CHAPTER – V

SUMMARY AND CONCLUSION

Waste Sugarcane bagasse is considered a type of unconventional fibre because of its very limited applicability in the textile industry. Sugarcane (Saccharum officinarum) family Gramineae (Poaceae) is a widely grown crop in India. It employs over a million people directly or indirectly besides contributing significantly to the national exchequer. Broadly there are two distinct agro-climatic regions of sugarcane cultivation in India, viz., tropical and subtropical. The tropical region shared about 45% and sub-tropical 55% of the total sugarcane area and production in the country.

Minor cellulosic fibres which are abundantly available can be modified for their use in textiles for technical textiles. Therefore, this process can be termed as converting waste to wealth as it involves extracting the fibres from waste sugarcane and using it for technical textile applications. Simultaneously, reduce waste and provide innovative technical textiles. Further research will increase the use of these minor fibres in 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, processing and limited knowledge of these fibres to be used as textile fibre.

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. 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. 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.

Sugarcane bagasse fibres have significant potential as a Non-woven & composite application due to their high strength, environmentally friendly resource, low cost, availability, and thus sustainability. Non-wovens are unique, high-tech, engineered fabrics made from fibres bonded together by chemical, mechanical, heat or solvent treatment. Non-wovens are innovative, versatile and indispensable. Non-wovens 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.

Thus, the study entitled "Application of Sugarcane bagasse fibre in Technical Textiles" has been planned with the following objectives.

5.1 Objectives of the study

5.1.1 To extract and optimise conditions for extraction of fibre.

5.1.2 To test the physical and chemical properties of extracted fibres.

5.1.3 To fabricate an apparatus for extraction of fibre.

5.1.4 To modify the extracted fibres to enhance their sorption capacity through Acetylation, Cyanoethylation and Enzymatic treatment.

5.1.5 To test the modified fibres and optimise the treatments :

i. Oil sorption capacity

ii. Recovery of sorbed oil

iii. Reusability of sorbents

iv. Oil retention ability

5.1.6 To study the characterisation of optimised fibres: FTIR, SEM analysis.

5.1.7 To prepare oil sorbent Non-woven and test its sorption and recovery properties.

5.2 Materials and Methods

For the present study, waste Sugarcane bagasse was utilised for extracting fibres. The research was an experimental study which was divided into three phases:

5.2.1 Phase I: Extraction of fibres from waste bagasse and test its properties.

5.2.2 Phase II: Fabrication of an apparatus for fibre extraction and optimisation of fibre modification treatment.

5.2.3 Phase III: Characterisation of modified fibres through FTIR and SEM. Bulk extraction of fibre and manufacturing of Non-woven and testing its sorption properties.

5.2.1 Phase I

Waste Sugarcane bagasse was procured from local sugarcane juice extraction vendors of Vadodara city, Gujarat at an earlier stage and later stage, the waste bagasse after juice extraction was procured from Main Sugarcane Research Station, Navsari Agricultural University, Gujarat. After procurement of wet bagasse, it was kept under the sun for proper drying. The bagasse is composed of an outer rind and an inner pith. The outer rind of cane contains a bundle of fibres. By mechanical means, the outer rind was separated from the inner pith for the extraction of fibre. The outer rind was subjected to boiling for the removal of colour and loosening of fibres. Fibres were extracted at different alkaline conditions viz. 0.1 (N), 0.2 (N), 0.3 (N) with varying time. Based on chemical composition, tensile strength and fibre quantity, fibre extraction conditions were optimised through statistical analysis (DOE). Physical and chemical properties viz. microscopic appearance, length, diameter, fineness, moisture regain, chemical composition and tensile strength of the extracted fibre were studied.

5.2.2 Phase II

An apparatus (Sugarcane fibre extractor) was fabricated for the extraction of fibres. The fibres were extracted at optimised conditions. The extracted fibres were further modified with three treatments viz. Acetylation, Cyanoethylation and Enzymatic treatments for enhancing its oil sorption capacity. The modified fibres through all three modification treatments were tested for their oil sorption capacity, oil retention ability, recovery of sorbed oil and reusability of the sample. The results of oil testing were statistically analysed through a full factorial design of the experiment. Based on statistical analysis, the modification treatment parameters were optimised for all three treatments.

5.2.3 Phase III

The untreated and treated fibres were physically and chemically characterised through SEM and FTIR respectively. Fibres were extracted in bulk through the fabricated apparatus and Non-wovens were prepared through the needle-punch method and hand-lay-up techniques in different GSM. Further, the Non-woven were tested for sorption capacity test in three different viscosities of oil viz Motor oil (Mo), Light viscosity crude oil (LvCo) and High viscosity crude oil (HvCo). The results of the testing were calculated and discussed.

