



Daffodil
International
University

Faculty of Engineering
Department of Textile Engineering

Thesis on:

Advancing Sustainability: Development Of Water-Repellent Jute-Cotton fabric Bags Alternative to Synthetic Bags.

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A thesis report submitted in partial fulfillment of the requirements for the degree of Master of Science in Textile Engineering.

DECLARATION

I hereby declare that the work presented herein to Daffodil International University, under the Thesis entitled “**Advancing Sustainability: Development of Water-Repellent Jute-Cotton fabric Bags Alternative to Synthetic Bags**” is an original work, this research has not been submitted for any degree, diploma, or certification at this or any other institution. All materials, methodologies, and references utilized in this Thesis have been duly acknowledged.



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LETTER OF APPROVAL

This thesis report prepared by Md. Al-Amin, Id- 0242220014123012 is approved in Partial Fulfillment of the Requirement for the Degree of MASTER OF SCIENCE IN TEXTILE ENGINEERING. The said students have completed their thesis work entitled “**Advancing Sustainability: Development of Water-Repellent Jute-Cotton fabric Bags Alternative to Synthetic Bags**” under my supervision. During the research period I found his sincere, hardworking and enthusiastic.



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Abstract

Jute is relative cheap and commercially available natural fiber. Jute is eco-friendly and also biodegradable. Jute fiber recognized for its sustainability & diversified end uses of its excellent mechanical properties. Jute fiber contains higher moisture that causes swelling as a result it degrades the mechanical properties. To overcome this difficulties water repellent jute fabric have been prepared by applying Zelan R3(Alkyl Urethane) a water repellent functional finishing on scoured, bleached & dyed jute fabric by pad-dry-cure method. The outcomes assessed through the drop test & spray test method (ISO 4920; 2012), aim to sustainable development of diversified jute products.

Key Words-Biodegradable, Sustainable, Water repellent, Alkyl Urethane, Diversified

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Chapter 01: Introduction

1.1 Background of the study

Jute, often referred to as the "golden fiber," has been a crucial part of Bangladesh's economy and textile industry for centuries. The country's favorable climate, with its high humidity and fertile deltaic soil, makes it one of the world's leading producers of jute. Bangladesh is 2nd largest jute producer country, annual production approximately 9.0 million bales. Average internal production of jute good is 1.6 million metric tons and average internal consumption is 1.4 metric tons. Bangladesh exports 42% jute products worldwide. Bangladesh holds around 72% of the global export earnings of jute. Average contribution of 3% annual earning and 1% GDP in Bangladesh economy. Jute goods export in FY 2022-2023 was 708.08 million US dollar where jute bags and sacks were accounted for 109.84 million. Bangladesh Govt. declared in 2023 jute as the product of the year. Bangladesh exports jute products to 135 countries. Bangladesh Govt. declared compulsory use of jute bags for 19 products. Bangladesh Govt. banned use of polythene bags from 1st October 2024 across all superstore and across Bangladesh form November 2024. Around the world 32 countries including members of the European countries have already banned the use of plastic bags. About 700 diversified jute producers produce 282 jute goods designated as diversified jute products. Annual demand for jute bags is 8.13 million US dollar. Annual demand of jute shopping bags stands at around 500 billion pieces globally. Jute and other form of packaging material are biodegradable. In recent years, efforts have been made to revitalize the industry by promoting diversified jute products for sustainable development and alternatives to plastic and synthetic fibers. [1]



Figure-1: Raw jute



Figure-2: jute products

1.2 Expanding Applications in Diversified Sectors

- **Agriculture, Automotive, build tech & Geotextiles:** Water-resistant jute can be used for soil conservation, erosion control, and biodegradable plant protection.



Jute Technical (Agrotech, Buildtech, Clothtech) and Geo Textiles- Canvas cloth and tarpaulins, jute laminates, jute and jute blended fabrics, soil savers.

Automotive Textiles- Jute application in automobiles has been expanding. Nearly two thirds of the automobile textiles are for interior trim, i.e., seat cover, carpets and roof and door liners. Global brands such as BMW, Mercedes, Volvo, Audi, Daimler Chrysler and Ford have been using jute-based composites for door panels and dashboards.



Jute Stick Charcoal Products - Foreign investors are welcome to invest for commercial production of jute stick charcoal products, such as cosmetics, medicines, battery, photocopier (dried ink), water purification filter, etc.

Biodegradable Jute-tin Foreign investors are welcome to invest for commercialization and mechanization of biodegradable jute-tin.



Figure: Diversified jute products (Source: <https://bida.gov.bd>)

- **Outdoor & Home Furnishings:** Jute-based upholstery, carpets, and mats with water-repellent properties enhance usability in indoor and outdoor settings.



Figure: Outdoor & Home Furnishings jute products(Source: <https://bida.gov.bd>)

- **Fashion & Apparel:** Water-resistant jute fabrics can be used for making jackets, shoes, and accessories, promoting eco-friendly fashion.

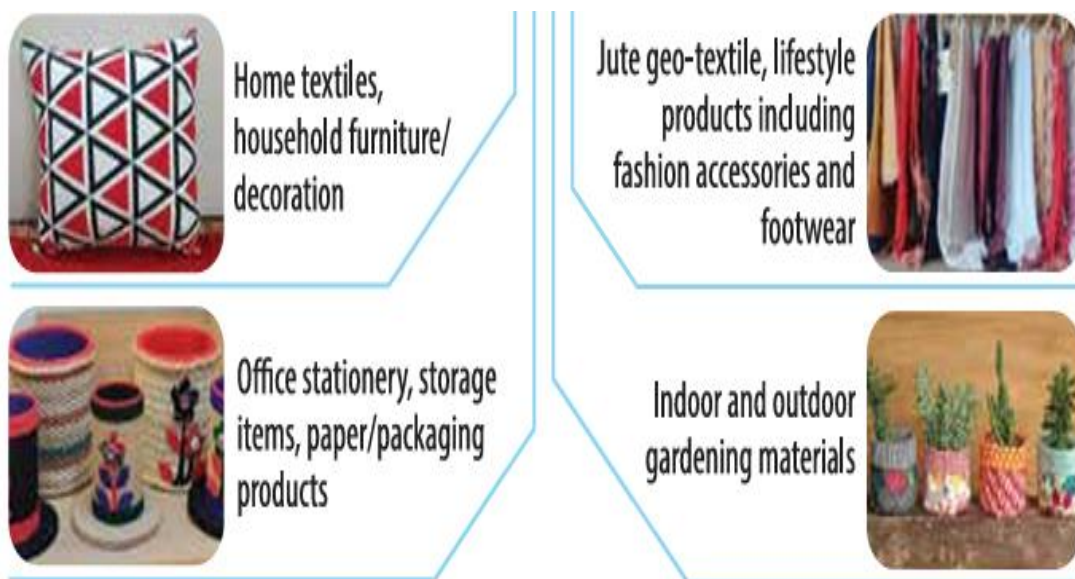


Figure: Fashion & Apparel jute products (Source: <https://bida.gov.bd>)

- **Industrial Packaging:** Waterproof jute sacks and bags provide better storage solutions for grains, cement, and other moisture-sensitive materials.



Figure: Jute Bag

1.3 Aims and objectives

- II. Develop an effective water-repellent jute-cotton natural woven fabric by chemical treatment with Bio-based polymer.
- III. Promote the widespread usage of sustainable diversified jute products.
- IV. Enhance Economic growth.

1.4 Scope of the Study

- I. Focus on natural and eco-friendly water-repellent treatments of jute-cotton fabric.
- II. Application possibilities in apparel, home textiles, and technical textiles

1.5 Significant of the study

- I. Promote sustainable eco-friendly & biodegradable diversified jute products instead of synthetic products.
- II. Reduction in environment pollution.
- III. Enhance Economic growth.
- IV. Employment.

Chapter 2: Literature Review

2.1 Introduction:

Jute is a ligno-cellulosic natural fiber that falls into the bast fiber category, derived from the skin of the plant's stem. It is a composite fiber, where many ultimate fibers (1-4 mm) are cemented together by lignin to form a long fiber. A single technical fiber contains 5-10 ultimate fibers crosswise and more than thousands lengthwise. Jute is one of the cheapest natural fibers and is considered the fiber of the next generation. In terms of use, worldwide consumption, production, and availability, it is the second most significant vegetable fiber after cotton. The Bengali word "jhuto" is the source of the name "jute." Jute is frequently referred to as the "Golden Fiber" of Bangladesh because of its golden, smooth sheen. [2]

Jute plants thrive in rich land, especially along tidal basins. The leading producers of jute are Bangladesh, India, China, and Myanmar. Bangladesh is the largest cultivator of raw jute, while India is the largest producer of jute goods globally. Jute is also produced in southwest Asia. The fiber is known by various names such as Pat, kosta, Nalita, Bimli, or Mesta (kenaf). Kenaf, known as Mesta, is cultivated in the Indian subcontinent, Thailand, China, and Africa. [3]

Jute fiber comes from annual plants, including white jute (*Corchorus capsularis*), which originates from Asia, Tossa jute (*Corchorus olitorius*), originating from Africa/Asia, and mesta (*Hibiscus sabdariffa*), originating from East Asia (Bangladesh/Thailand). The two main types of jute grown in Bangladesh are white jute (*Corchorus capsularis*) and dark jute or Tossa (*Corchorus olitorius*). [4]

Shine, high tensile strength, low extensibility, moderate heat and fire resistance, and long staple lengths are just a few of the many inherent benefits of jute fiber. It offers numerous benefits over synthetic fibers while preserving ecological balance and being biodegradable.[5]

In addition to being a popular textile fiber, jute is also used as a raw material to make unique and valuable products. Numerous traditional packaging fabrics, hessian, sacking, carpet backing, mats, bags, tarpaulins, ropes, and twines are all made with it. Jute fibers have recently been utilized in a variety of diverse products, including: Products include greeting cards, molded door panels, soft luggage, footwear, stylish saris, salwar kameezes, and countless

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other practical consumer goods. It has average resistance to fire and heat, good insulation to sound and heat; it has been used successfully as flexible low-cost packaging material for packing industrial and food products. [6]

One of Bangladesh's primary cash crops is jute. The Bangladeshi economy greatly benefits from the jute industry. From an economic, agricultural, industrial, and commercial standpoint, jute is an essential industry in Bangladesh. A variety of jute goods that are also ecologically beneficial are produced in Bangladesh. Bangladesh exports jute and jute goods to many nations worldwide, generating a certain amount of foreign exchange each year. That goes towards Bangladesh's national income. Jute used to be known as the "Golden Fibre" of Bangladesh. However, the expansion and success of this business are at risk, both now and in the future. Bangladesh's jute industry faces numerous challenges, including a lack of scientific expertise and contemporary equipment, market tools, high-quality seed availability, low productivity, inaccurate market forecasting, land fragmentation, natural disasters, conflicts, and global economic crises, among others. In light of the current issues, we will attempt to propose some measures that could aid in their eradication and enhance the current state of the Bangladeshi jute industry.[7]

Cellulosic fibers have hydrophobic property due to the presence of free hydroxyl groups[3] . Jute a cellulosic fiber contains higher moisture approximately 12%, due to higher moisture regain properties degrade the mechanical as a result it becomes difficult to produce longer lasting diversified jute products for particular end uses. [8]

Surface characterization finishing can be used to develop diversified water repellent textile products. Cellulosic fiber can be used for diversified textile products by chemical finishing converting hydrophilic to hydrophobic. [9]

Jute fiber is one of the most important fiber to develop diversified jute products such as bags, carpets and other forms of packaging materials [10].

