



Bacterial Consortia as a Sustainable Alternative to Jute Batching Oil (JBO) in Jute Yarn Manufacturing Process

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Abstract: *Jute fiber used in the production of yarn is traditionally treated with a 2% emulsion of jute batching oil (JBO) to reduce stiffness and improve processability. However, due to the high cost and potential carcinogenic effects of JBO, there is a pressing need for alternative methods. This study investigates the use of a microbial consortium to achieve a cost-effective and eco-friendly reduction of JBO use in yarn production. A total of 51 bacterial strains were isolated from JBO-treated jute fiber at Janata Jute Mills, with 17 strains exhibiting significant growth in 2% JBO. After excluding duplicates, potential pathogens, and strains with endoglucanase activity, a final consortium of nine bacteria was established. The physical properties of jute fiber treated with this consortium alongside varying concentrations of JBO (1% and 2%) were analyzed over different incubation periods. Results indicated that treatment with 1% JBO and the bacterial consortium produced comparable effects on temperature and moisture regain to the control group (2% JBO). Notably, fibers treated with the consortium exhibited enhanced elasticity, showing a 46.6% increase in maximum pressure and 12.2% increase in extension at breakage compared to the control (2% JBO). Additionally, wastage during processing was reduced by 24.1% for breaker card processing in the treated group. Scanning electron microscopy (SEM) revealed a rough surface morphology in the treated fibers, indicative of biofilm formation. This study suggests that employing microbial consortia with reduced JBO concentrations offers a promising alternative for enhancing fiber quality in jute yarn manufacturing while promoting environmentally sustainable practices.*

Keywords: *Jute; Jute yarn; Jute Batching Oil (JBO); Bacterial consortia; Fiber strength.*

Type of the Paper: Original Research Article.

1. Introduction

Jute, a biopolymer of cellulose, hemicelluloses, and lignin-derived from the *Corchorus* genus, is predominantly cultivated in tropical and subtropical regions, particularly in India, Bangladesh, China, Nepal, and Thailand [1]. Due to its abundance, inexpensive cost of production, light weight, high individual fiber length, and reasonable mechanical qualities, jute is the most alluring substitute for other natural fibers [2,3]. As the second most-produced natural fiber globally after cotton, jute plays a vital role in the technical textile industry [4], with an annual production of approximately 3.63 million tons [5].

Jute yarn, which consists of twisted jute fibers with a length significantly greater than its diameter, serves as an essential intermediate in the production of various jute-based products such as hessian bags, carpet backing, and other textiles [1]. In 2021, Bangladesh emerged as the largest exporter of jute yarn globally, generating \$550 million in export revenue and ranking it as the country's 20th most exported product [6]. Jute Market size in terms of transactions was valued at USD 2.5 billion in 2022, and it is estimated to reach USD 4.9 billion by 2032, and is anticipated to register a CAGR (Compound Annual Growth Rate) of over 5.9% between 2023 and 2032 [7]. However, despite its many advantages, jute fibers exhibit considerable stiffness and harshness that complicate spinning processes. To mitigate these issues, raw jute fibers are traditionally treated with a 2% emulsion of jute batching oil (JBO) prior to spinning. This treatment involves passing the fibers through a series of fluted rollers after applying an emulsion of water and oil. The water component softens the fibers, while the oil acts as a lubricant [8] that enhances moisture retention capacity [9] and reduces flexural stiffness. This reduction in stiffness minimizes the likelihood of fiber tearing during the combing process in breaker carding and results in stronger and more uniform yarn with improved shine and reduced hairiness [8]. After applying the batching oil, the fibers are piled and incubated for 72-96 hours to allow for maturation; however, this process can be significantly affected by seasonal temperature variations.

In JBO, historically, whale oil and spermaceti oil were used [1,10] before being replaced by petroleum-based oils. Currently, C12–C31 fractions of mineral oil are commonly employed; however, these oils can impart undesirable odors to the finished products. The use of up to 2% oil in jute yarn production raises concerns over fossil fuel depletion and high costs [11]. This has led researchers to explore eco-friendly alternatives. Previous studies have investigated the use of selected vegetable oils as substitutes for mineral oil in conditioning jute fiber and have examined the simultaneous application of reduced mineral oil proportions alongside suitable softeners during fiber conditioning [1,12]. Additionally, enzyme treatments have been shown to improve spinning quality [1,13].

