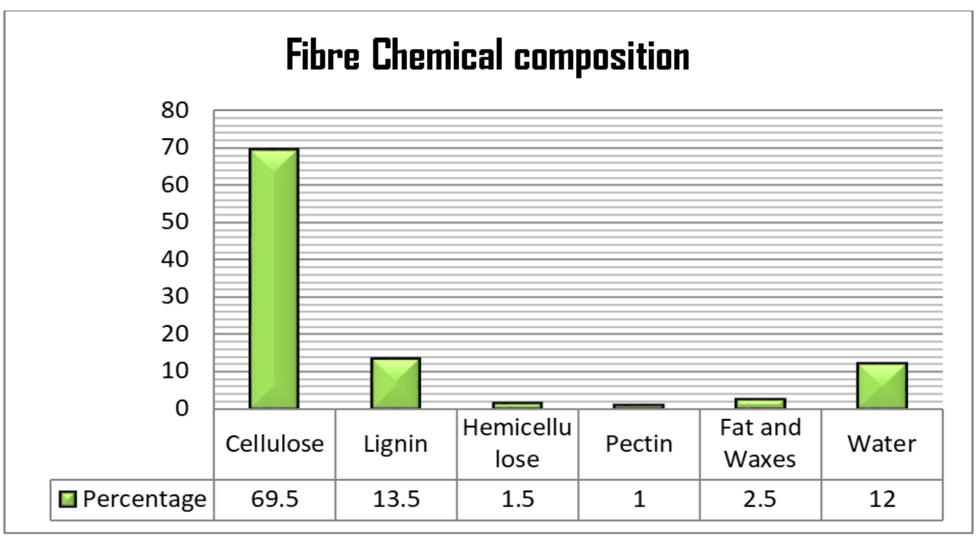


Fig.4.3. Chemical composition of fibre extracted in optimized condition

From the above Fig 4.3., it was observed that fibre extracted at optimized condition has cellulose content of 69.5% and lignin content was 13.5%, followed by water soluble content, fat & waxes content, hemicelluloses and pectin content viz. 12%, 2.5%, 1.5% and 1%.

4.4 Fabrication of Sugarcane Fibre Extractor

The machine for extraction of fibre is being fabricated successfully and further, the experiment for bulk extraction of fibre had performed by the researcher in the Department laboratory. The fabricated machine is under the process of Patent (Patent application No:202121017962).

4.5 Modification of fibre through chemical and enzymatic treatments

Extracted grey fibres were modified with the three different treatments viz. Acetylation, Cyanoethylation & Enzyme treatment. After modification treatment, Oil sorption capacity, recovery and reusability of the sample were tested for each treatment and the average of readings was calculated for further optimization of treatment parameters. The results of the testing were obtained from the following graphs:

