ABSTRACT

Blending of hard fibres (sisal) with soft and weak fibres (waste recycle) for optimization in the quality of pulp in paper making

In the wake of the great applicability of paper as a versatile material, it is important to address some serious issues associated with it, which pose a great threat to its basic survival. Due to exhaustive uses of natural raw materials and threat to the resulting ecological problem, search for secondary and sustainable sources is of present interest of research. Sometimes recycled secondary sources afford poor quality of paper. This Ph. D. programme is an attempt in using a natural fibre (sisal) as an additive to the secondary sources for improving the paper quality. The results of the work undertaken in the Ph.D. Programme are presented in the thesis in four chapters.

Chapter 1 is a review on the importance of paper and includes description of its applications in various important sectors for different purposes like writing, printing, filtering, etc. Future demand of paper has been projected to increase considerably due to its wide scale applications leading to ever increasing consumption of this crucial substance.

It has been generally accepted that different types of paper can be made from any type of fibre (vegetable, mineral or man-made). In the existing scenario, forest based resources (wood and bamboo) have contributed predominantly to cater to the raw material requirement of the pulp and paper industries and still happen to be the leading fibrous resource for papermaking. However, attention has shifted from wood based fibres to non-wood fibres (which include agro residues, suitable plant crops and secondary fibres), owing to the fast diminishing forest cover, followed by strict government restrictions arising out of increasing environmental concerns. Due to the sustainable nature of the secondary fibres, more reliance on them is inevitable in the existing scenario of the raw material crises for the conventional papermaking fibres and hence, they may be perceived as the future papermaking fibres. Weak fibre and pulp characteristics have been pointed out as one of the major limitations associated with them.
Since, paper has been found to be made up of different types of fibre, the quality of the sheets has been considered to get affected by the characteristics of the fibres. The morphological features, physical and chemical properties of the fibres have been described as some of the major factors influencing paper quality. Morphological features (cell wall thickness, fibre width, fibre length, fibril angle etc.) have been found to affect the sheet properties significantly.

As the properties of natural fibres have been identified as one of the major factors affecting sheet properties, the review has elaborated on these aspects especially emphasizing the chemical properties which mostly involve the compositional features. The major chemical constituents of the natural fibres like cellulose and lignin play a very crucial and decisive role in good quality paper formation.

The physical and chemical characteristics of the sisal fibre, which has been used as an additive to improve the quality of the pulp from secondary sources of fibre, have been reported in Chapter 2. Sisal is a strong leaf-fibre obtained from the leaves of the plant Agave sisalana, a monocotyledonous perennial shrub which grows in the tropical and sub-tropical regions. It occupies sixth place among fibre plants, representing 2% of the global production of plant fibres, which provides 65% of the world’s fibre. In India, it is mainly grown or cultivated in the arid and semi-arid regions of Andhra Pradesh, Bihar, Odisha, Karnataka, Maharashtra and West Bengal. The application of sisal fibres in different composite materials as a reinforcing fibre with and without chemical treatments establishes the mechanically strong and versatile nature of the sisal fibres. Microscopic photographs of the raw, modified and beaten sisal fibres provide a great support in revealing the papermaking potentials of the fibres.
Sisal fibres have been subjected to proximate analysis and its potential to be used in paper making has been studied. The lignin, cellulose, hemicelluloses, acetone extractive, silica, etc. contents in sisal fibres have been determined by standard methods. The chemical compositions are found to be not of much difference in the sisals obtained from different regions. Analysis of chemical treatments on the sisal fibre reveals that better separation of fibril can be achieved by acid treatment when compared to treatment with alkali (1% - 7% NaOH w/w), aqueous solution of sodium dodecyl sulfate and acetone. Mechanical beating resulted in better defibrillation. Pulping of sisal fibres by mechanical (≥ 90%) and semi chemimechanical (≥ 75%) methods showed good pulp yields. Results of the various physical tests conducted on papers prepared from sisal pulp are found to be encouraging. Paper made from sisal fibres exhibited high tear strength, moderate tensile strength, high porosity and nearly 100% opacity at low level of beating. Chemical treatments of the fibres while pulping resulted in improved properties of the ensuing paper sheets. Increase in beating time also had a positive impact on the strength properties particularly, the tensile strength (in terms of breaking length). Comparison of the various properties of hand-sheets from sisal pulps and rag pulps (conventional raw material for paper manufacturing in the handmade sector) further, substantiates the suitability and possibility of using sisal fibres for papermaking.