The need for safer alternatives is underscored by concerns regarding the carcinogenic potential of certain JBO varieties (specifically JBO-p), which have been identified as tumorigenic agents in mouse skin, specifically Swiss albino mice [14]. Therefore, any substitute that meets safety standards for workers and machinery, has no adverse health effects or risks of spontaneous combustion, and has acceptable color and odor profiles, while also being affordable, is highly considered.

Given that the jute yarn manufacturing process occurs under non-sterile conditions, microbial associations are likely to occur. These associations may influence fiber processing positively. Utilizing microbial consortia could potentially reduce or replace JBO while offering

environmentally friendly and biodegradable processes that enhance fiber quality. In recent years, there has been increasing interest in harnessing microbial communities for industrial processes due to their ability to degrade complex organic materials effectively. The application of microbial consortia in jute processing could lead to significant reductions in chemical usage while enhancing fiber quality through biological means.

This study aims to investigate the potential of JBO-tolerant bacterial consortia as substitutes for traditional JBO in yarn manufacturing. By analyzing the physical properties of piled jute fiber treated with these consortia alongside varying concentrations of JBO emulsion (1% vs. 2%), we seek to establish a more sustainable approach to enhancing fiber quality in jute yarn production. In addition to evaluating physical properties such as elasticity and moisture regain, this study also assesses the impact of microbial treatment on waste generation during processing. This research seeks not only to contribute valuable insights into alternative processing methods but also to promote environmentally friendly practices within the jute industry. As global demand for sustainable materials continues to rise, finding innovative solutions that reduce reliance on harmful chemicals will be crucial for ensuring the long-term viability of natural fibers like jute.

2. Materials and methods

2.1 Screening of bacteria for JBO tolerance

Jute batching oil (JBO)-treated jute fiber was collected from Janata Jute Mills, Cumilla, Bangladesh, and thoroughly cleaned. The cleaned fibers were then incubated in phosphate-buffered saline (PBS) solution (137 mM NaCl, 2.7 mM KCl, 10 mM Na₂HPO₄, and 1.8 mM KH₂PO₄; pH 7.4) for 1 hour at room temperature to facilitate the release of bacteria from the fiber. The PBS solution containing the released bacteria was serially diluted and spread onto 3% Tryptic Soy Agar (TSA) plates. The plates were incubated at 37 °C for 24 to 72 hours. The distinct morphological characteristics of the resulting colonies, including color, shape, and growth patterns, were examined to identify different bacterial species. Isolated colonies were sub-cultured for further analysis.

To assess JBO tolerance, isolated bacteria were cultured in Tryptic Soy Broth (TSB) containing 2% JBO emulsion. Bacteria exhibiting significant growth in this medium were classified as JBO-tolerant and selected for further characterization.

2.2 Screening of bacteria for endoglucanase activity

Endoglucanase activity of the JBO-tolerant bacteria was evaluated using Azo-CM-cellulose (Megazyme, Ireland), a substrate specifically used for endo-1,4- β -glucanases. All solutions were prepared according to the manufacturer's instructions. The enzymatic reaction was initiated by

combining 0.5 mL of the bacterial culture (pre-equilibrated at 40 °C) with an equal volume of pre-heated Azo-CMC solution in a 10 mL tube. After a 10-minute incubation at 40°C, the reaction was terminated by adding 2.5 mL of precipitant solution (4% sodium acetate trihydrate and 0.4% zinc acetate in ethanol) while vigorously mixing on a vortex mixer for 10 seconds. The samples were allowed to reach room temperature for 10 minutes before stirring them once more and subjecting them to centrifugation at 1,000xg for 10 minutes. The absorbance of the supernatant was measured at 590 nm against a blank control to determine enzyme activity using a standard curve prepared with *Aspergillus niger* cellulase (Sigma). Enzymatic activity was calculated using the following Eq. (1).