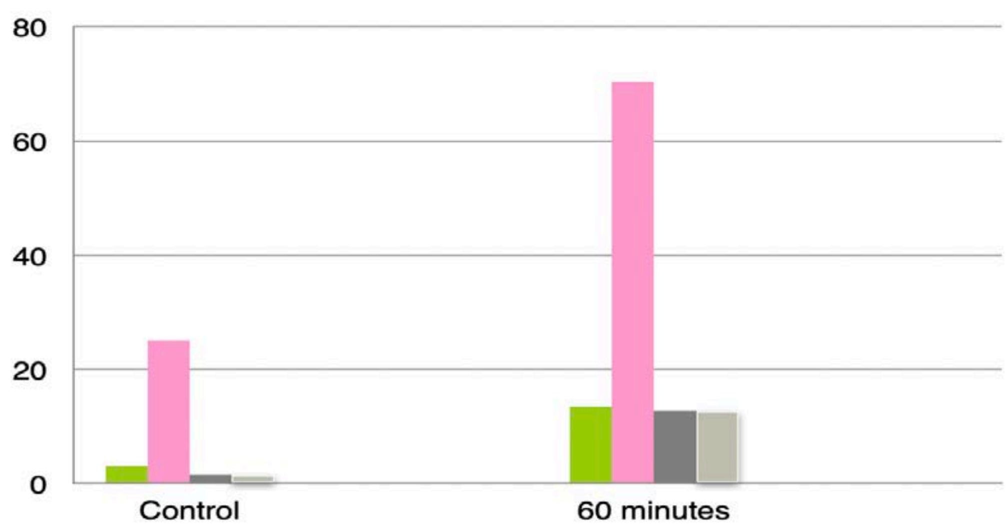


Fig.4.4. Oil sorption, recovery & reusability of Acetylated fibre

From Fig.4.4, the sorption capacity of the acetylated modified fibre sample is higher than the control sample and recovery is calculated 70% of the total sorption by the sample. The treated sample reusability shows a minor difference from the first to second & second to third time of reusability of the sample.

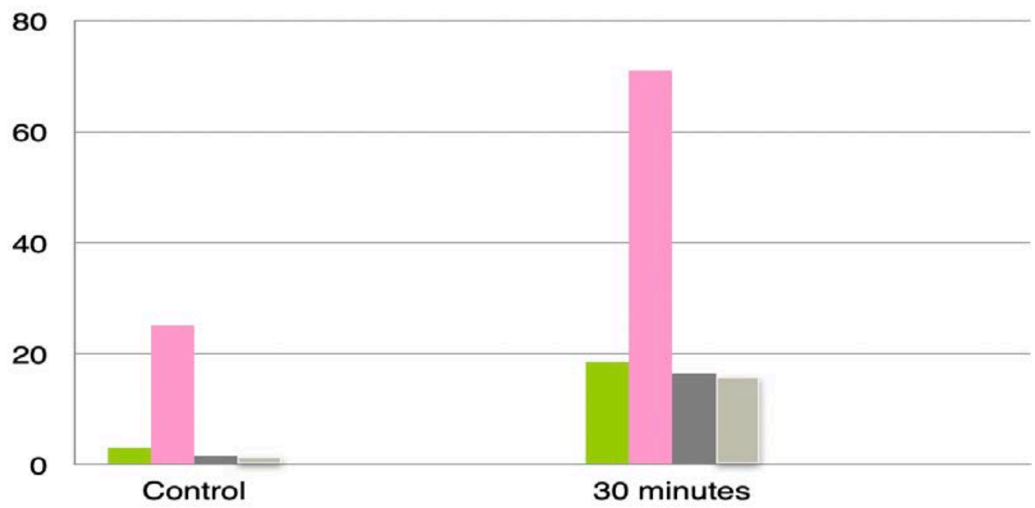


Fig.4.5. Oil sorption, recovery & reusability of Cyanoethylated fibre

From Fig.4.5, the sorption capacity of the cyanoethylated modified fibre sample is much higher than the acetylated fibre sample & control sample. The recovery is calculated higher i.e 75% of the oil sorbed by the sample. The treated sample reusability follows approximately similar differences in values same as the acetylation treatment.