2.2 History of jute fiber:

Poor Indian villages were accustomed to dressing in jute during the reign of the great Mughal emperor Akbar. Bengali Indians have been using jute ropes and twines since ancient times. The British East India Company assigned authority in Europe in the 17th century. Margaret Donnelly was working in the jute industry by the turn of the 20th century. In 1793, the East India Company began exporting jute. In the beginning of the year 1830, Dundee spinners had

determined spinning of jute yarn by transfiguring their power-driven flax machinery. This led to an increase in the export and production of raw jute from the Indian sub-continent, which was the single supplier of jute. The major jute-growing areas were mainly in Bengal, on the Kolkata side. In 1855, the first power-driven weaving plant was built in Rishra, close to Kolkata, beside the Hooghly River. Five mills with about 950 looms were established by 1869. The rate of expansion was so rapid that by 1910, 38 companies were running about 30,685 looms, producing about 450 million bags and a billion yards of cloth. Nearly all of Dundee and Kolkata had been taken over by the jute industry by the middle of 1880. Jute production began in other nations, including France, America, Italy, Austria, Russia, Belgium, and Germany, later in the 1800s. In the 19th century, the jute industry saw remarkable growth. Approximately 68,377 looms were set up on the Hooghly River close to Kolkata during the year 1939. Jute is primarily used to weave coarse bagging materials, which are made from finer fabrics called burlap or hessian. Kolkata gained world-class leadership in burlap and other bagging materials thanks to the establishment of handlooms there.[11]

The majority of the jute barons had begun to leave India after it gained independence, leaving the jute mills in place. Marwari businessmen took control of the majority of them. East Pakistan had the best supply of jute in 1947, following the partition. Since then, numerous mills have been established in Narayanganj by various groups of Pakistani families who entered the jute industry. The majority of jute mills were taken over by the Bangladeshi government in 1971 following the country's independence from Pakistan. Later, the government. The recent mapping of the genome of the jute seed by several Bangladeshi scientists working in collaboration has opened up a new horizon for the jute sector. [12]

2.3 Geographical distribution of jute fibre:

Jute fiber, primarily derived from the plants *Corchorus olitorius* (tossa jute) and *Corchorus capsularis* (white jute), is predominantly cultivated in tropical and subtropical regions. The geographical distribution of jute fiber production is concentrated in specific areas due to the crop's requirement for warm, humid climates with ample rainfall. Below is an overview of the key regions where jute is grown. [13]

1. South Asia (Major Producer)

- **Bangladesh:** Bangladesh is the largest producer of jute in the world, accounting for a significant portion of global production. The Ganges-Brahmaputra delta region, with its fertile alluvial soil, is ideal for jute cultivation.
- **India:** India is the second-largest producer of jute, with major cultivation in the states of West Bengal, Bihar, Assam, Odisha, and Andhra Pradesh. The Hooghly Basin in West Bengal is particularly renowned for high-quality jute.
- **Nepal:** Jute is also grown in the Terai region of Nepal, which shares similar climatic and soil conditions with neighboring India and Bangladesh.

2. Southeast Asia

- **Myanmar (Burma):** Myanmar has a long history of jute cultivation, particularly in the Irrawaddy Delta region.
- **Thailand:** Small-scale jute cultivation occurs in Thailand, though it is not a major producer compared to South Asia.
- **Vietnam:** Jute is grown in some parts of Vietnam, but production is relatively limited.

3. China

- China cultivates jute in its southern provinces, such as Guangdong, Guangxi, and Yunnan, where the climate is suitable for jute growth.

4. Africa

- **Egypt:** Jute has been historically cultivated in Egypt, particularly in the Nile Delta region.
- **Sudan:** Some jute cultivation occurs in Sudan, though it is not a major producer.
- **Other African Countries:** Small-scale jute farming is found in countries like Nigeria and Kenya, but production is minimal compared to South Asia.

2.4 Chemical Composition of jute fiber:

Table:1 Chemical Composition of jute fiber

Substances	Weight percent (%)
Cellulose	55-65
Hemi-Cellulose	14-20
Lignin	12-13
Moisture regains	12
Pectin	0.2
Wax	0.5

2.5 Micro-Structure of jute fiber:

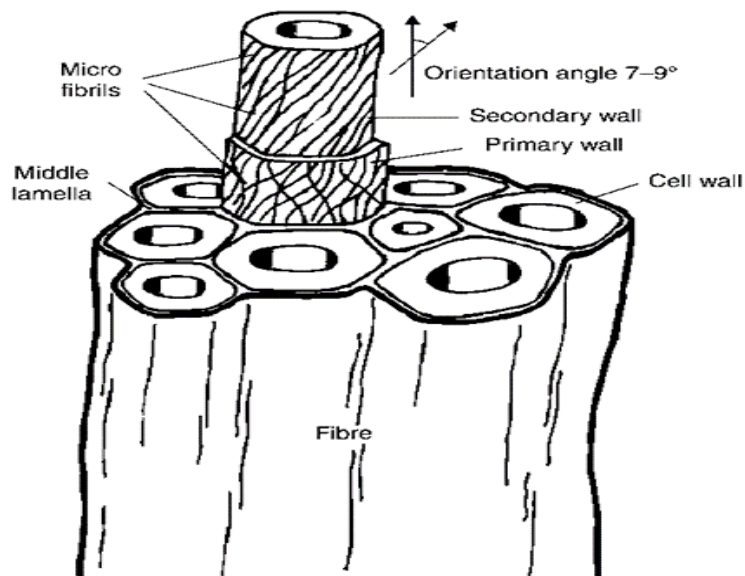


Figure: Micro-structure of jute fiber (source google)

2.6 Chemical structure of jute fiber

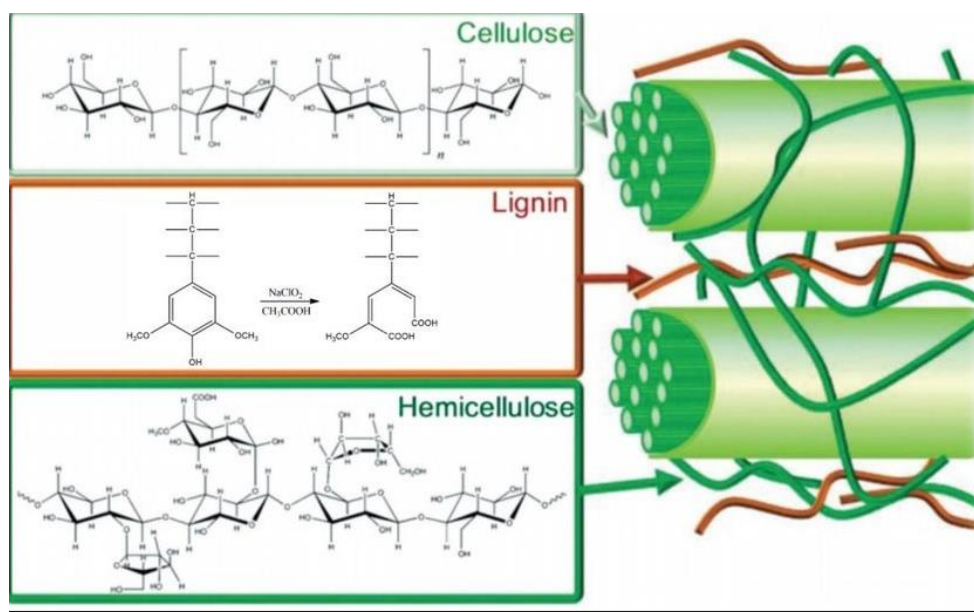


Figure: Chemical structure of cellulose, lignin, hemicellulose (Source: Journal)

2.7 Properties of Jute

The specific strength and stiffness of jute fiber are moderately high. Each fiber has a different slinness ratio. Size, maturity, and the processing techniques used to extract the fiber are some of the variables that affect the fiber's characteristics.

2.7.1 Physical properties of jute fiber are as follows:

Length of ultimate fiber	:1.5 to 4 mm (Individual fibrils).
Diameter of ultimate fiber	:0.015 to 0.002 mm.
Length width ratio	: 90:1 (approximately).
DP of cellulose	: 500 - 2000
DP of Hemi-cellulose	:50 – 200
DP of Lignin	: Variable (not fixed)
Length of technical fiber	:150 to 300 cm (5 to 12 feet).
Color	: Blonde, white, yellow, brown, or grey.
Strength	: 3.5 to 5 gm/denier.
Specific Gravity	: 1.48
Specific Heat	: 0.325
Moisture Content	:12.1%
Moisture Regain	:13.75% (Standard).
Elasticity	: Elastic recovery very low.
Breaking Extension	: 1.8%
Resiliency	: Bad.
Abrasion resistance	: Moderate
Dimensional stability	: Good on average
Thermal Insulation	: Good
Thermal conductivity	: Low
Antistatic	: Good
Acoustic Insulation	: Good

2.7.2 Chemical properties of jute fiber are as follows:

Acids and Alkalis: Jute is a lingo-cellulosic fiber. It has cellulose, hemi-cellulose, and lignin. It represents also some similar character of another cellulosic fiber (cotton and flax). It is easily damaged by acids. But it has good resistance to Alkalis.

Organic solvents: Resistant to organic solvents.

Effect of Bleaching: It is affected by oxidizing or reducing agents.

Resistance to sunlight and heat: Poor resistance to strong sunlight. At high temperatures, it burns rapidly.

Dye ability: Good affinity to Basic Dyes, but light and wash fastness is very poor. Other dyes are like for the cellulosic fibers such as natural, vat, sulfur, reactive, and pigment dyes.

Biological properties: Scoured jute has good to excellent resistance to microorganisms and insects.

2.8 Jute Product Types

Jute products can be divided into four manufacturing types for general utility purposes:

HESSIAN or BURLAP: A high-quality jute yarn used to weave a simple cloth that weighs 5 to 12 ounces per yard. It is utilized for many different purposes, including as making bags and textiles.

SACKING: Also referred to as "heavy goods," these loosely woven, lower-grade fabrics in plain or twill weaves weigh between 12 and 20 ounces per yard and come in a variety of widths. It works with many kinds of bags.

JUTE YARN AND TWINE: The mills themselves use the majority of the single-strand jute yarn they produce to make fabric and twine. Both in India and elsewhere, jute twine in a range of weights and thicknesses is widely used for tying, sewing, and a number of industrial uses such cable binding and packing pipe joints.