Cotton rag has been projected to have high demand as papermaking fibre and has already been recognized as a conventional papermaking fibre in the handmade sector basically, due to its high cellulose content and the ease of manufacturing paper from these resources. Chapter 3 describes an attempt to prepare paper from cotton rags blended with sisal fibre. Sisal fibres obtained from local sources are used as such just after cleaning and also used after some chemical treatment.

The sisal fibres and the cotton rags were subjected to proximate analysis in order to compare their papermaking abilities, which would further help to predict their blending potentials in papermaking. The chemical constituents like lignin, cellulose, holocellulose etc. of the cotton rags are analyzed by using standard methods. Morphological features of these fibres (sisal and cotton rags) have also been analyzed by observing their microscopic photographs in the beaten and unbeaten conditions. Indistinguishable nature of the beaten pulps of structurally two different types of
fibre, as observed from their microphotographs, render support to the feasibility of blending sisal virgin fibres with the textile wastes (cotton rags).

A minor dose (10% w/w) of sisal fibres refluxed in a few common solvents like distilled H₂O and 5% NaOH (w/w), for different time intervals (5, 10, 15 and 20 h) and with an azeotropic mixture of HCl + H₂O in dioxane for 8 hr with the help of a soxhlet apparatus, was found to influence the properties of the rag paper sheets containing them to varying degrees. Particularly, the strength properties like the tear factor, burst factor and the breaking length values of the blended sheets containing sisal fibres with mild chemical treatments (H₂O and 5% NaOH) for an optimum time period (10-15 hr), were identified to show a phenomenal growth in their values. The properties of the blended sheets have also been examined and compared with those of the unblended ones, as well as with those blended sheets containing unmodified sisal fibres. The overall results are encouraging as it is found that the addition of only 10% by weight of unmodified sisal fibres into the rag pulp is able to bring positive changes in most of the properties of the sheets especially, the strength properties.

Studies on similar type of blending of sisal fibre with pulp from paper waste have been reported in Chapter 4. Recycling of waste paper for paper production is also economic and environment benign technology. On recycling, the fibers become weak and quality of paper decreases. Sisal has already been identified as a reinforcing fibre for several other applications as described in chapter 2. Attempt has been made to improve the strength of fibres by blending sisal fibre with the pulp of waste paper.

Blending of sisal fibre with the waste paper pulp has been found to be instrumental in bringing out some ameliorative changes in the pulp quality of the recycled pulp. Sisal pulp has been blended with the waste papers (used notebooks) in different ratios and various physical properties of the blended sheets have been examined. The effect on paper properties (breaking length, tear and burst factors) by mixing 50% (w/w of waste paper) of chemically and thermally modified sisal fibres with the waste papers (waste press cuttings) have also been analyzed. The findings were interesting as blending of sisal with the recycled fibres resulted in a substantial improvement in strength characters without adversely affecting other properties like the optical (in terms of percentage brightness and yellow index) and water absorption
properties (or sizing) as determined from their one minute cob test values. Chemically
digested (alkaline peroxide) sisal fibres (50% by weight) have been observed to have
increased the strength property of the ensuing sheets more drastically than the
uncooked fibres, with the process advantage of considerable reduction in beating time
and energy.

The following papers containing the work undertaken in this Ph D
programme are under communication to different journals.

1. Fibre properties and its modification in paper making, a review, Journal of
Scientific and Industrial Research (Communicated).

2. Sisal fibre: a potential raw material for handmade paper, IPPTA (Accepted)

3. Blending of sisal fibres with cotton rags (textile wastes) in manufacturing of
handmade paper, IPPTA (Communicated)

4. Blending of sisal fibres with waste paper pulps for the manufacturing of
handmade paper, IPPTA (Communicated)

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