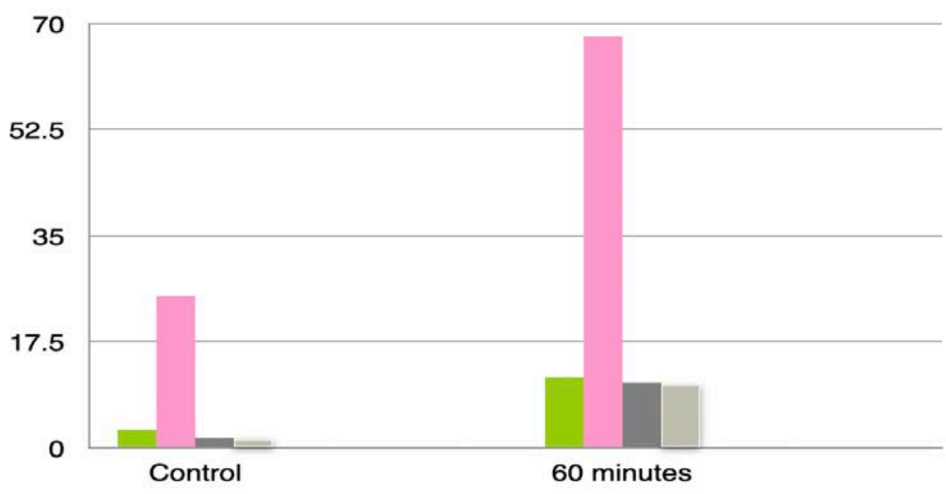


Fig.4.6. Oil sorption, recovery & reusability of Enzyme treated fibre

From Fig.4.6, the sorption capacity of the enzyme-treated fibre sample is higher than the acetylated fibre sample but lower than the cyanoethylated fibre sample. The recovery is calculated similarly to the acetylation-treated fibre sample. i.e 70% of the oil sorbed by the sample..