2.9 Necessity of Water-Repellent treatment on Jute Fabric for Sustainable & Diversified applications

Jute is a natural, biodegradable, and eco-friendly fiber widely used in various industries, including textiles, packaging, and home furnishings. However, its hydrophilic nature (high water absorption approximately 13.75%) limits its application, especially in humid and wet environments. To enhance its usability, the development of water-repellent jute fabric is essential, promoting sustainability while expanding its applications.

2.10 Limitations of existing water-repellent treatments for Jute fabrics

Khatun, A., Islam, M. N., Hossen, M., Sarker, J., Sikder, H. A., & Chowdhury, A. M. S. (2022). Developed "Development of water repellency on jute fabric by chemical means for diverse textile uses" by fluorocarbon compound (NUVA TTC) that contains Perfluoro Octane Sulphonate (PFOS) & Perfluoro Octanoic Acid (PFOA).

According to American Cancer Society PFOS & PFOA both are toxic and carcinogenic.

Ammayappan, L., Chakraborty, S., & Pan, N. C. (2020). Silica nanocomposite based hydrophobic functionality on jute textiles by silica nano sol and fluorocarbon compound (NUVA TTC) that is toxic and hazardous.”

2.11 Sustainable Alternatives to Synthetic Water-Repellent

Coatings

- I. **Wax-based coatings** (e.g. beeswax)
- II. **Silicon-based treatments** (biodegradable and less toxic)
- III. **Bio-based polymers** from plant extracts
- IV. **Plasma treatment and nanotechnology** for fluorine-free water repellency

2.11.1 Bio-based water repellent: (DUPONT™ ZELAN™ R3):

For fabrics, textiles, and nonwovens, DUPONT ZELAN™ R3 is a long-lasting water repellent treatment. It is made from plant-based, non-fluorinated, renewable materials that naturally replenish over time.

2.11.2 Features

- I. Outstanding water resistance for rain and water-based stains on natural and synthetic fibers and blends
- II. Excellent resilience to dry cleaning and home washing, enabling prolonged water repellent protection following several washes.
- III. Fabrics' breathability will be preserved, resulting in their comfort.
- IV. Good runnability, which permits a continuous production process
- V. Compatible with finishing auxiliaries that are frequently used.
- VI. 63% of materials are sourced sustainably (ASTM D-6866-12)
- VII. Alkyl phenol ethoxylates (APEO) are not used in its manufacture.

2.11.3 Product characteristics

Ionic type	Non-ionic/ Cationic
Appearance	Off-white to white liquid

Chemical structure	Alkyl Urethane
Active matter, wt%	25
Solvent	Water
Specific density	1.001 g/ml
pH	4-7
Solubility	Readily dispersible in water between 10-35 ⁰ C
Storage Stability	Stable for 2 yrs properly stored in closed containers at 20° C

2.11.4 Bath preparation

- I. Adjust pH of water bath with acetic acid to between 4.0-5.5, when using cellulose-cross linking agent on cotton fabrics, it may not be necessary to add acetic acid to the bath to adjust pH.
- II. If using combined with cross-linking agents, fillers or additives dilute each and add to the water bath.
- III. Dilute Zelan TM R3 with an equal amount of cold water, and add to the bath last.

2.11.5 Application to Fabric

- I. Immerse Fabric into Solution.
- II. Typical padding liquor pick-up of approximately 40-80% based on the fibre.
- III. Bath temperature of 20-30°C.

2.11.6 Drying & Curing:

- Drying at 110-130°C
- Separate curing: 5 min at 150°C on curing machine

Chapter-3: Materials & Methods

3.1 Materials:

A plain jute woven fabric collected from Mony jute, Dhaka, Bangladesh.



Figure: Mony jute sales office, Farmgate



Figure: Jute Fabric

The technical specifications of the fabric are as follows:

- **Weave structure:** Plain weave
- **Warp yarn:** Cotton (20% by weight)
- **Weft yarn:** Jute (80% by weight)
- **Ends per inch (EPI):** 48
- **Picks per inch (PPI):** 18
- **Measured GSM:** 302

3.2 Chemicals:

Wetting agent and sequestering agent, Sodium bi carbonate, Sodium hydroxide, Hydrogen Peroxide, Peroxide stabilizer, Alkyl Urethane (**ZELAN™ R3**), Cellulose cross-linking agent **ARKOPHOB® DAN**), purchased from Dhaka, Bangladesh.

3.2.1 Pretreatment Chemicals: Here is a table listing the chemicals along with their functions

Chemical name	Chemical formula	Functions
Wetting Agent	$C_{20}H_{37}NaO_7S$	Reduces surface tension, improves fabric wetting.
Sequestering Agent	$C_{10}H_{10}C_{12}O_3$	Deactivate metal ion to reduce water hardness
Sodium bi Carbonate	$NaHCO_3$	Mild alkali for scouring
Sodium Hydroxide	$NaOH$	Strong alkali used for scouring, mercerization, and pH control.
Hydrogen Peroxide	H_2O_2	Oxidizing agent used for bleaching textiles.
Na silicate	Na_2SiO_3	Stabilizes hydrogen peroxide during bleaching

3.2.2 Finishing Chemicals:

Chemical name	Functions
Alkyl Urethane (ZELANTTM R3)	One of the most well-known PFAS-free* technologies is ZELANT TM R3. Teflon Eco Elite TM with ZELANT TM R3, the first renewable-source DWR in the industry, was unveiled in 2015 in partnership with The Chemours Company and works with all kinds of fibers. It is composed of 63% plant-based materials and provides exceptional durability and water resistance while maintaining breathability.
Cellulose Cross-linking Agent (ARKOPHOB[®] DAN)	A unique stabilized formaldehyde-free crosslinking agent called ARKOPHOB [®] DAN is used to increase the effectiveness of water repellent products free of PFAS, fluorocarbon-based emulsions, and waterborne polymer dispersions.

3.3 Tools & Equipment:

In this procedure digital electronic balance, hand gloves, glassware, pipette, laboratory jute padder, stenter, Jute dryer machine were used.

3.4 Experimental procedure:

3.4.1 Pretreatment of jute-Cotton fabric:(Exhaust method)

Combined Scouring & Bleaching of Jute -Cotton fabric:

3.4.2 Definition of Scouring:

In order to create hydrophilic and pure textile material, scouring is the process of eliminating all natural and additive impurities, such as oil, wax, fat, hand dust, etc. It is among the most important wet processing procedures.

3.4.3 Objects of Scouring:

- I. To make the fabric highly hydrophilic.
- II. To eliminate impurities as nearly as possible, including gum, husks, oils, and waxes.
- III. To improve fabric or textile materials' absorbency without causing chemical or physical harm.
- IV. To add alkali to create a clean material.
- V. To prepare the fabric for the following step.
- VI. In the case of cotton, to eliminate non-cellulosic material.

3.4.4 Definition of Bleaching

Bleaching is the process of decolorizing the natural coloring material (found in the fabric) by treating it with oxidizing and reducing agents to guarantee a lasting whiteness.

3.4.5 Objectives of Bleaching

- Achieve a high level of consistent fabric absorbency to dyes and water.
- Make sure the whiteness is consistent.
- The fabric's DP should stay high and it shouldn't be damaged.
- Eliminate the fabric's natural coloring materials.

Make sure the dyeing property is level.

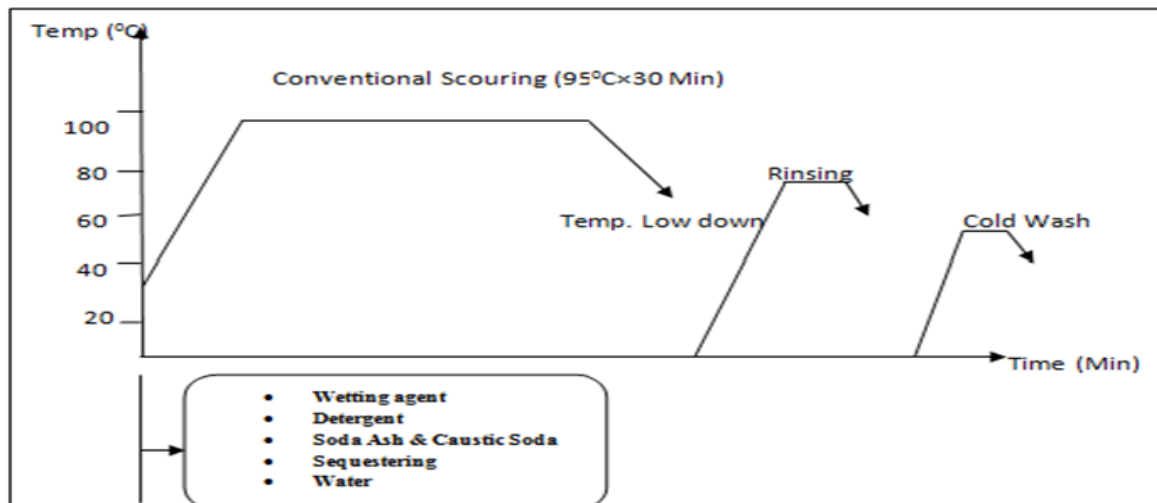
- Prepare textile materials for further processing, such as printing, dying, etc.

3.5.6 Recipe (Sample Weight: 1 kg)

Chemical name	(g/L)	Amount
Wetting Agent	1	10 ml
Sequestering Agent	1	10 ml
Detergent	2	20 ml
Sodium bi Carbonate	5	50 gm
Sodium Hydroxide	1	10 gm

Hydrogen Peroxide (50%)	5	50 ml
Peroxide stabilizer	1	10 ml
Time	30 min	
Temperature	95-100°C	
p ^H	11	
M: L	1:10	10 L

3.4.7 Process Curve: Process curve is clearly lining system that will gives a clear conception about use of different chemicals and auxiliaries



3.4.8 Procedure:

- Set the bath with substrate at room temperature with auxiliary agent, stabilizer and caustic soda.
- Start to raise the temperature and add hydrogen peroxide after few minutes.
- Raise the temperature to 85 – 90 °C at 1 – 2 °C/minute.
- Run the bath for 45 – 60 minutes; for rapid bleaching need higher temperature.
- Cool down 70°C and drop the bath
- Peroxide killing treatment can be applied to remove residual peroxide in goods.