$\text{Enzyme activity (U/mL)} = (\text{mU from standard curve} \times \text{dilution factor}) / 1000$	(1)
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2.3 Identification of bacteria for bacterial consortia preparation

Colony PCR [15] was performed for different bacterial isolates to amplify the 16S rRNA gene region using specific primers: forward primer 27F (5'-AGAGTTTGATCCTGGCTCAG-3') and reverse primer 1492R (5'-GGTTACCTTGTTACGACTT-3') [16]. The PCR products were sequenced and analyzed using BLAST (www.ncbi.nlm.nih.gov/BLAST). Any duplicated and pathogenic bacteria are excluded from the final bacterial consortium preparation.

2.4 Preparation of Bacterial Consortia

A final consortium comprising nine JBO-tolerant bacterial isolates was established based on their growth characteristics and enzyme activity. Growth characteristics were assessed based on an OD₆₀₀ reading of 1.2, and cellulase activity was observed. The bacterial suspension was prepared at a concentration of 10⁸ cells/mL using sterile glycerol (10%) as a cryoprotectant.

2.5 Evaluating the physical characteristics of piled jute fiber treated with bacterial consortia and JBO over varied incubation periods

Jute fiber rolls were treated with a bacterial consortium prior to the application of jute batching oil (JBO) emulsion. For microbial treatment, a total volume of 600 mL bacterial suspension (10⁸ cells/mL) was uniformly sprayed onto each jute fiber roll using a spray gun (Fig. 1). Subsequently, JBO emulsions were applied at concentrations of 1% and 2%, following the conventional industrial procedure.

Control groups consisted of jute fibers treated only with JBO emulsions (1% and 2%) without bacterial inoculation. Experimental groups included jute fibers treated with bacterial consortia in combination with either 1% or 2% JBO emulsion. After treatment, all fiber rolls were piled and incubated for different maturation periods of 24, 48, and 72 hours under typical mill conditions.



Fig. 1. Spraying Bacterial suspension at a 100 mL/min rate using a spray gun just before oil.

The conventional industrial condition (2% JBO emulsion with 72 h incubation) was used as the reference control for percentage comparisons throughout the study unless otherwise specified. The evaluated treatment groups therefore included: (i) 2% JBO emulsion (industrial control), (ii) 1% JBO emulsion, (iii) 1% JBO emulsion with bacterial consortia, and (iv) 2% JBO emulsion with bacterial consortia.

Following incubation, several physical parameters were evaluated to assess the impact of microbial treatment on fiber processing performance. The 24 h incubation groups were excluded from subsequent analyses because no measurable changes in temperature or fiber softening were observed compared to the controls. Additionally, bacterial consortia-treated fibers incubated for 72 h were not considered in the final comparison, as the objective of this study was to evaluate whether microbial treatment combined with reduced JBO concentration could achieve comparable or improved results relative to the conventional industrial process (2% JBO for 72 h).

2.5.1 Temperature Measurement

The temperature of the incubated pile rolls was measured (n=18) using a thermometer (TLC 700) immediately after each incubation period.

2.5.2 Moisture Regain Analysis

Samples (n=18) from various stages—including piled jute fiber after incubation, breaker card roll, finisher card roll, third drawing roll, and final yarn product—were analyzed for moisture regain percentage using a moisture meter (Jute Moisture Tester, HX-400).

2.5.3 Wastage Analysis

Wastage percentages during processing were calculated for breaker card and finisher card operations using the Eq. (2).

$Wastage (\%) = (Weight\ of\ wasted\ fiber\ (g) / Total\ input\ fiber\ weight\ (g)) \times 100$	(2)
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2.5.4 Analyzing Maximum Pressure and Extension at Breakage Point

A Universal Tensile Machine (UTM) from James Heal (UK) was utilized to measure (n=5) maximum pressure and extension at breakage point of jute fiber under standardized conditions: jaw separation set to 508.0 mm (20 inches) and test speed maintained at 20.0 mm/min. Pressure (Pa) and extension (%) at the breakage point were recorded for a total of seven (7) samples, including both consortia-treated and untreated fibers. For data analysis, Eq. (3) was used to calculate the percentage increase or decrease.