4.6 Optimization of treatments through Response Surface Design of experiment.

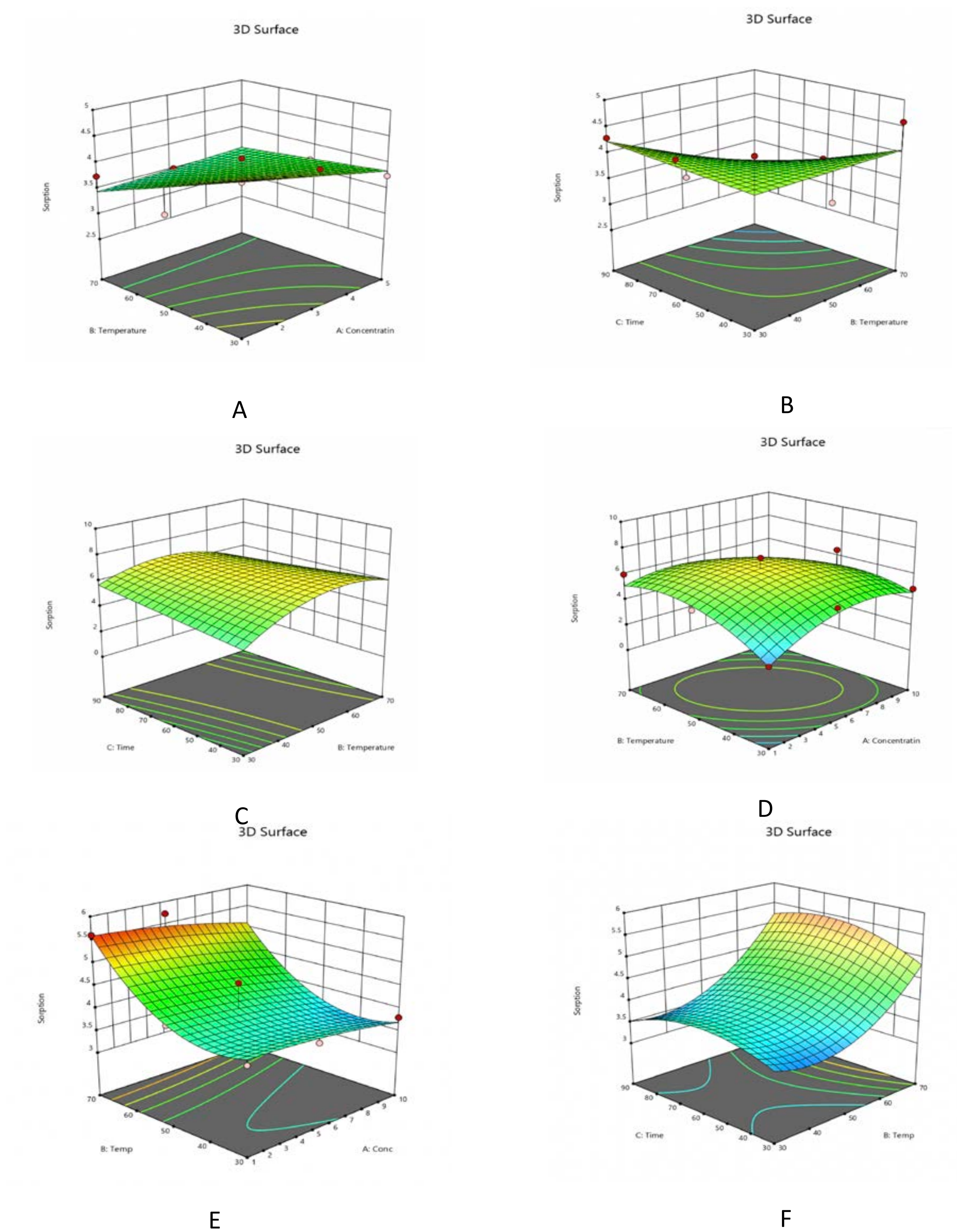


Fig.4.7.Effect of different variables on sorption capacity of treated fibres : Acetylated (A&B), Cyanoethylated (B&C), Enzyme Treated (E&F)