Figure: Modern Exhaust Dyeing machine

3.4.9 Finishing of Jute-Cotton fabric: Finishing Recipe:

Sample 1

S/L	(Scoured & Bleached, Blue & Dark-blue Jute-Cotton fabric)	
1	Chemical name	Amount (g/L)
2	Alkyl Urethane (ZELAN™ R3)	50
3	Cross-linking Agent (ARKOPHOB® DAN)	10
4	Acetic acid	Maintain P ^H 4-5.5

Sample 2

S/L	(Scoured & Bleached, Blue & Dark-blue Jute-Cotton fabric)	
1	Chemical name	Amount (g/L)
2	Alkyl Urethane (ZELAN™ R3)	80
3	Cross-linking Agent (ARKOPHOB® DAN)	10
4	Acetic acid	Maintain P ^H 4-5.5

Sample 3

S/L	(Scoured & Bleached, Blue & Dark-blue Jute-Cotton fabric)	
1	Chemical name	Amount (g/L)
2	Alkyl Urethane (ZELAN™ R3)	100
3	Cross-linking Agent (ARKOPHOB® DAN)	10
4	Acetic acid	Maintain P ^H 4-5.5

3.4.10 Finishing method (Pad-Dry -Cure method)

Jute-Cotton fabrics were treated with 50 g/l, 80 g/l & 100 g/l Alkyl urethane 10 g/l, cross linking agent add acetic acid to maintain P^H 4.0-5.5 bath temperature 20-30⁰C. The immersed jute fabrics were then padded in laboratory padding mangle liquor pick-up of approximately 90%, drying at 110⁰C for 30 min cured for 5 min 150⁰C in stenter machine. After finishing the finished fabrics were conditioned at standard temperature.

Liquor pick-up: Liquor pick up of the samples was determined by before and after padding by the following formula.

Liquor pick-up = (wt. of sample after padding- wt. of sample before padding) *100/wt. of sample before padding.

$$= ((180-100) \div 100) * 100$$

$$= 80 \%$$

3.4.11 Working mechanism of Padder m/c:

A Padder is a compact, laboratory-scale machine used to apply liquids like dyes, chemicals, and finishes to fabric samples. It simulates the padding process in textile manufacturing, where fabric is passed through a liquid solution, then squeezed between rollers to ensure uniform application and absorption.

Key Features of a Laboratory Padder:

1. Adjustable Rollers – The fabric is passed through two or more rollers to apply even pressure and squeeze out excess solution, ensuring uniform chemical or dye application.
2. Variable Pressure Control – Allows adjustment of roller pressure for different fabric types and chemical formulations, ensuring optimal penetration without damage.
3. Solution Bath – Holds the liquid (e.g., dye, finish, or other chemical treatments) in a bath through which the fabric is dipped before passing through the rollers.
4. Fabric Speed Control – Adjustable conveyor speed allows for control over the time the fabric spends in contact with the liquid solution, affecting the degree of treatment.
5. Digital Control Panel – Provides easy adjustment of pressure, speed, and solution volume to ensure precise and reproducible results.
6. Compact Design – Smaller, lab-scale version of industrial padders, ideal for research, development, and small-scale testing.

7. Safety Features – Safety guards, emergency stops, and proper handling mechanisms to prevent accidents during operation.

Applications:

- Dyeing: For even application of dye or pigment on fabric.
- Finishing: Applying finishes like softeners, water repellents, or flame retardants.
- Chemical Treatments: Applying various chemicals used in textile manufacturing, such as anti-microbial treatments or stain-resistant solutions.
- Shrinkage Testing: Simulating treatments to test fabric behavior under different conditions.



Figure: Padder Machine

3.4.12 Drying & Curing: Stenter Machine:

As the fabric travels through multiple hot-air chambers (3–5, each about 3 meters long), its edges are held in place by two endless, self-lubricating, driven chains, typically 40 to 60 meters long. The fabric receives equal amounts of hot air from above and below. A stenter can overfeed the fabric to provide the required shrinkage during heat setting, while the width is increased to the precise value specified by the chains. The challenge of applying overfeed has led to a decrease in the use of clip stenters. The stenter speed ranges from 10 m/min for

heavy weight furnishing fabrics to 100 m/min for lightweight dress-goods. The speeds depend on -Drying, Heat setting, Curing after application of finishes.

A modern stenter's controllers can keep an eye on and regulate the following variables:

- a. Temperatures
- b. Moisture regains,
- c. The width of the fabric
- d. Fabric weight,
- e. padder pressures, and
- f. humidity in the exhaust.



Figure: Stenter Machine

3.5 Water repellent test: Sample was stored at standard 65% RH and 25°C for 24 Hrs. Three tests were done for the assessment of water repellency –

3.5.1 Drop test-

It is a visual test method for evaluating water repellency. In this procedure 1% direct red solution was prepared and by pipette a droplet was placed on the water repellent treatment sample and untreated sample.



Figure: 1% direct red solution.

Observation-The droplet will rest up on it and will not be absorbed by the treated sample for long time but untreated sample absorbed water within a few seconds.



Figure-1(a) Control fabric

Figure-1(b): Treated fabric



Figure-2(a) Control fabric

Figure-2(b) Treated fabric

3.5.2 The Spray Test Method (ISO 4920:2012):

It is a standardized test used to evaluate the water repellency of textiles by assessing the resistance of the fabric surface to wetting.

Test Procedure (ISO 4920:2012)

250 cu.cm. of water at $27^{\circ} \pm 2^{\circ}\text{C}$ is gradually poured into the funnel to conduct the test. Six inches separates the center of the fabric from the bottom of the spray. After the spraying is complete, the sample holder is taken out, and the excess water is extracted by tapping the frame six times against a solid object while the sample's face is facing the solid object. The tapping is done in two steps: three taps at one spot on the frame, followed by three taps at another spot, and finally three taps at a point that is completely opposite. The spray rating provides an evaluation of the fabric's water repellency. The fabric surface is visually inspected by comparing it to the rating chart of photographs once the excess water has been removed.

Nomenclature for rating:

100 (ISO 5): No sticking or wetting of upper surface

90 (ISO 4): Slight random sticking or wetting of upper surface

80 (ISO 3): Wetting of upper surface at spray points

70 (ISO 2): Partial wetting of whole of upper surface

50 (ISO 1): Complete wetting of whole of upper surface

0 (ISO 0): Complete wetting of whole and lower surface

©Daffodil International University



Figure: Test Sample



Figure: Spray Tester

3.5.3 Tensile Strength Test Method (ISO 13934-1:2013)

This is referred to as a strength test where the load is applied along the direction of the test sample. Tensile strength test of fabric is divided into **two** groups-

- Strip test
- Grab test.

Strip Strength Test:

Five fabric samples are stretched parallel to the weft and five parallel to the warp.

After cutting the specimens to a width of 2.5 inches, the threads are removed from both edges, reducing the width to 2 inches.

It is necessary to allow enough extra length for gripping in the jaws because the test length should be 8 inches between the jaws.

In ideal circumstances, the specimen will be positioned in the center. To stop slipping, security gripped the entire width.

Until the specimen tears out, the load is applied consistently throughout its entire width.

A test specimen should not be used in calculations if it breaks within 0.25 inches of either pair of jaws' line of contact at a load lower than the average of typical breaks.

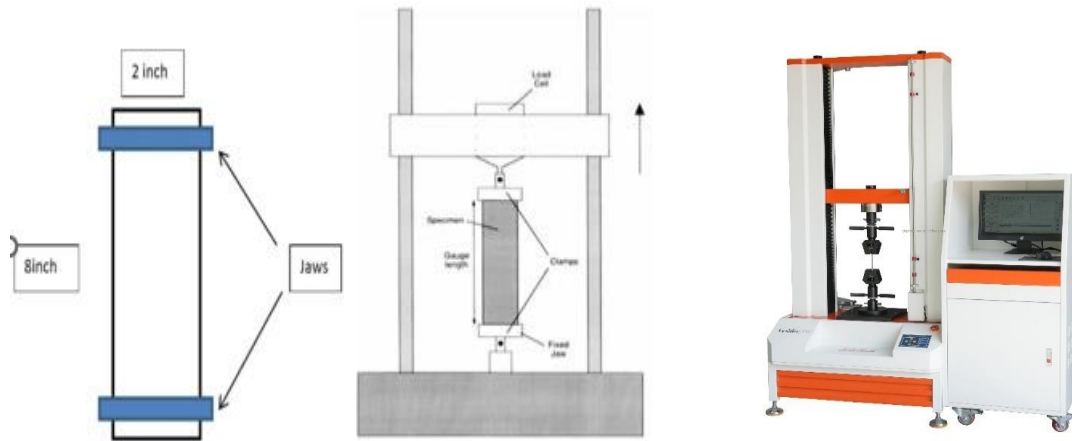


Fig: Tensile Tester

3.5.4 Tear Strength Test Method (ISO 13937-1:2000)

Tear Strength: The force needed to initiate or maintain a tear in a fabric under particular circumstances is known as tear strength.

Three Types of Tear Test:

- The tongue
- Trapezoid
- Elmendorf

Elmendorf Tear Test: Sample Preparation:

- ❖ First, we take a specimen that is 100 x 75 mm².
- ❖ The template is positioned on the specimen and cut in accordance with the template, as shown in the figure.
- ❖ A 20 mm slit is made in the center of the specimen.
- ❖ The Elmendorf continuous is used in the test to tear the fabric 43 mm

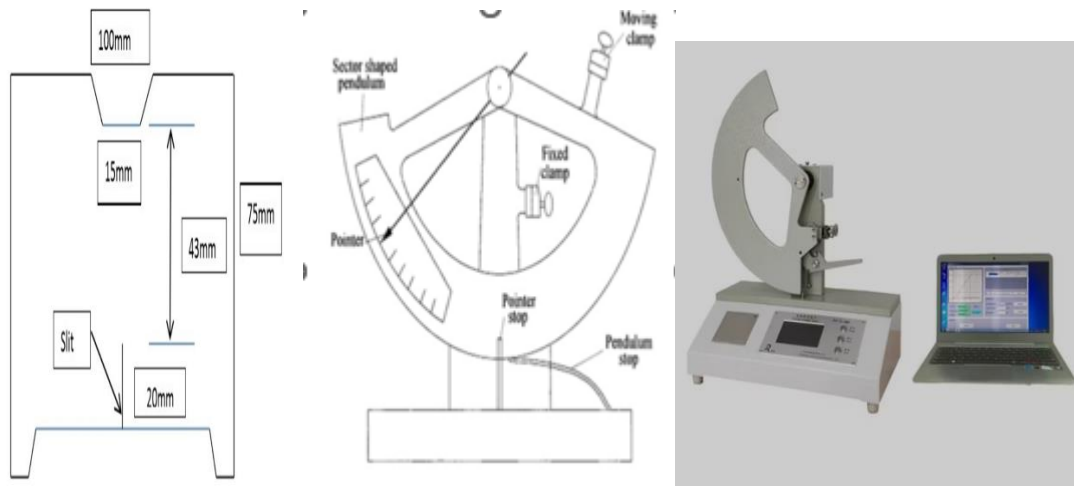


Figure: Elmendorf Tear Tester.

Working Procedure:

A sector-shaped pendulum with a moving sample clamp and another clamp fixed to the frame make up the apparatus. The specimen is secured between the two clamps when the pendulum is in the elevated starting position.

A slit cut in the specimen between the clamps initiates the tear, and when the pendulum is released, the specimen is torn as the moving clamp separates from the fixed one. The pendulum's pointer, which is graduated to directly read the tearing force.