$Percentage\ change\ (\%) = \{(Treatment\ value - Control\ value) / Control\ value\} \times 100$	(3)
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2.5.5 Scanning Electron Microscopy (SEM) Analysis

Total six (6) groups of samples from the manufacturing process were examined under a field emission-scanning electron microscope (FE-SEM; model Carl Zeiss Sigma 300, Germany) to visualize surface morphology changes in fibers treated with bacterial consortia mixed with a reduced concentration of JBO emulsion (1%) incubated for 48 hours compared to controls without bacterial treatment.

2.6 Statistical Analysis

All experiments were performed in triplicate unless otherwise stated. Data are presented as mean \pm standard deviation (SD). Statistical comparisons between treatment groups and control were performed using one-way analysis of variance (ANOVA) followed by Tukey's post hoc test. Differences were considered statistically significant at $p < 0.05$. All statistical analyses were conducted using R v4.3.2.

3. Results and Discussion

This study aimed to develop an eco-friendly and cost-effective method for jute yarn production by utilizing a microbial consortium alongside a reduced concentration of jute batching oil (JBO). This approach offers a promising strategy for minimizing the environmental and economic drawbacks of traditional jute processing methods.

JBO has long been used in the jute industry to soften fibers, reduce their stiffness, and facilitate spinning [8]. The emulsion, typically containing 2% JBO, penetrates the fiber structure by allowing water molecules to swell the fibers and create fissures, into which the oil molecules insert themselves. This process acts as a lubricant, reducing friction during mechanical processing and improving the uniformity and strength of the resulting yarn [8]. However, despite its efficacy,

JBO is associated with several negative impacts. The oil is petroleum-based, costly, and carcinogenic, leading to increased concern about its use in industrial processes. There is a growing need to find sustainable alternatives that can maintain or even improve fiber quality while addressing the health and environmental risks associated with JBO.

The use of microbial consortia has gained increasing attention in biomass processing due to their ability to produce a wide range of extracellular enzymes that modify plant fiber structures. Members of the genus *Bacillus* are particularly known for producing enzymes such as pectinases, xylanases, and other hemicellulolytic enzymes that can partially degrade non-cellulosic components of plant fibers, thereby improving fiber flexibility and surface smoothness [17,18]. Pectinase breaks down pectin, the cementing agent that holds the fibers to the stalk, and xylanase brings smoothness to the fibers [19]. These enzymatic activities may help loosen the fiber matrix, reduce brittleness, and improve mechanical performance during spinning. In addition, some members of the consortium may contribute to biofilm formation on the fiber surface, which can facilitate sustained microbial activity and enzyme production during the incubation period. Improved fiber–matrix bonding further enhances tensile strength by enabling better load transfer across the composite surface [20]. On the other hand, batching oil reduces fiber breakage and wastage by retaining moisture without altering equilibrium moisture regain [21]. In addition, thermophilic *Bacilli* are potential microbes in a variety of industries where elevated temperatures (40–65 °C) prevail during the manufacturing process or when the product is stored [22]. Therefore, using a microbial consortium with a reduced JBO concentration may provide a biologically assisted conditioning process that improves fiber quality while reducing dependence on JBO.

3.1 Screening of JBO-tolerant bacteria

A total of 51 bacterial isolates were obtained from JBO-treated jute fiber and screened based on their morphological characteristics. These isolates were cultured in Tryptic Soy Broth (TSB) containing 2% JBO emulsion to assess their tolerance. After the incubation period, it was observed that only 17 isolates exhibited significant growth in the culture media exceeding an OD₆₀₀ to 1.2.

3.2 Screening of bacteria for endoglucanase (cellulase) activity and pathogenicity

Given that cellulose is a crucial structural component of jute fibers, the presence of endoglucanase-positive bacteria could lead to fiber degradation. So, for evaluating the endoglucanase activity of the JBO-tolerant bacterial isolates, a standard curve (OD₅₉₀ vs mU/Assay) was established using *Aspergillus niger* cellulase (Sigma) as a reference enzyme. Out of the 17 isolates, two strains, PB-44 and PB-51, demonstrated positive endoglucanase activity with values of 10.2 units/mL and 13.21 units/mL, respectively (Fig. 2). Consequently, these two strains, along with other duplicates, were excluded from the final bacterial consortium preparation,

resulting in a total of 11 bacterial isolates. Further identification revealed by Sanger Sequencing that two of these bacteria, PB-08 and PB-19, were *Enterobacter* species (*Enterobacter mori* and *Enterobacter ludwigii*, respectively). Due to their potential pathogenicity, these two strains were also excluded from the consortium. Thus, the final bacterial consortium comprised nine JBO-tolerant bacterial isolates (Table 1).