5.3 Results and Discussion

The present study has been carried out for the utilisation of waste bagasse and its application in technical textiles. The results of the study were concluded under the following sub-heads:

5.3.1 Fibre extraction and optimisation of fibre extraction conditions

Fibres were extracted from procured waste sugarcane bagasse. It was aimed to evaluate and optimise conditions for fibre extraction. The raw material (Outer rind stalks) was subjected to sodium hydroxide (NaOH) solution in three different concentrations of 0.1(N), 0.2(N), 0.3(N) for 60, 120, 180 and 240 minutes for each concentration at 90ºC. The extraction at 0.3(N) Concentration for 180 and 240 minutes resulted to the dissolution of fibres, hence that could not be considered for the optimisation process. Therefore, to select optimal extraction parameters, the effect of two independent variables viz. chemical concentration and time were observed based on the four response variables viz. fibre quantity, tenacity and chemical composition viz. Cellulose and Lignin content of the fibre. Statistical analysis revealed that the optimised condition for fibre extraction was 0.1(N) Concentration Of NaOH, 180 minutes and temperature was 90℃. The fibres extracted at optimised conditions were tested for their physical and chemical properties. The tenacity of fibres extracted under optimised conditions was found to be 2.02 g/den. Fibre quantity was obtained at 55%. Chemical composition was found to be 69.15% cellulose and 14.5% lignin, respectively.

5.3.2 Chemical modification treatment and optimisation of treatments

Sugarcane bagasse fibre has been modified through Acetylation, Cyanoethylation and Enzymatic treatments to enhance its oil sorption capacity. Recipe for acetylation treatment using acetic anhydride in the presence of $HClO_4$ as catalysts and cyanoethylation using acrylonitrile were taken. For enzymatic treatment, two enzymes were selected viz. Cellulase and Pectinase in a 1:1 ratio. The modified fibres were tested for their oil sorption capacity, oil retention ability, recovery of sorbed oil and reusability of the sample. Statistical analysis were performed to optimise the test results of oil sorption properties of modified fibres. The parameters of acetylation treatment were optimised based on three response variables viz. sorption capacity, recovery of sorbed oil and reusability of fibre sample. The results of acetylation treatment were found to have higher sorption capacity in 1% concentration of perchloric acid, 30℃ temperature and 30 minutes of treatment time. The enzyme treatment parameter was optimised at 4% enzyme concentration,70℃temperature and 55 minutes. The results of cyanoethylation treatment optimised the treatment parameters at 5% NaOH concentration, 55℃ temperature and 60 minutes of treatment time which resulted in the highest sorption capacity.

5.3.3 Characterisation of untreated and optimised fibre: SEM and FTIR analysis

The effect of chemical modification treatment on Sugarcane bagasse fibres was analysed using physical characterisation (SEM) and chemical characterisation (FTIR) of fibres before and after treatment. The SEM images of the longitudinal view of untreated and chemically modified fibres were studied. The SEM photographs of untreated fibres revealed the structure having bundles of fibre together. The smooth fibre surface and compact structure were also observed through the images. In FTIR spectra of untreated sugarcane fibre, the peak was observed at 1374 cm^{-1} is indicative of an ether bond. Ether bonds are found in lignin and hemicelluloses and also as an inter-polymer linkage between the two. The negative peak at 1640 cm-1 indicates COO stretching, and vibrations. This indicates the presence of lignin.

5.3.3.1(a) Acetylated fibre physical characterisation through SEM

In the case of acetylated fibre, there were changes observed on the fibre surface, the wax and cuticle on the surface were removed by the interaction with the acetylating reaction and the surface became smoother. Fibrillation is also found to occur as the binding material is also removed and some micropores appear in the treated fibres. Increased thickness, smooth surface, and bulky groups clearly show the degree to which the internal 'channels' in the fibre open up and at the same time become straighter and confer greater rigidity upon the fibre. It was for this reason oleophilicity of the treated fibre increased.

5.3.3.1 (b) Cyanoethylated fibre physical characterisation through SEM

The cyanoethylated fibre surface images showed the swelling of the fibre structure along with the assumption of diameter increases due to the NaOH effect. After NaOH pretreatment fibre bundles were separated and also appeared more flexible due to their curved and twisted appearance. More sorption of oil into the fibre inside resulted in a very smooth surface.

5.3.3.1 (c) Enzyme-treated fibre physical characterisation through SEM

The Enzyme-treated fibres look much smoother as compared with untreated fibre which was bio-polishing of the fibres and minor removal of non-cellulosic materials. The enzyme-treated fibres after oil sorption showed sorption of oil into the surface less as compared to the cyanoethylation-treated fibre surface.

5.3.3.2 (a) Acetylated fibre chemical characterisation through FTIR

The peak at 1500 cm^{-1} indicates for introduction of an acetyl group in the FTIR spectra of acetylated fibre. The broadening and reduction in the intensity of the peak for O-H stretching prove that some of the O-H groups are utilised by other reactors which were acetylation in this case.

5.3.3.2 (b) Cyanoethylated fibre chemical characterisation through FTIR

In the FTIR spectra of cyanoethylated fibre a strong transmittance band appeared at 2251 cm^{-1} for the nitrile group (−C≡N) was appeared which confirms successful Cyanoethylation of the fibre.