3.5.5 Air Permeability Test (ISO 13937-2:2000)

Air permeability: The volume of air, measured in cubic centimeters, that passes through 1 cm² of fabric per second at a pressure of 1 cm head of water is known as the fabric's air permeability.

Purpose of the Test

- Assess the breathability of the cloth.

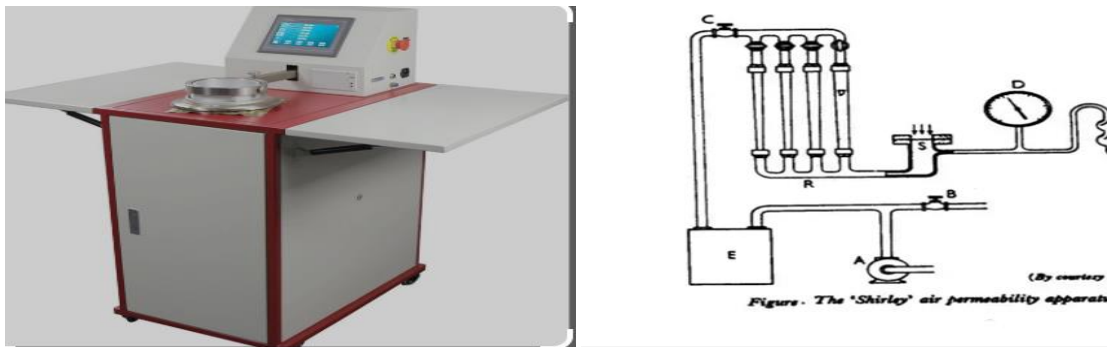


Fig. Shirley Air permeability Tester

Test Procedure:

Air is drawn through test specimen "S" by suction pump "A" at $20 \pm 2^\circ\text{C}$ and $65 \pm 2\%$ relative humidity. The by-pass valve "B" and the series valve "C" regulate the flow rate. The flow rate is changed until a draught gauge "D," graduated from 0 to 25 head of water, shows the necessary pressure drop across the fabric. "E" is a reservoir that evens out any disruption caused by the different air stream velocities that the pump draws through its different paths.

The rate of air flow is read off one of the four Rota meters "R," which are chosen based on the permeability of the test specimen, once the necessary pressure drop—typically 1 cm of water—is reached and the draught gauge's indicator is stable. To show air flow in cm³/sec, the Rota meters are calibrated at 20°C and 760 mm of mercury. They span the following ranges: R1: 0.05-0. R2: 0.5-3.5 R3: 3-35 R4: 30 – 350. R4 is open when the test starts, and the other Rota meters are closed. R3 is opened and R4 is closed if the flow is less than 30 cm³/sec.

Until the best range for the fabric being tested has been chosen, this process is repeated. A safety valve F is included to guard against harm to the draught gauge. The Rota meter's readings can be used to calculate the resistance or air permeability in the 5.07 cm² test area.

Five specimens are used to calculate the average flow rate.

3.5.6 Scanning Electron Microscopy (SEM) Test:

The basic idea behind scanning electron microscopy (SEM) is to create high-resolution pictures of the surface composition and topography by using a concentrated stream of high-energy electrons to scan a material's surface. When the sample's surface is struck by the electron beam it produces a variety of signals, including X-rays, backscattered electrons, and secondary electrons. After being identified, these signals are transformed into a picture. The picture displays microstructural characteristics, surface shape, and texture.



Figure: SEM Machine

3.5.7 FTIR (Fourier Transform Infrared Spectroscopy)

FTIR is used to identify the chemical composition and functional groups present in a material. In this process infrared light passed through a sample and measuring how much of the light is absorbed at different wavelengths. Each chemical bond absorbs IR radiation at specific frequencies.

In textile engineering, **FTIR** is commonly used to confirm surface modifications, chemical coatings, or functional group changes after treatments (such as water repellency or dyeing). It helps to determine whether new chemical bonds or finishes have successfully formed on fiber surfaces.

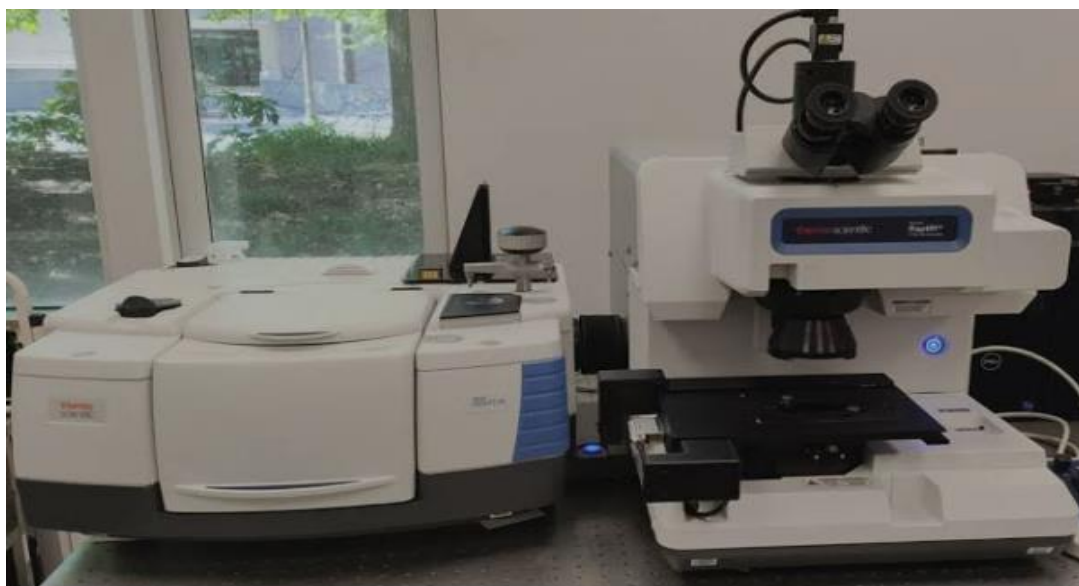


Figure: FTIR Analyzer

Table of standard FTIR absorption frequencies

Wavenumber (cm ⁻¹)	Bond Type	Functional Group
4000–3200	O–H stretch	Alcohols, Phenols
3300–2500	O–H stretch	Carboxylic Acids
3500–3300	N–H stretch	Amines, Amides
3300	C–H stretch	Terminal Alkynes
3100–3000	C–H stretch	Alkenes, Aromatics
3000–2850	C–H stretch	Alkenes, Aromatics
2260–2220	C≡N stretch	Nitriles
2260–2100	C≡C stretch	Alkynes
1760–1660	C=O Stretch	Carbonyls (Ketones, Aldehydes, Esters)
1680–1620	C=C Stretch	
1600–1475	Various	Complex pattern of bending and single-bond vibrations, unique to a specific compound

Chapter 4: Results and Discussion

4.1 Table Summary of the process

Sample	Water Repellency treatment						Drying & Curing Temperature
	Recipe-1		Recipe-2		Recipe-3		
1,2,3	Chemical name	g/l	Chemical name	g/l	Chemical name	g/l	110°C for 30 min & 150°C for 5 min
	Alkyl Urethane (ZELAN™ R3)	50	Alkyl Urethane (ZELAN™ R3)	80	Alkyl Urethane (ZELAN™ R3)	100	
	Cross-linking Agent (ARKOPHOB® DAN)	10	Cross-linking Agent (ARKOPHOB® DAN)	10	Cross-linking Agent (ARKOPHOB® DAN)	10	
	Acetic Acid for pH	4-5	Acetic Acid for pH	4-5	Acetic Acid for pH	4-5	
1,2,3	Water Repellency Testing						
	Drop Test		Spray Test (ISO4920:2012)		Washing Durability		
3	Fabric Physical Testing						
	Tensile & Tear strength Test		Air Permeability		SEM & FTIR analysis		

4.2 Drop Test Results:

Sample no.01: Jute -Cotton fabrics are treated with 50 g/l Alkyl Urethane (ZELAN™ R3), 10 g/l Cross-linking Agent (ARKOPHOB® DAN) & Acetic Acid for pH 4-5, **Sample no.02:** 80 g/l Alkyl Urethane (ZELAN™ R3), 10 g/l Cross-linking Agent (ARKOPHOB® DAN) & Acetic Acid for pH 4-5 **Sample no.03:** 100 g/l Alkyl Urethane (ZELAN™ R3), 10 g/l Cross-linking Agent (ARKOPHOB® DAN) & Acetic Acid for pH 4-5 drying at 110° C for 30 min curing 150° C for 5 min.

Sample	Specimen	Control Fabric	Treated fabric
1	1	1-2 Sec.	No absorbency
	2	1-2Sec	No absorbency
	3	1-2 Sec.	No absorbency
2	1	1-2 Sec.	No absorbency
	2	1-2 Sec.	No absorbency
	3	1-2 Sec.	No absorbency
3	1	1-2 Sec.	No absorbency
	2	1-2 Sec.	No absorbency
	3	1-2 Sec.	No absorbency

Analysis of absorbency of Control, treated fabric:

By pipette a droplet of 1% direct red solution was placed on the control sample and water repellent treated sample.

Observation- Droplet absorbed by Control sample absorbed within 1-2 seconds but will rest up on it and will not be absorbed by the treated sample for long time.

4.3 Spray test (ISO 4920; 2012): Results:

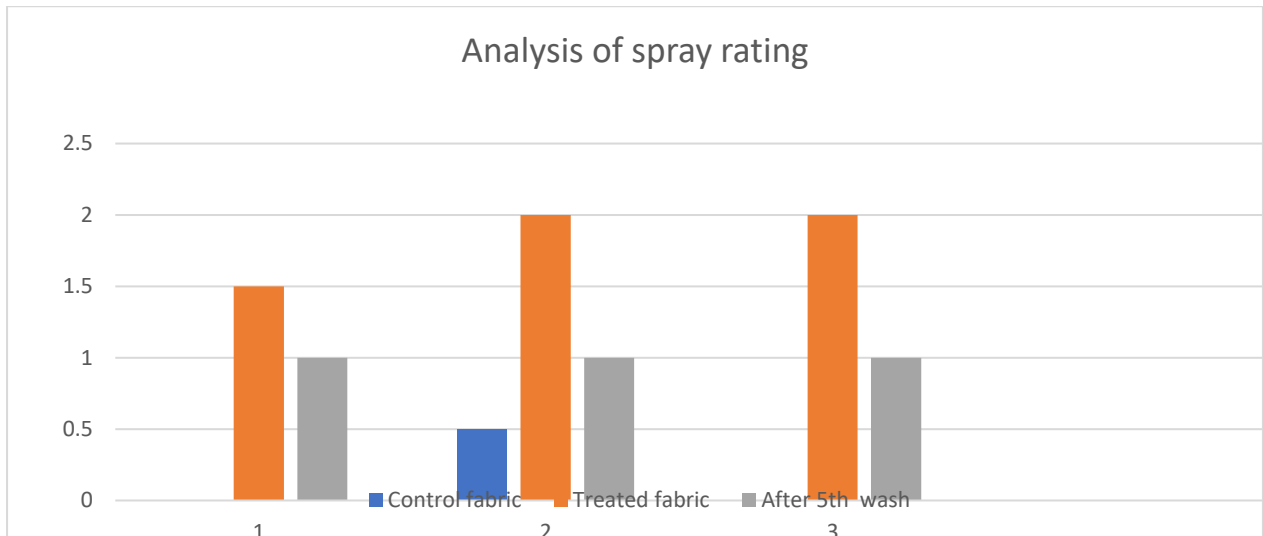
4.3.1 Sample no.1 (BD 24081300553) Test is Conducted by TTCS, BuTex.