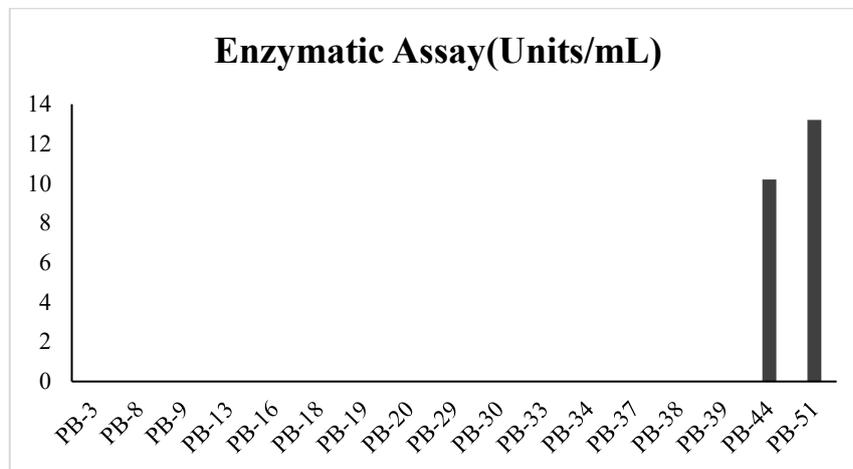


Fig. 2. Endoglucanase (cellulase) activity of the JBO-tolerant bacterial isolates.

Table 1. Bacterial consortia comprising nine different JBO tolerant bacterial isolates.

SL No	ID	Name
1	PB-3	<i>Bacillus pumilus</i>
2	PB-9	<i>Franconibacter daqui</i>
3	PB-13	<i>Bacillus thuringiensis</i>
4	PB-29	<i>Priestia megaterium</i>
5	PB-33	<i>Bacillus zanthoxyli</i>
6	PB-34	<i>Bacillus stratosphericus</i>
7	PB-37	<i>Bacillus safensis</i>
8	PB-38	<i>Staphylococcus carnosus</i>
9	PB-39	<i>Bacillus cereus</i>

Among the remaining isolates, one strain was identified as *Bacillus cereus* based on 16S rRNA gene sequencing. Although certain *B. cereus* strains are known to be opportunistic pathogens, environmental isolates lacking virulence determinants have been widely reported in industrial and environmental biotechnology applications. The isolate used in this study originated from jute-processing environments and was included in the consortium based on its non-cellulolytic behavior and compatibility with other consortium members. In addition, potentially pathogenic isolates identified during screening were intentionally excluded from the final consortium to ensure biosafety. Since the bacterial consortium is applied only for fiber treatment in non-sterile industrial processing environments, the use of such environmental isolates is considered consistent with standard microbial applications in biomass processing systems.

The physical properties of jute fibers treated with the microbial consortium alongside varying concentrations of JBO were thoroughly evaluated. The temperature and moisture regain

of piled jute fiber are crucial for determining fiber quality during the incubation or maturation process. The mechanical properties of jute fibers treated with the microbial consortium were tested by evaluating the maximum pressure required at breakage and the extension at breakage.

3.3 Physical properties of piled jute fiber after treatment of bacterial consortia

3.3.1 Temperature of incubated raw jute rolls

Following treatment with bacterial consortia and varying concentrations of JBO (1% and 2%), the jute fibers were incubated for periods of 24, 48, and 72 hours. The temperature changes in the pile rolls were measured after incubation (Fig. 3A). Notably, jute fibers treated with a 1% JBO emulsion and bacterial consortia for both 48 and 72 hours showed a temperature increase with $p < 0.05$ than the control group treated with 1% JBO emulsion for 48 and 72 hours, and had a comparable result with the control containing 2% JBO emulsion with 72 hours of incubation (Fig. 3B). The 24 h incubation groups were excluded from subsequent analyses because no measurable changes in temperature or fiber softening were observed compared to the untreated controls. In contrast, the 48 h incubation period showed clear differences while maintaining a shorter processing time than the conventional 72 h incubation used in industry. These findings suggest that the microbial treatment enhances the effectiveness of JBO at lower concentrations, which has important implications for reducing both costs and environmental impacts.

