Dyeability and Different Wet Processing Technologies were Tried to Develop for Indigenous Leafy Sansevieria-Trifasciata Fibre

A. B. M Abdullah[1*], M.T. Islam[1], M.S Hasan, M.A.K. Oyon[1], Md. Billal Hossain[1]

Abstract

Background: Fibrous materials are pivotal in textile manufacturing and are categorized into natural and manmade fibers. Natural fibers include cellulose-based (e.g., cotton, jute, flax) and protein-based fibers. Despite synthetic fibers' dominance, natural fibers are gaining traction due to eco-friendly attributes. This study focuses on Sansevieria trifasciata fibers (STF), a lingo-cellulosic natural fiber with promising textile applications. Methods: The study examined STF's physical and chemical properties, employing standard processes for scouring, bleaching, and dyeing. Raw STF fibers underwent cleaning, scouring with sodium hydroxide, and bleaching with hydrogen peroxide. Dyeing trials utilized Direct, Reactive, and Vat dyes, optimizing parameters such as concentration, pH, time, and temperature, adapted from jute fiber methods. Results: Scouring effectively removed impurities, achieving significant fiber cleanliness. Bleaching produced high whiteness (>80%). Post-treatment, STF exhibited altered weight, strength, elongation, and moisture content. Dyeing with Direct, Reactive, and Vat dyes yielded vibrant hues, with Reactive and Vat dyes displaying superior wash fastness (4 and 4/5, respectively). Photodegradation tests revealed colour susceptibility under sunlight. Conclusion: STF demonstrates potential as a sustainable alternative in textiles, suitable for diverse applications including weaving, non-woven textiles, composites, and handicrafts. Adaptation of jute processing techniques was viable, though further research is needed for optimization. STF's renewable nature, eco-friendliness, and air purification benefits enhance its appeal for sustainable textile production and urban landscaping. Sansevieria trifasciata fibers present a viable eco-friendly option in the textile industry, warranting continued exploration and development.

Keywords: Natural Fibers, Ligno-cellulosic Fibers, Textile Processing, Sustainable Materials, Dyeing Techniques

Significance | This study showed a sustainable alternative to traditional and synthetic fibers, the environmental benefits of Sansevieria trifasciata fibers (STF), and potential textile applications.

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Introduction

Fibrous materials are the basic raw materials for any textiles. Fibers are classified as natural and manmade on the basis of their origins. While natural fibers are again divided into vegetable and protein fibers. Cellulose and protein both are polymeric in origin. Cotton, jute, kenaf, flax, ramie, sisal, hemp (Abdullah & Miles, 1985) are cellulosic commercially used fibers in textile products manufacturing both apparels and other uses. But cotton is the most abundantly used cellulosic fiber for its inherent quality. While lingo-cellulosic fibers such as jute, flax, ramie, kenaf are also used for apparels and- functional textiles. Presently 70 million tons of

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fibers used in world textile sector but 40 million of them are synthetics. 30 million are natural, cellulosic and lingo-cellulosic fibers. Demand and uses of naturals are in increasing trend due to nondestructive and environmentally pollution characteristics properties of synthetics (Abdullah & Rahman, 2017). Natural fibers are biodegradable, reusable, recyclable, and ecofriendly. For sustainable and inclusive development indigenous resources of materials are needed and focused. Consequently, the demand of natural fibrous material is increasing, so research and development of renewable and nonconventional natural fibers are increasing.

Sansevireia-trifasciata fibres (STF) have more than 70 species and grow in different climates both tropical, subtropical and desert countries. Presently different studies have been taken to extract fibres (Abdullah & Rahman, 2017) and various physical, chemical, biological and other properties along with structural features and crystallinity, functional groups were studied (Abdullah et al, 1992). It is a lingo-cellulosic natural fiber. Cellulose, lignin and other constituents of the fiber also determined (Abdullah & Matin, 1992). Its applications as various fields such as fishing net, handicrafts, decorative, composites with carbon fiber and nonwoven etc. are also indicated. It is also evergreen leafy fiber plant. In India some parts of the plant are used as medicine in indigenous ways. Now this plant is exported to our country from China and urbanized to be used as garden decorative plant for its air purificational properties by converting CO_2 to O_2 at night (Abdullah & Miles, 1984). The objective of this study is to determine preliminary physical, chemical pretreatments and dyeing properties of this newly extracted fiber. Here scouring, bleaching and dyeing with direct, reactive, vat dyes were tried to develop standard recipes by trial error method with some modification of jute system as both are lingo-cellulosic in nature (Allen, 1971).

Materials and Methods

Raw materials and chemical used

200 gms Sansevireia-trifasciata (STF) was collected from dyeing laboratory of PAU.

H_2O_2, NaOH, Na_2SiO_4 common wetting agent, sequestering agent,levelling agent all are commercial grades are used. Archroma brand Direct, Reactive and Vat dyes were collected from local agent.

Equipment and machinery

Glass Beakers, Steel pot, pH meter, Desiccator, Digital balance, Thermometer and common laboratory textiles testing equipments of materials were used in this study.