Fabrics are treated with 50 g/l Alkyl Urethane (ZELAN™ R3), 10 g/l Cross-linking Agent (ARKOPHOB® DAN) & Acetic Acid for pH 4-5 drying at 110⁰ C for 30 min curing 150⁰C for 5 min. washing condition: Machine wash at 30⁰C, Normal cycle, followed by line dry (After 5th wash).

From table it can be stated that the water repellency rating.

Specimen	Rating	Rating	Rating	Average
Control fabric	ISO 0	ISO 0-1	ISO 0	ISO 0
Treated Rating	ISO 1-2	ISO 2	ISO 2	ISO 2
After 5 th wash	ISO 1	ISO 1	ISO 1-2	ISO 1

The table and chart in the image provide an analysis the spray test rating according to ISO 4920; 2012:



4.3.2 Nomenclature for rating:

100 (ISO 5): No sticking or wetting of upper surface

90 (ISO 4): Slight random sticking or wetting of upper surface

80 (ISO 3): Wetting of upper surface at spray points

70 (ISO 2): Partial wetting of whole of upper surface

50 (ISO 1): Complete wetting of whole of upper surface

0 (ISO 0): Complete wetting of whole and lower surface.

4.3.3 Analysis of water repellency of Control, treated fabric & after 5 wash:

The evaluation is based on three separate tests, with ratings provided for each test. The rating scale typically ranges from (ISO 0) Complete wetting of and lower surface to (ISO 5) No sticking and wetting of upper surface.

- ❖ **Control fabric shows water repellency rating ISO 0: Complete wetting of and lower surface**
- ❖ **Treated fabric shows water repellency rating ISO 2: partial wetting of whole of upper surface**
- ❖ **After 5 wash fabric shows water repellency rating ISO 1: Complete wetting whole of upper surface.**

Observation: Water repellency and washing durability is not satisfactory level.

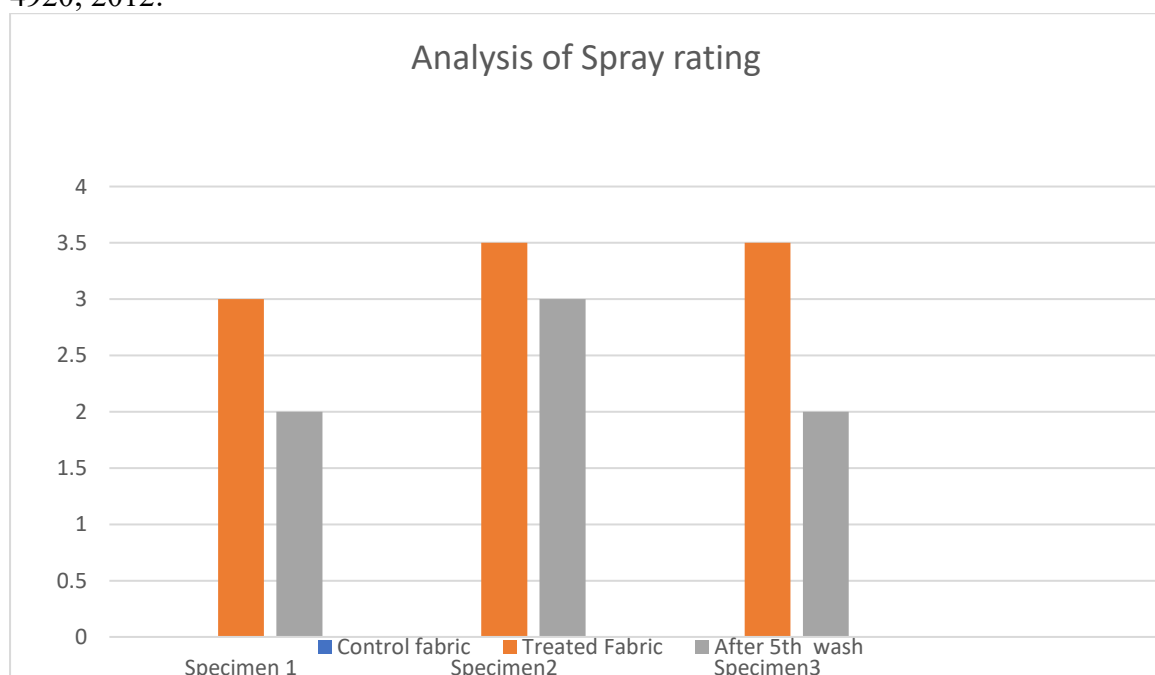
4.3.4 Sample no.2 TTEC.TTQC. Lab/01 TTEC, TTQC Lab

Fabrics are treated with 80 g/l Alkyl Urethane (ZELAN™ R3), 10 g/l Cross-linking Agent (ARKOPHOB® DAN) & Acetic Acid for pH 4-5 drying at 110⁰ C for 30 min curing 150⁰C for 5 min. washing condition: Machine wash at 30⁰C, Normal cycle, followed by line dry (After 5th wash).

From table it can be stated that the water repellency rating.

Specimen	Rating	Rating	Rating	Average
Control fabric	ISO 0	ISO 0	ISO 0	ISO 0
Treated Fabric	ISO 3	ISO 3-4	ISO 3-4	ISO 3
After 5 th wash	ISO 2	ISO 2	ISO 2	ISO 2

The table and chart in the image provide an analysis the spray test rating according to ISO 4920; 2012:



4.3.5 Analysis of water repellency of Control, treated fabric & after 5 wash:

The evaluation is based on three separate tests, with ratings provided for each test. The rating scale typically ranges from (ISO 0) Complete wetting of and lower surface to (ISO 5) No sticking and wetting of upper surface.

- ❖ **Control fabric shows water repellency rating ISO 0: Complete wetting of and lower surface**
- ❖ **Treated fabric shows water repellency rating ISO 3: Wetting of upper surface at spray points.**
- ❖ **After 5 wash fabric shows water repellency rating ISO 2: Partial wetting of whole of upper surface**

Observation: Water repellency and washing durability is average level.

4.3.6 Sample no.3: BD/T/(F)/25/012587 TÜV SÜD Bangladesh (Pvt.) Ltd, Dhaka.

Fabrics are treated with 100 g/l Alkyl Urethane (ZELAN™ R3), 10 g/l Cross-linking Agent (ARKOPHOB® DAN) & Acetic Acid for pH 4-5 drying at 110⁰ C for 30 min curing 150⁰C for 5 mi. washing condition: Machine wash at 30⁰C, Normal cycle, followed by line dry (After 5 wash).

From table it can be stated that the water repellency rating.

Specimen	Rating	Rating	Rating	Average
Control fabric	ISO 0	ISO 0	ISO 0	ISO 0
Treated fabric	ISO 4	ISO 4-5	ISO 4	ISO 4
After 5 th wash	ISO 3	ISO 3	ISO 3	ISO 3

The table and chart in the image provide an analysis the spray test rating according to ISO 4920; 2012:

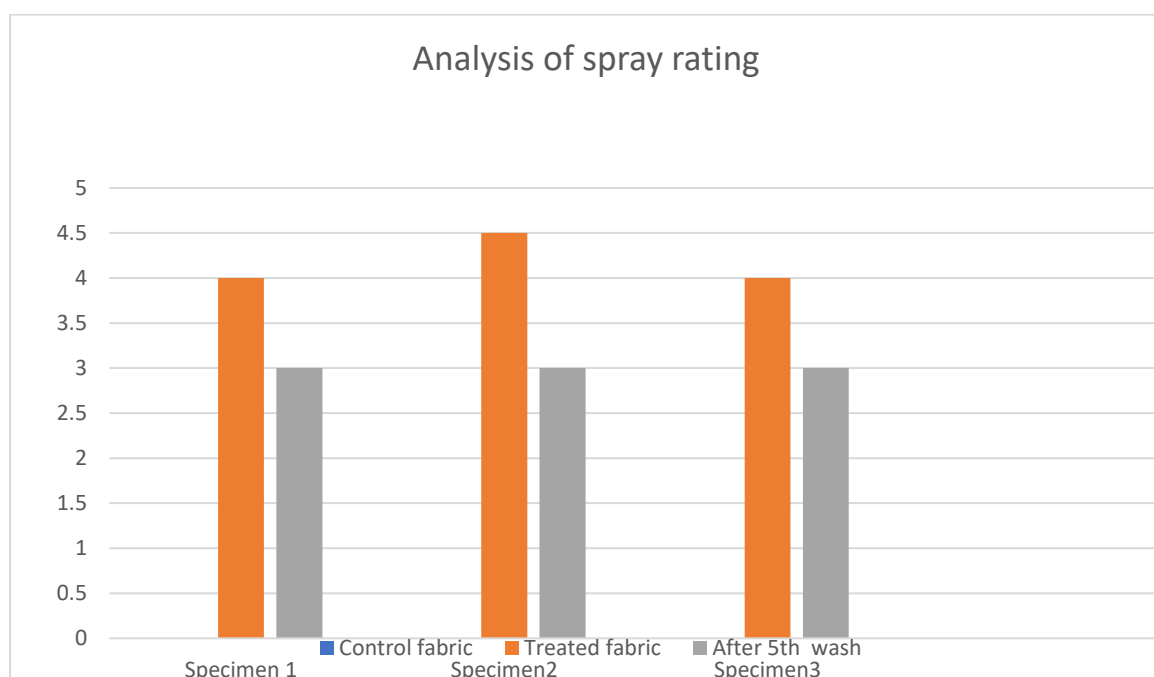


Figure: Effect of water spray rating on water repellency treatment.

3.6.7 Analysis of water repellency of Control, treated fabric & after 5 wash:

The evaluation is based on three separate tests, with ratings provided for each test. The rating scale typically ranges from (ISO 0) Complete wetting of and lower surface to (ISO 5) No sticking and wetting of upper surface.

- ❖ Control fabric shows water repellency **rating ISO 0**: Complete wetting of and lower surface
- ❖ Treated fabric shows water repellency **rating ISO 4**: Slight random sticking or wetting of upper surface.
- ❖ After 5 wash fabric shows water repellency **rating ISO 3**: Wetting of upper surface at spray points.

Observation: Water repellency and washing durability both are satisfactory level.