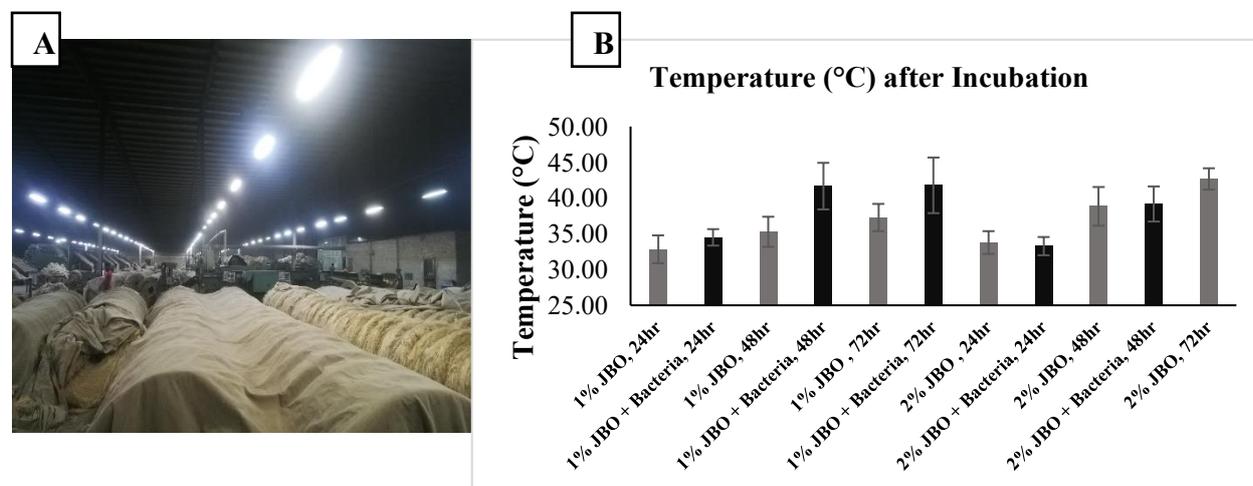


Fig. 3. (A) Incubation of piled jute fiber rolls treated with bacterial consortia and control for different incubation periods, and (B) Temperature changes of different samples at different incubation periods. Asterisks indicate level of statistical significance: * $p < 0.05$

3.3.2 Analyzing Maximum Pressure and Extension at Breakage Point

Jute fiber treated with 2% and 1% JBO emulsion mixed with bacterial consortia for 48h and 72h of incubation was used for further analysis of maximum pressure and extension at the breakage point. Only fibers treated with 2% and 1% JBO emulsion without bacterial consortia were used as controls. The analysis of maximum pressure at the breakage point indicated that jute fibers treated with a combination of 1% JBO emulsion and bacterial consortia for a 48-hour incubation period

exhibited a 46.6% increase (* $p < 0.05$) in maximum pressure compared to fibers treated with the control (2% JBO emulsion for 72 hours of incubation) (Fig. 4A). On the other hand, fibers treated with the same combination (1% JBO emulsion and bacterial consortia for a 48-hour incubation) demonstrated a 12.2% increase (* $p < 0.05$) in extension at the breakage point compared to the control (2% JBO emulsion for 72 hours of incubation) (Fig. 4B). These improvements in tensile strength and elasticity are critical for yarn quality, as they contribute to stronger, more durable products.