5.3.3.2 (c) Enzyme-treated fibre chemical characterisation through FTIR

FTIR spectra of enzyme-treated fibre look the same as the enzyme makes the fibre softer and no major chemical changes take place.

5.3.4 Manufacturing of Non-woven and testing for oil sorption

The fibres were extracted in bulk and Non-woven were created by two different methods viz. Hand lay-up technique and mechanical bonding through needle punching method. The needle punched Non-woven were prepared in two different GSM i.e. 800 g/m^2 and 1000 g/m^2. The Non-woven through hand lay-up technique was prepared in 328 g/m^2.

The prepared Non-woven were tested for oil testing viz. oil sorption capacity, oil retention ability, recovery of sorbed oil and reusability of sample for three different viscosities of oil. The oil sorption capacity of untreated bagasse showed that the fibre has the highest sorption capacity in High viscosity crude oil (HvCo) and the lowest sorption capacity was found in Low viscosity crude oil (LvCo). The acetylated fibres showed the highest sorption towards Low viscosity crude oil (LvCo) whereas low sorption was found in Motor oil (Mo). The highest sorption capacity for Cyanoethylated fibre was observed in High-viscosity crude oil (HvCo) and the lowest was in motor oil (Mo) which was similar to acetylated and enzyme-treated fibre. The enzyme-treated fibres have higher sorption in low-viscosity crude oil

(LvCo) similar to acetylated fibres. Therefore, the overall oil sorption capacity for Non-woven showed the highest sorption capacity of all the three oils observed by the Cyanoethylated sample.

Oil retention ability after 15 minutes of dripping time of untreated fibre showed higher retention ability in high-viscosity crude oil and lowest retention in motor oil. The acetylated fibre showed higher retention observed in high-viscosity crude oil and lowest in low-viscosity crude oil whereas cyanoethylated fibre showed higher retention in high-viscosity crude oil, followed by motor oil and low-viscosity crude oil. The retention ability of enzyme-treated fibre resulted in a similar way of oil retained as acetylation.

Recovery of sorbed oil for untreated sugarcane fibre resulted higher in low-viscosity crude oil and lower in high-viscosity crude oil. Similarly, acetylated samples showed high recovery in low-viscosity crude oil and lower in high-viscosity crude oil whereas the Cyanoethylated and enzyme-treated samples were found to have lower recovery in motor oil and higher in low-viscosity crude oil.

The reusability of samples was tested and it was found that untreated, acetylated and cyanoethylated fibre showed higher reusability in high-viscosity crude oil. Cyanoethylated and untreated fibres resulted in lower reusability in low-viscosity crude oil whereas acetylated and enzyme-treated fibres showed lower reusability in motor oil. The reusability of the sample was found high in low-viscosity crude oil tested by enzyme-treated samples.

The Non-woven was tested for oil sorption capacity in an oil-layer system containing all three oils and the results of testing were observed. It was observed that the Cyanoethylated Non-woven samples had good sorption capacity and separation of high-viscosity crude oil from the water layer followed by low-viscosity crude oil and motor oil. The above-specified results of testing were also characterised by SEM and FTIR analysis which also revealed that the sorption capacity of modified fibres was found to be higher than the untreated fibres.

Conclusion

- The fibres were extracted from waste Sugarcane bagasse through mechanical and chemical treatment at 0.1 (N) concentration of NaOH, 180 minutes and 90℃ temperature with continuous stirring.
- The tenacity of fibres extracted under optimised conditions was found to be 2.02 g/den. Fibre quantity was obtained at 55%. Chemical composition was found to be 69.15% cellulose and 14.5% lignin, respectively.
- The morphological characteristics of fibre revealed irregular shapes 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.
- Non-woven treated with Cyanoethylation have the highest sorption capacity and recovery properties, followed by Enzymatic treatment and Acetylation treatment respectively.
- Acetylated fibre spectra showed the peak at 1743 cm^{-1}, 1368 cm^{-1},1234 cm^{-1} &3339 cm^{-1}. Due to acetylation, hydroxyl groups are replaced by bulkier acetyl groups resulting in an increase in hydrophobicity and also a decrease in H-bonding. It also gives rise to an increase in accessibility or amorphous content. Both these factors thus cause enhancement in oleophilicity which has been depicted by the results.
- The results of the study indicate that Non-woven sorbent can absorb the oil from the water layer completely (2-3 times) and also recover the oil.
- 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. Proper extraction methods will contribute to the maximum utilisation of agricultural waste. The study concluded 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 (polypropylene) oil sorbents. The sorbent can be used more than three times for oil sorption, recovery and separation of the oil layer from water layer.

5.5 Recommendations

1. The study can be further explored for the utilisation of extracted fibres for Woven fabrics.

2. The extracted fibres can be utilised for other technical textile applications eg. Geo-textiles, Agrotextiles, Industrial textiles etc.

3. Chemically modified fibres can be explored for further composite structures and other applications.