4.4 Tensile Strength Test (ISO 13934-1:2013): Results:

Fabrics are treated with 100 g/l Alkyl Urethane (ZELAN™ R3), 10 g/l Cross-linking Agent (ARKOPHOB® DAN) & Acetic Acid for pH 4-5 drying at 110⁰ C for 30 min curing 150⁰C for 5 min

Table: Effect of fabric tensile strength on water repellency treatment

Control Fabric		Treated fabric		Change	
Warp	Weft	Warp	Weft	Warp	Weft
650 N	810 N	630 N	800 N	-20 N	-10 N

The table and chart in the image provide an analysis the Tensile strength test according to ISO 13934-1; 2013:

Effect of Fabric Tensile Strength on Water Repellency Treatment

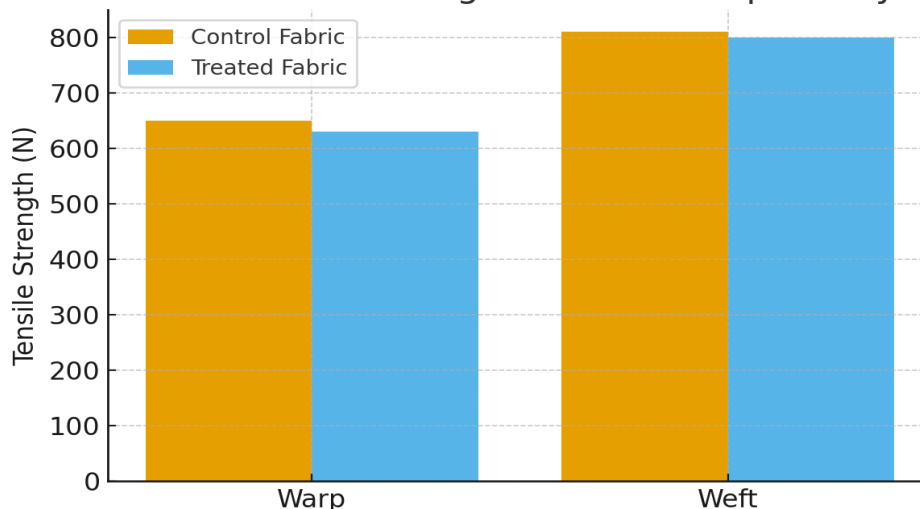


Figure: Effect of Fabric Tear Strength on Water Repellency Treatment.

4.5 Analysis of Tensile strength of Control & treated fabric:

The evaluation is based on three separate tests. The water-repellency treatment produces negligible changes in fabric Tensile strength in both warp and weft directions.

Observation: Suitable for making diversified jute products e.g.: Bags, Home furnishing, automobiles application.

4.6 Tear Strength Test Method (ISO 13937-1:2000): Results:

Fabrics are treated with 50 g/l Alkyl Urethane (ZELAN™ R3), 10 g/l Cross-linking Agent (ARKOPHOB® DAN) & Acetic Acid for pH 4-5 drying at 110⁰ C for 30 min curing 150⁰C for 5 min.

Table: Effect of water repellent treatment on fabric tear strength

Control Fabric		Water repellent treated Fabric		Tear strength comparison	
Warp	Weft	Warp	Weft	Warp	Weft
65 N	80 N	60N	70 N	- 5 N	-10 N

The table and chart in the image provide an analysis the Tear strength test according to ISO 13937-1; 2000:

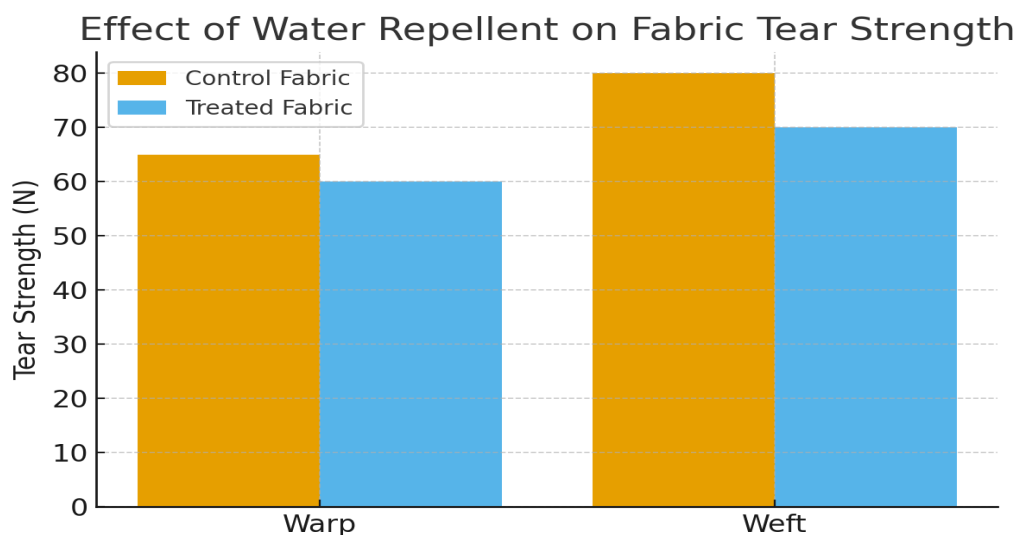


Figure: Effect of Fabric Tensile Strength on Water Repellency Treatment.

4.7 Analysis of Tear strength of Control, treated fabric:

The evaluation is based on three separate tests. The water-repellency treatment produces negligible changes in fabric tear strength in both warp and weft directions.

Observation: Suitable for making diversified jute products e.g.: Bags, Home furnishing, automobiles application.

4.8 Air Permeability Test (ISO 13937-2:2000)

Table: Effect of water repellent treatment on air permeability.

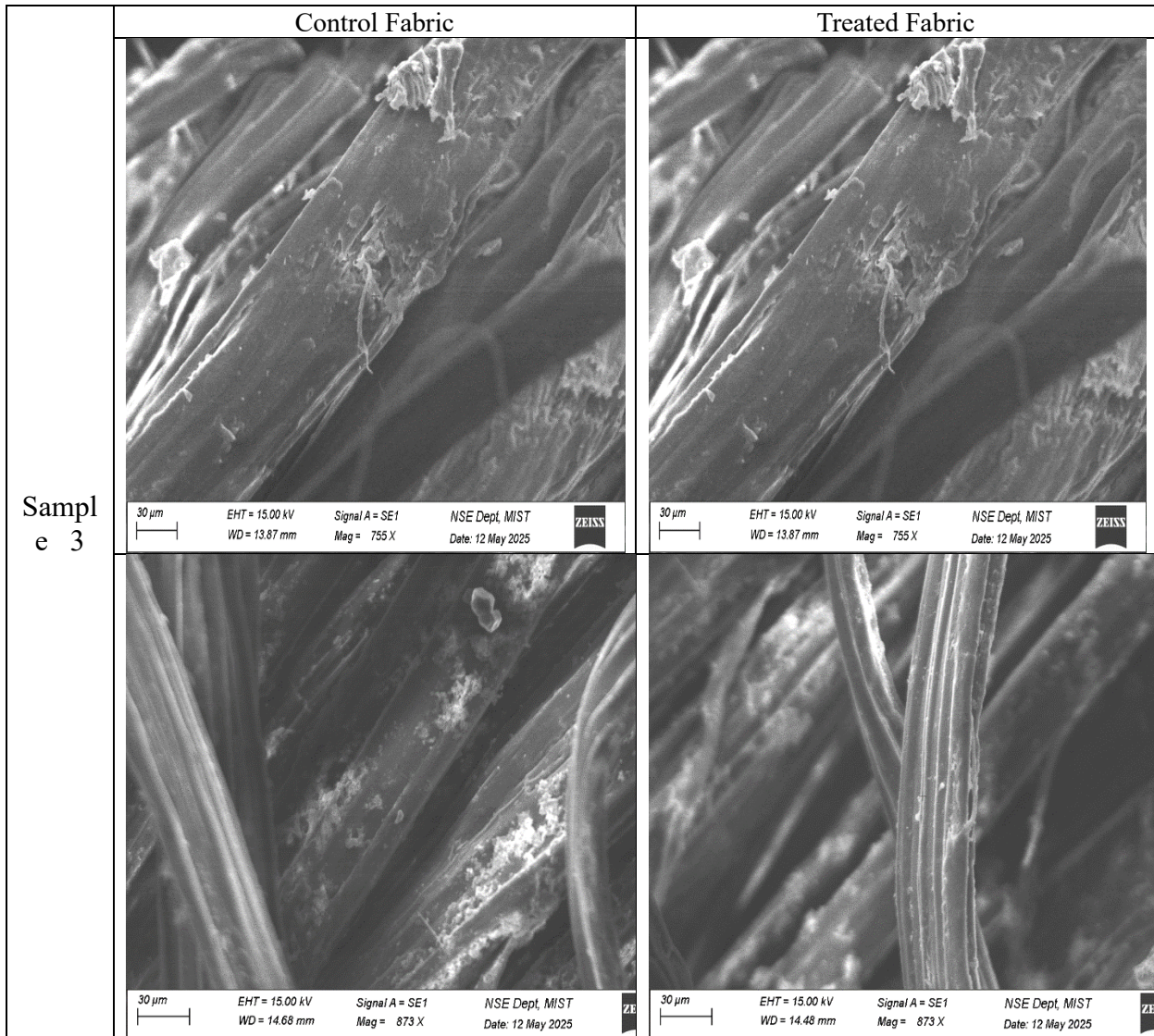
Air permeability Control Fabric	Air permeability Treated fabric	Change in Air permeability
112 cm ³ /cm ² /s	102 cm ³ /cm ² /s	10 cm ³ /cm ² /s

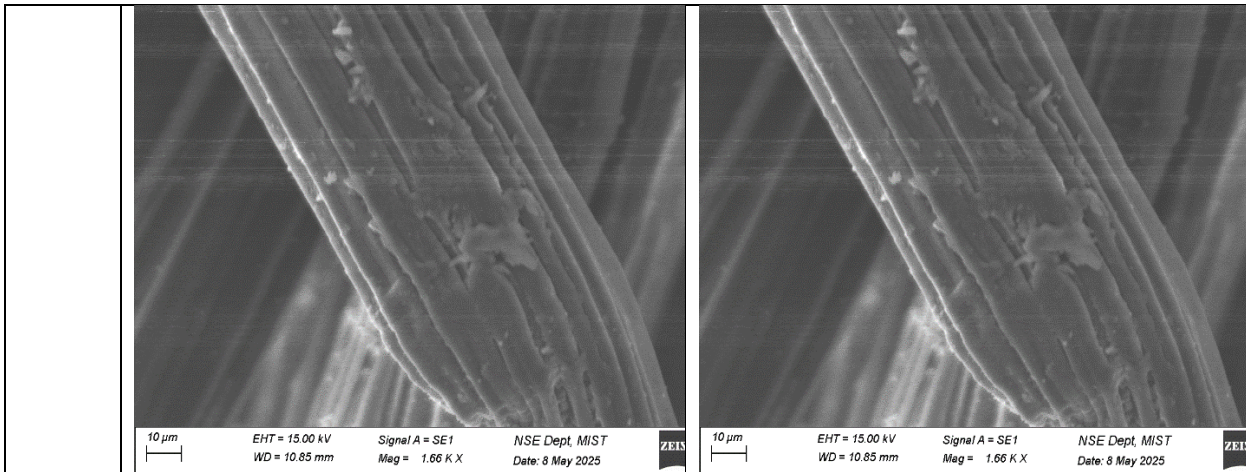
4.9 Analysis of Air permeability of Control, treated fabric:

The air permeability of the treated fabric decreased slightly compared to the control fabric. This reduction indicates that the water repellent treatment formed a thin hydrophobic layer on the fabric surface, partially blocking air passage through the fabric pores.