Experimentation and Analysis

Cleaning & combing

Before any treatments raw fibers (STF) were cleaned and combed with standard laboratory combing machine to remove non fibrous materials.

Scouring process

Scouring is a pretreatment process where oily, fatty, waxy materials are removed with saponification reaction. The STF was treated with sodium hydroxide at boiling with following reaction

$C_n+1COOH+NaOH \qquad C_nH_{2n+1}COONa+H_2O$ (Glycerin)

The following scouring recipe was adopted by a few trial & error experiments.

After scouring fibers were thoroughly washed with tap water and finally washed with distill water as shown in table 1.

Bleaching process

Bleaching is one of the most important wet processing textile technologies where coloring elements are removed by redox reactions. Hydrogen peroxide, bleaching powder, sodium hypochlorite, potassium permanganate, sodium dithionate etc. are common bleaching agents generally used in textile processing. Presently, hydrogen peroxide are widely used for its eco friendliness. STF is a ligno-cellulosic fiber like jute. Cellulose, hemicellulose and lignin are major constituent components3. Here, a modification method is adapted by preparative experiments by variation of bleaching parameter like H_2O_2, PH, liquor ratio, time temperature etc. The following standard bleaching recipe was adapted for STF bleaching after scouring with above scouring recipe with reaction as shown in table 2.

$H_2O_2+H_2O \qquad H^+ + OOH^-$

After bleaching, fiber was thoroughly washed with tap water and distills water and dried in room temperature. A bright white fiber was obtained (whiteness more than 80% visually). This fiber was then used for dyeing experiments as shown figure 1.

Dyeing process

Dyeing and printing are most important wet processing technologies where complex chemical reaction mechanism involved. Fibrous materials are colored with dyes/pigments having various chromophoric groups for colorifications. Dyes are classified as direct dyes, Reactive dyes, Vat dyes, Acid dyes, Basic dyes, and Disperse dyes (Mauersberger et al, 2007). Presently, cellulosic and ligno cellulosic fibers are commercially dyed with Direct, Reactive, and Vat dyes for this higher fastness & economic reasons as shown in figure 2. Here jute dyeing method were adapted for dyeing STF with Direct, Reactive and Vat dyes with certain modification with preparative experiments with variation of different dyeing parameters such as concentration of dye, PH, time, temperature (Roy et al, 2010) etc.

Direct dyeing process

Direct dyes are common coloring agent having big molecules that adhere to the fiber/substrate without forming any chemical bonds (Mauersberger et al, 2007). These dyes are applied to substrate in neutral or alkali media. Here, STF were dyed with Direct Archroma yellow 0.5%, 1% and 2% o.w.f with the following recipes as shown in table 3. Direct dye produces bright shades but exhibit poor wash fastness.

Table 1. Recipe for Alkaline Treatment Solution.

Ingredients	Amount
Alkali (NaOH)	3-5 gm/l
Wetting agent	1cc/l
Sequestering agent	1cc/l
Detergent	2cc/l
pH	10-11
Time	60 min
Temperature	90°c
M:L	1:50
Sample weight	50 gm

Table 2. Bleaching Recipe

Ingredients	Amount
H_2O_2	7-10 cc/l
NaOH	3-5 gm/l
Sequestering agent	1 cc/l
Detergent	3 cc/l
Wetting agent	1 cc/l
pH	9-11
Time	80-90 min
Temperature	80-90°c
M:L	1:50
Sample weight(scoured)	50 gm

a reactive dye, a chromophore group that presence responsible for the colorification, also contain certain reactive group that formed

Reactive dye

Reactive dyes are the most widely and commonly used in dyeing of cellulosic and ligno cellulosic fibers such as cotton, jute, flax etc. In covalent bond with the fiber/substrate (Mauersberger et al, 2007). Thus, they produce good fastness properties due to their chemical bonding. Here, STF were dyed with Archroma Red 0.5%, 1% and 2% owf with following recipe and then washed and dried. Fastness properties which were determined by standard laboratory method also shown respective place as shown in table 4.

Vat dye

Vat dye is one of the most widely used dye in textile colorification. Like other ligno cellulosic fibers vat dye also used commercially for better wash and light fastness characteristics properties. Here, a modified jute vat dyeing method was used for dyeing of STF with 0.5%, 1% and 2% Archroma Red with following recipes. And wash fastness was excellent results are shown in respective table 5,6,7,8, and 9.

Results

Sansevieria trifasciata is a leafy fibrous material. It is a ligno cellulosic fibre. Cellulose, hemicellulose & lignin are its major components. In this study, various physical, chemical properties along with different wet processing technologies such as souring, bleaching & dyeing with direct, reactive & vat dyes were performed to measure and analysis for optimizing the recipes for various pretreatments & dying. Recipes are shown in respective tables (1, 2, 3, 4, 5). Combing to clean the raw fibres were made & subsequently weight, strength, elongation at break, moisture contain etc. before and after scouring and bleaching were determined and the result are shown in the tables no (6, 7).