4.7 Optimized fibre Characterization through FTIR

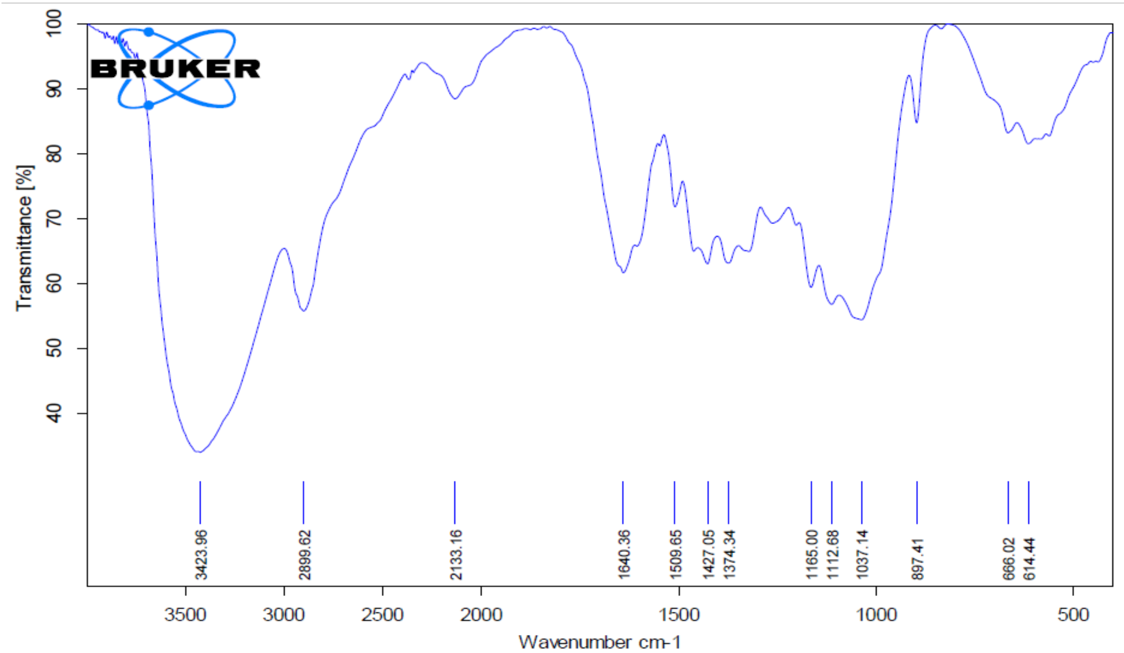


Fig.4.8. FTIR spectra of Control fibre

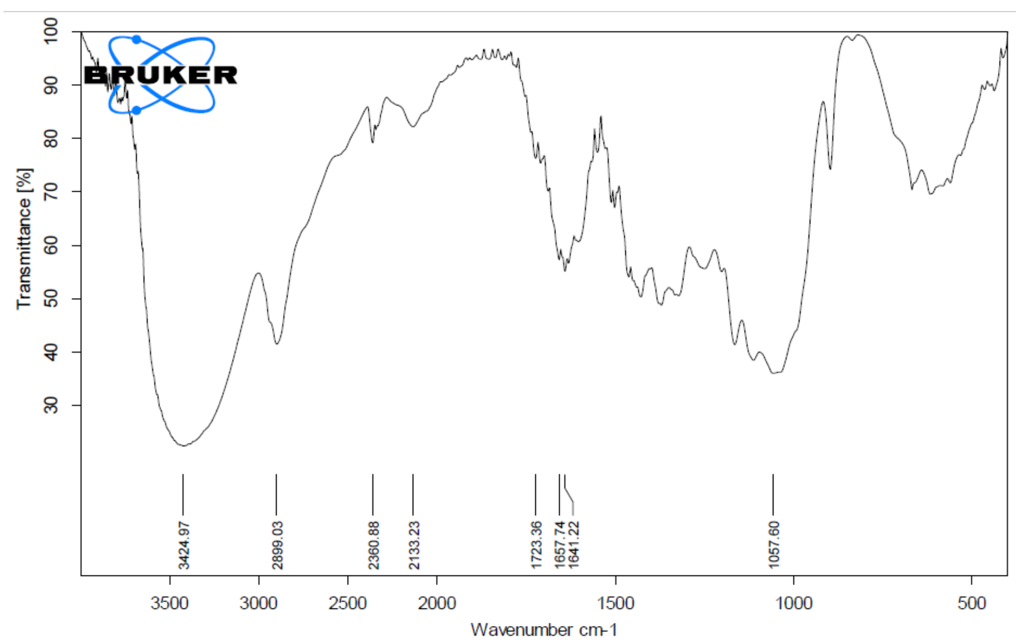


Fig.4.9. FTIR spectra of treated Acetylated fibre

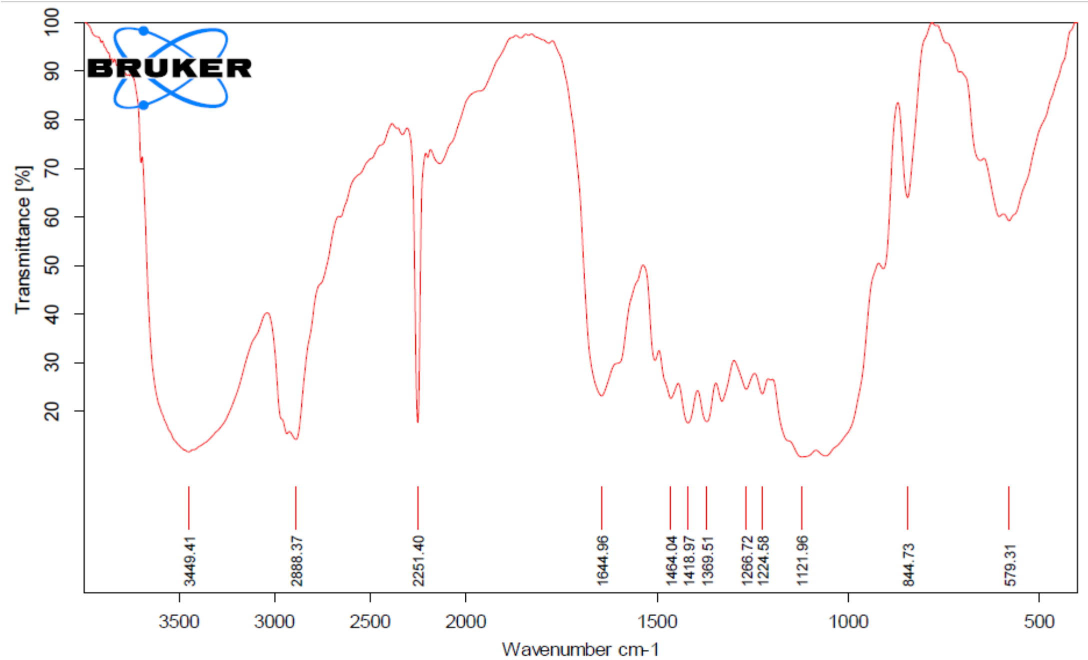


Fig.4.10. FTIR spectra of treated Cynoethylated fibre

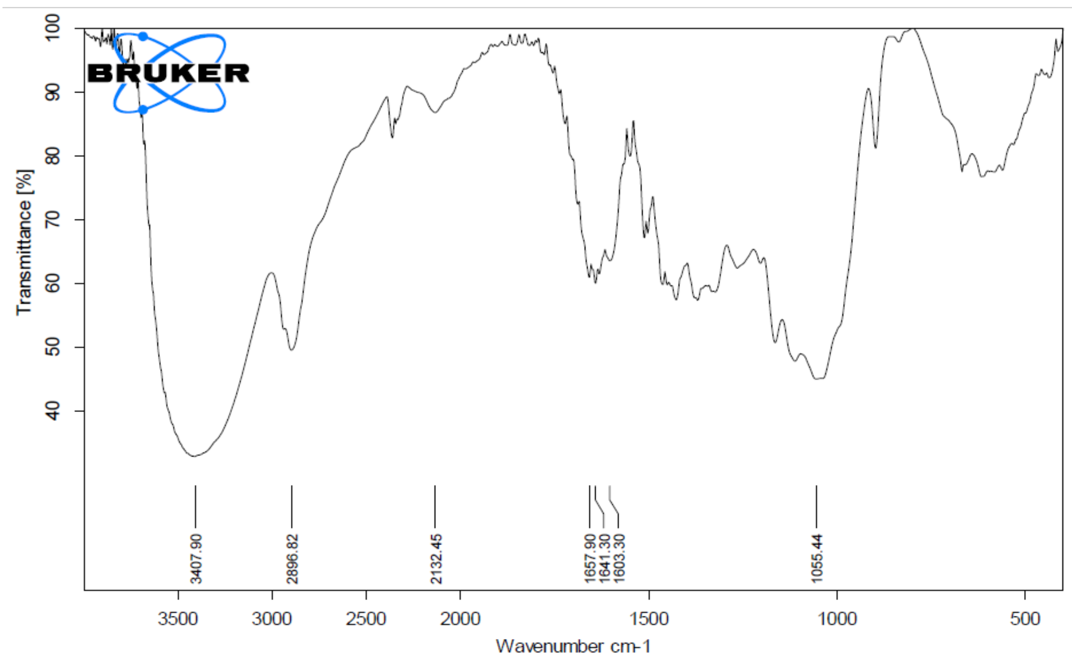


Fig.4.11. FTIR spectra of treated Enzyme treated fibre

In the FTIR spectra of control fibre which are shown in Fig.4.8, the strong band is around 3449 cm-1 due to the -OH stretching. The band is around 2899cm-1 corresponding to the C-H asymmetric stretching of the -CH2 group. The spectra of the acetylated fibre sample shown in Fig.4.9 show evidence of acetylation with three easter bands appearing at 1723cm-1, 1368cm-1 and 1234cm-1 (C-O stretching of an acetyl group).In FTIR spectra of cyanoethylated fibre which is shown in Fig.4.10., a strong band appeared at 2251cm-for nitrile group is appeared which confirms successful cyanoethylation.

4.8 Optimized fibre Characterization through SEM

Fig.4.12. SEM images of Control fibre (A),Treated Acetylated fibre (B),Treated Cyanoethylated fibre (C), Enzyme treated fibre(D) at 100 X

The SEM photographs of control, acetylated, cyanoethylated & enzyme-treated samples were examined at a magnification of 100X using a Scanning Electron Microscope. The change in fibre morphology after chemical and enzymatic modification is clear from the SEM microphotographs (Fig.4.12). The chemically modified samples are quite rough with wrinkles and grooves compared to untreated samples. The roughness of the chemically modified samples helped in oil absorption. Cyanoethylated samples (c) visible some swelling in the fibre structure which also helped in absorption. Enzyme-treated samples (d) are some smooth surfaces with little rough & wrinkled spaces, swelling of fibre also shown in the SEM photographs.