4.10 SEM Analysis

Table: -SEM analysis on jute-cotton fabric





4.11 Analysis of water SEM of Control, treated fabric

Control Fabric: Fibers appear relatively rough and uneven, with clear fibrillation and micro-cracks typical of natural jute. Numerous micro-voids and inter-fibre gaps are visible, which facilitate water absorption and wicking. Loose microfibrils protrude from the fibre surface, indicating natural lumen exposure and less compact bonding

Water-Repellent Treated Fabric: The treated fabric shows a smoother, more continuous surface, suggesting deposition of a hydrophobic finish (e.g., fluorocarbon or silicone oil, Alkyl urethane). The coating fills small voids, leading to fewer capillary pathways. Inter-fiber gaps appear partially sealed, lowering fabric wettability.

Observation: SEM micrographs confirm that water-repellent finishing on jute–cotton fabric creates a uniform hydrophobic film, reduces micro fibrillation, and blocks capillary pores, thereby improving water-repellency while maintaining the fiber’s structural integrity

4.12 FTIR Analysis

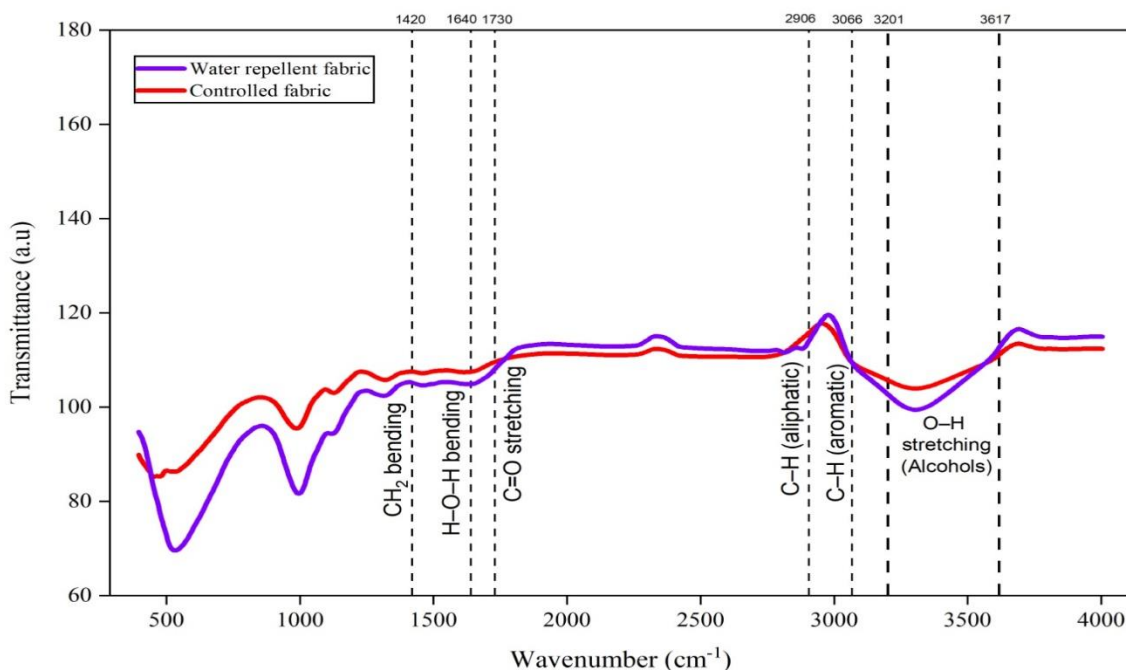


Figure: FTIR Spectrum of Control & Water Repellent jute-cotton Fabric in the wavenumber range of 400–4000 cm^{-1} .

Peak Assignments and Discussion

1. **$\sim 1420 \text{ cm}^{-1}$ (CH_2 bending):**

This band corresponds to the bending vibrations of methylene ($-\text{CH}_2-$) groups, which are characteristic of the cellulose backbone in cotton or polyester molecular chains. The intensity of this band remains relatively unchanged, indicating that the basic structure of the fabric polymer was not affected by the surface treatment.

2. **$\sim 1640 \text{ cm}^{-1}$ (H-O-H bending):**

This peak is associated with the bending vibration of absorbed water molecules. The treated (water-repellent) fabric shows a reduction in intensity at this band compared to the control sample, confirming a lower amount of bound moisture due to the hydrophobic surface modification.

3. **$\sim 1730 \text{ cm}^{-1}$ (C=O stretching):**

This band represents carbonyl stretching vibrations, possibly originating from ester. The slight increase in intensity for the treated fabric indicates the introduction of carbonyl-containing compounds, which may arise from fluorocarbon, silane, or polyurethane-based water-repellent finishes.

4. **$\sim 2906 \text{ cm}^{-1}$ (C-H aliphatic stretching):**

This region corresponds to the symmetric and asymmetric stretching vibrations of aliphatic $-\text{CH}$ and $-\text{CH}_2$ groups. The enhanced peak intensity in the treated sample

suggests the presence of additional hydrocarbon chains, confirming the deposition of hydrophobic agents on the fabric surface.

5. **~3066 cm⁻¹ (C–H aromatic stretching):**

This band may arise from aromatic rings in the polymer backbone or finishing molecules. The small shift or intensity change indicates possible interactions between the finishing chemical and the fabric structure.

6. **~3201–3617 cm⁻¹ (O–H stretching):**

This broad absorption band represents hydroxyl (–OH) stretching vibrations, typical of cellulose and adsorbed moisture. The decrease in peak intensity for the water-repellent fabric indicates successful reduction of surface hydroxyl groups' accessibility, implying a significant increase in hydrophobicity.

Overall Interpretation

The FTIR spectra confirm that the water-repellent treatment effectively altered the surface chemistry of the fabric without damaging its fundamental polymer structure.

- The reduction in O–H and H–O–H bending intensities indicates lower hydrophilicity.
- The appearance or enhancement of aliphatic C–H stretching bands verifies the presence of hydrophobic functional groups introduced by the finishing agent.

Therefore, the FTIR analysis substantiates the successful application of a water-repellent finish on the fabric surface.

5.5 Key Findings & Recommendations

Process Highlights

- ❖ **Control fabric:** 80% jute / 20% cotton plain-weave fabric (302 GSM).
- ❖ **Finishing:** Pad-dry-cure method using bio-based Alkyl Urethane (ZELAN™ R3) 50, 80, and 100 g/L concentrations with a formaldehyde-free cross-linker (ARKOPHOB® DAN).

Table: Summary of the Test Result

Summary of the Test Result								
Sample	Drop Test (Drop absorbency)			Spray Test (ISO 4920:2012) Rating			Aftre 5 wash	Avarage
	Specimen	Control fabric	Treated fabric	Control fabric	Treated fabric	Average		
1	1	1-2 Sec	No	0	1-2	2	1	1
	2	1-2 Sec	No	0	2		1	
	3	1-2 Sec	No	0	2		1	
2	1	1-2 Sec	No	0	3	3-4	2	2
	2	1-2 Sec	No	0	3-4		1-2	
	3	1-2 Sec	No	0	3-4		2	
3	1	1-2 Sec	No	0	4	4	3	3
	2	1-2 Sec	No	0	4-5		3	
	3	1-2 Sec	No	0	4		3	

Summary of the Test Result				
Property	Direction	Control Fabric (N)	Treated Fabric (N)	Change (N)
Tensile strength	Warp	650	630	-20
	Weft	810	800	-10
Tear strength	Warp	65	60	-5
	Weft	80	70	-10
Air permeability		112 cm ³ /cm ² /s	102 cm ³ /cm ² /s	10 cm ³ /cm ² /s

Key findings:

Experiment	Control	Best Treated Sample (100 g/L)	Change
Drop Test	Drop absorbed in 1–2 s	No absorbency	
Spray Rating (ISO 4920:2012)	ISO 0	ISO 4 (good repellency)	ISO 3 (after 5 wash)
Tensile Strength (ISO 13934-1:2013):	650 N (warp) / 810 N (weft)	630 N / 800 N	-20N/-10N
Tear Strength (ISO 13937-1:2000):	65 N (warp) / 80 N (weft)	60 N / 70 N	-5N/-10N

Experiment	Control	Best Treated Sample (100 g/L)	Change
Air Permeability	112cm ³ /cm ² /S	102 cm ³ /cm ² /S	12cm ³ /cm ² /S
SEM Analysis	Rough, porous surface	Smooth hydrophobic film sealing capillary pores	—

Recommendation:

Fabric treated with the 100 g/L ZELAN™ R3 formulation for commercial production of biodegradable, water-repellent jute–cotton shopping bags and diversified home-textile products, supporting Bangladesh’s eco-packaging goals while maintaining fabric strength and wash durability.

Chapter 5: Conclusion and Recommendations

5.1Conclusions

This study successfully developed water-repellent jute–cotton fabrics as an eco-friendly alternative to synthetic shopping and packaging bags. Key findings include: Drop and spray tests confirmed that Alkyl Urethane (ZELAN™ R3) with ARKOPHOB® DAN produced ©Daffodil International University

durable hydrophobic finishes. The highest concentration (100 g/L) achieved an ISO spray rating of 4 (good repellency) and retained an ISO 3 rating after five wash cycles, demonstrating acceptable washing durability. Tensile strength decreased slightly (warp –20 N, weft –10 N) and tear strength showed negligible reduction (warp –5 N, weft –10 N), indicating that water-repellent finishing did not compromise structural integrity. SEM analysis revealed a smoother, more compact fiber surface with reduced micro-cracks and sealed inter-fiber gaps, confirming the formation of a uniform hydrophobic layer. The process employed a fluorine-free, bio-based polymer (ZELAN™ R3) aligning with current environmental and regulatory demands to replace PFAS-based finishes and reduce plastic bag usage.

Overall, the research demonstrates that bio-based water-repellent finishing can create commercially viable jute-cotton fabrics suitable for diversified applications such as shopping bags, home furnishings, and technical textiles.

5.2 Recommendations

1. This is a lab base experiment for further more need Industrial Trials.
2. Washing durability was assessed after 5 wash need extended durability test.
3. For industrial production necessary to cost and life-cycle assessment.
4. To promote diversified applications such as shopping bags, home furnishings, and technical textiles it should be necessary to Public and private collaboration.

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