STF is a ligno cellulosic fibre. Here above methods were determined by slight modification of jute scouring, bleaching, dyeing methods as both are lignocellulosic fibres (Allen, 1971). After pretreatments weight & strength both were decreased. On the other hand, absorption, moisture content & whiteness increased which is similar to jute fibre.

Dye-ability of STF was observed by dyeing with Archroma brand of dyes (direct, reactive& vat) with scoured &bleached fibres. The recipes of dyeing with 0.5%, 1%, 2% owf was optimized with certain modification of jute dyeing methods & shown in their respective tables. Better wash fastness was observed with reactive (4), vat (4/5) dyes due to covalent bonding with fibre & insolublization of reactive & vat dyes, respectively table 8. Similar to jute when this fibre exposed to direct sunlight color change /yellowing occurred & color change due to photo degradation & it is increased with exposer time & color change were measured by spectrophotometer by determining ΔE value (Roy et al, 2010), & shown in the respective table no. 9. This is a preliminary observatory study for finding various physio-chemical properties of STF & their wet processing technologies such as scouring, bleaching & dyeing related information. Here, some anomaly observed in moister regain properties after pretreatment and bleaching. This may be intrinsic properties difference between jute and STLF fibers. Furthermore, compressive study with modern instrumentation is highly needed for giving better and exhaustive information.

Discussion

Sansevieria trifasciata, commonly known as snake plant, is a notable source of ligno-cellulosic fiber, valued for its fibrous leafy material. This fiber primarily comprises cellulose, hemicellulose, and lignin, which are essential components influencing its physical and chemical properties. The present study investigates various aspects of this fiber, focusing on its physical and chemical characteristics, and explores different wet processing technologies such as scouring, bleaching, and dyeing with direct, reactive, and vat dyes to optimize recipes for various pretreatments and dyeing processes. The detailed recipes and processes are provided in respective tables (1, 2, 3, 4, 5).

Physical and Chemical Properties

Sansevieria trifasciata fiber (STF) shares similarities with jute, another ligno-cellulosic fiber, which guided the modifications in traditional jute processing methods applied in this study. The fiber was subjected to a series of pretreatments including scouring and bleaching, followed by dyeing processes. Before and after these pretreatments, key physical properties such as weight, strength, elongation at break, and moisture content were measured and are detailed in tables 6 and 7.

Pretreatment Processes

Scouring and Bleaching: Scouring removes natural waxes and impurities, whereas bleaching increases the whiteness and absorption capacity of the fiber. The processes were tailored slightly from standard jute methods, given the intrinsic differences between the fibers. Post-treatment analyses showed a decrease in both weight and strength, while absorption, moisture content, and whiteness increased, mirroring the behavior observed in jute fibers.

Dyeing: The dye-ability of STF was tested using Archroma dyes, specifically direct, reactive, and vat dyes, at concentrations of 0.5%, 1%, and 2% on the weight of fiber (owf). Recipes were optimized through modifications to traditional jute dyeing methods. The dyeing processes and their outcomes are illustrated in the respective tables.

Dyeing Outcomes

Direct Dyes: Direct dyes showed satisfactory initial coloration but lower wash fastness compared to reactive and vat dyes.

Reactive Dyes: These dyes exhibited better wash fastness, rated at 4, due to the formation of covalent bonds with the fiber.

Vat Dyes: Vat dyes demonstrated the highest wash fastness, rated at 4/5, attributed to the insolubilization of the dye within the fiber structure. Exposure to direct sunlight caused color changes and yellowing in the STF, similar to observations in jute fibers. This photodegradation, which increased with exposure time, was quantitatively measured by determining the ΔE value using a spectrophotometer, with results displayed in table 9 (Roy et al., 2010). This preliminary study provides essential insights into the physio-chemical properties and wet processing technologies for Sansevieria trifasciata fiber. The observed anomalies in moisture regain properties post-treatment suggest intrinsic differences between STF and jute fibers. Thus, comprehensive studies employing modern instrumentation are required to gain exhaustive information and address these anomalies. STF demonstrates potential as a ligno-cellulosic fiber with properties and processing requirements akin to jute. The modifications and optimizations in scouring, bleaching, and dyeing processes are crucial for its effective utilization. Future research should aim to refine these processes further and explore advanced applications for STF in various industries.

Conclusion

STF is an indigenous leafy lignocellulose fiber. In this study, some physico-chemical properties along with scouring, bleaching and dyeing processes were tried to find out with trial and error by modifying jute wet processing technologies. Here, it is observed that there is similarity between jute and STF wet processing technologies, but as the processes are rudimentary, further comprehensive study is needed. From the above information, it can be concluded that STF has some potential in uses in textile sector as woven, non-woven, composite and handicraft fields. As STF is a natural renewable and perennial fibre plant. It has definite potential for a raw material resource of fibre sector. Moreover, air purification property definitely get its urbanization potentiality, here, roof agriculture is a considerable source of plantation. Overall techno-economic feasibility study is needed for conclusive information.

Author contributions

A.B.M.A., Conceptualized and developed the methodology, M.T.I. and M.S.H., prepared the original draft and collected data. M.A.K.O. and M.B.H., reviewed and edited the writing.

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Competing financial interests

The authors have no conflict of interest.

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