4.9 Manufacturing of Nonwoven

Fibres extracted with optimized treatment conditions were found suitable for preparing Non-wovens. Web formation was done on a miniature carding machine (Roller and clearer card for long staple fibres)for bast fibres. This machine has a feeding passage and a cylinder with a series of sharp nails projecting from its periphery. The nails help in further opening the exposed disintegrated fibre coming from the feed passage and remove the pith and throw the cleaned fibres out. The fibres were fed between the rollers five runs using feed 1.53, cylinder 184.1 and doffer 17.38.

After web formation, the web was needle punched through DILO- Needle punching machine in a random laid direction using needle density of 150 cm^2 and needle penetration of 10 mm.

This machine has a feeding passage and a cylinder with a series of sharp nails projecting from its periphery. The nails help in the further opening of the exposed disintegrated fibre coming from the feed passage and removing the pith and throwing the cleaned fibres out.

Fig.4.13. Manufacturing of Non-woven through DILO-Needle Punching machine

4.10 Testing of Nonwoven

The prepared Non-woven was used for testing in three different viscosities of oil viz. Light viscosity crude oil (LvCo) : 352.3 mm2/s, Heavy viscosity crude oil (HvCo) : 623.3 mm2/s, Medium viscosity motor oil (MvMo) : 20W-40.

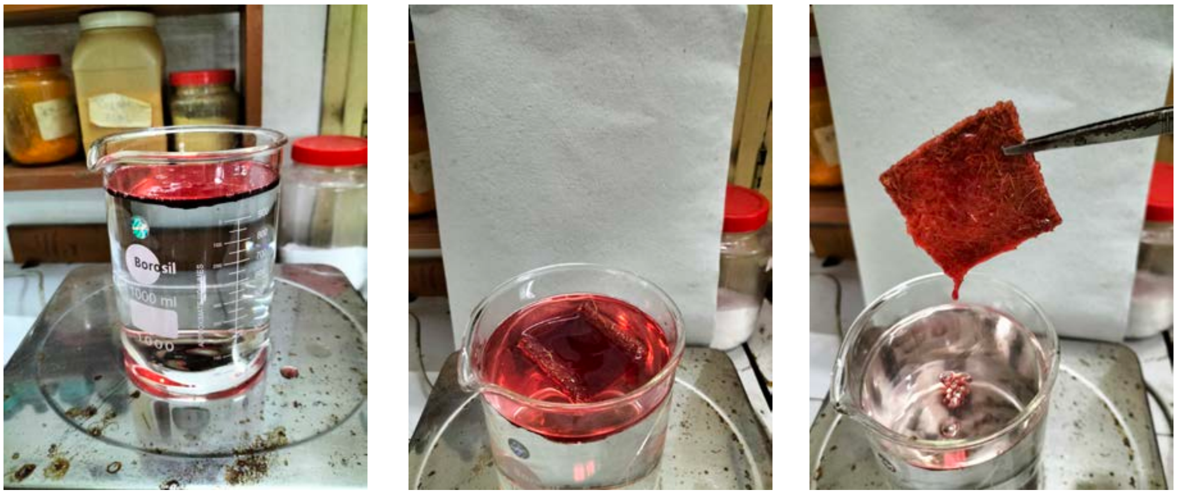


Fig.4.14. Oil sorption testing of Nonwoven in Medium viscosity motor oil

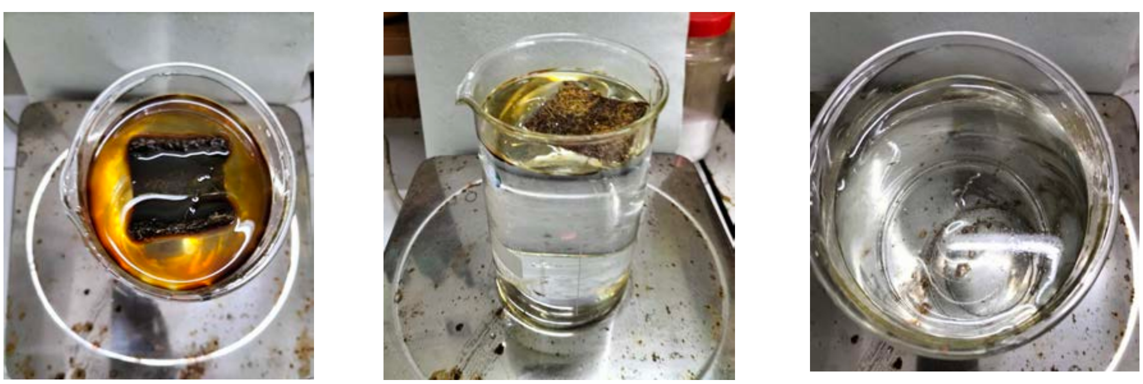


Fig.4.15. Oil sorption testing of Nonwoven in Light viscosity crude oil

Fig.4.16. Oil sorption testing of Nonwoven in Heavy viscosity crude oil

From the test results of Nonwoven oil sorption capacity (Fig.4.14), it was observed that the Nonwoven sample initially fast picked up the capacity of oil in heavy viscosity crude oil followed by light viscosity crude oil. The oil sorption capacity of the sample was slow to pick up in motor oil comparatively crude oil. The results also indicate that nonwoven sorbent can absorb the oil from the water layer completely and also recover the oil. The reusability of the sorbent was up to three times. These nonwoven sorbents were biodegradable as the raw material was natural and good sorption & recovery of oil were observed.

CONCLUSION

Waste bagasse is considered a type of unconventional fibre because of its very limited applicability in the textile industry. More processing steps are needed before it can be used as an alternative fibre for the textile industry. Fibres are to be modified chemically for specific end-use. From the results of the previous research, it is expected that sugarcane bagasse can be modified to increase sorption properties which can help in the separation and recovery of oil from the oil spill.

- Non-woven treated with Cyanoethylation have the highest sorption capacity and recovery properties, followed by enzyme treatment and Acetylation treatment.
- FTIR analysis reveals the required changes of functional groups in a particular treatment.
- Acetylated sample spectra shows peak at 1743 cm-1, 1368cm-1,1234 cm-1 &3339 cm-1.
- Cyanoethylated sample spectra show a strong absorption band that appeared for the Nitrile group at 2253 cm-1, 2251.40 cm-1
- Enzyme treated sample spectra shows peak at 1657cm-1, 1641cm-1 & 1603cm-1.
- SEM analysis focuses on essential morphological changes in the fibre structure.
- The study conclude that Sugarcane fibre has the inherent property of oil sorption which increased by treating the fibre through different treatments.
- The researcher concludes that non-woven prepared from sugarcane bagasse fibre have a higher sorption capacity of oil as well as recovery.
- The outcome of the study suggested that it is possible to replace synthetic oil sorbents. The sorbent can be used more than three times for sorption, recovery and separation of the oil layer from water.

At the current time, organic awareness and environmental consciousness of people have diverted the interest in textiles from natural fibres and more attention has been drawn to agricultural products, wastes and derivatives because of their renewability. Minor fibres which are just wasted till now can be used to their potential with proper exploration. Further research will increase the use of these minor fibres in the field of textiles. Due to the lack of awareness, the waste produced is burnt for energy production which causes environmental pollution. The reason for the limited use of these fibres is attributed to their difficult extraction, and processing and also limited knowledge of these fibres to be used as textile fibre among the people.

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Note: References are arranged according to in-text citation.