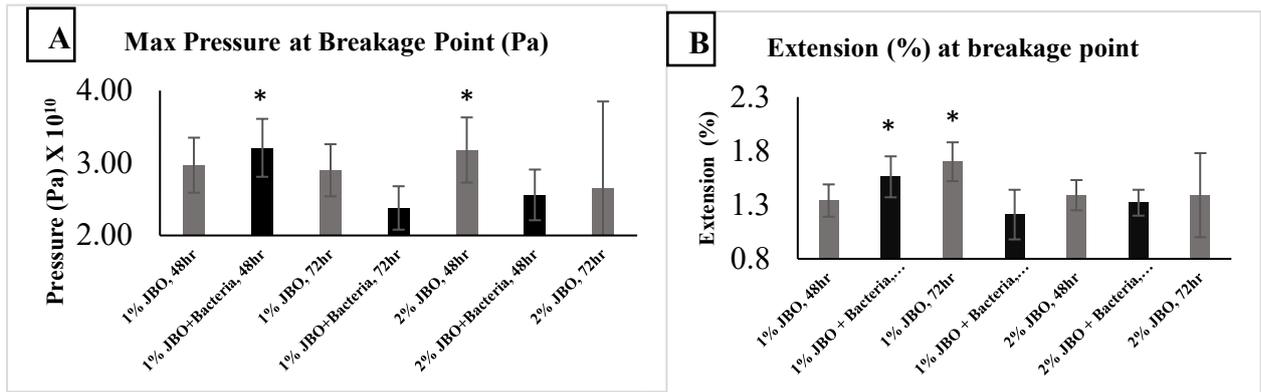


Fig. 4. Analyzing the changes of (A) maximum pressure at breakage point and (B) extension (%) at breakage point of jute fiber treated with bacterial consortia at different incubation periods compared to control. Asterisks indicate level of statistical significance: * $p < 0.05$

3.3.3 Moisture Regain Analysis

Moisture regain analysis was performed on jute fibers treated with both concentrations of JBO emulsion containing bacterial consortia and their respective controls over 48h and 72h incubation periods. The moisture regain percentages were measured using a moisture meter (Jute Moisture Tester, HX-400) at different stages: after incubation, breaker card processing, finisher card processing, third drawing roll, and the final yarn product. A total of 18 samples were analyzed at each stage. The moisture regain percentages for consortia-treated fibers did not significantly differ from those of the controls across all stages (Fig. 5).

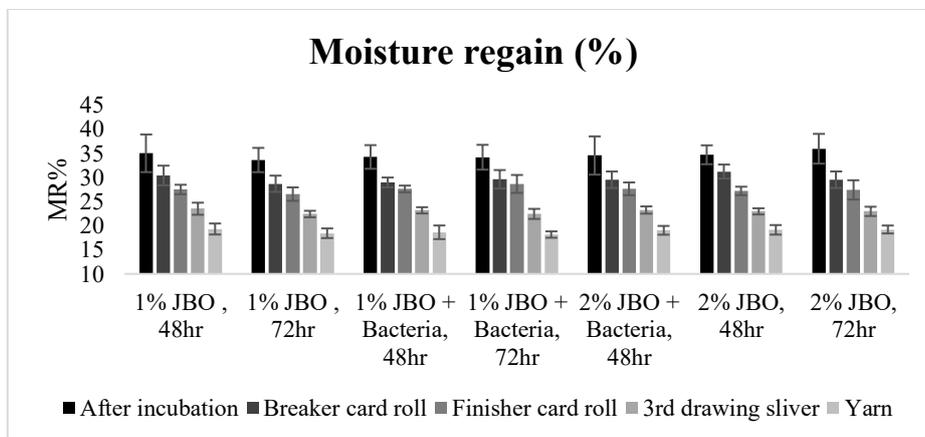


Fig. 5. Changes in moisture regain of jute fiber treated with bacterial consortia for different incubation periods compared to control

3.3.4 Wastage Analysis

Wastage of jute fiber at the breaker card and finisher card stages during fiber processing was analyzed for jute fibers treated with both concentrations of JBO emulsion with and without bacterial consortia, across 48h and 72h incubation periods. The results indicated that fibers treated with a combination of 1% JBO emulsion and bacterial consortia for a 48-hour incubation had 24.1% less wastage during breaker card processing compared to the control group treated with 2% JBO emulsion for 72h incubation period (Fig. 6B). Fiber wastage is a major concern in the jute industry as it directly affects production efficiency and cost. The reduction in wastage in the microbial treatment group is likely due to the microbial consortia's action on non-cellulosic components, which reduces fiber brittleness and improves uniformity. This reduction in wastage may be associated with microbial modification of non-cellulosic components such as hemicellulose and lignin, which are known to influence fiber stiffness.

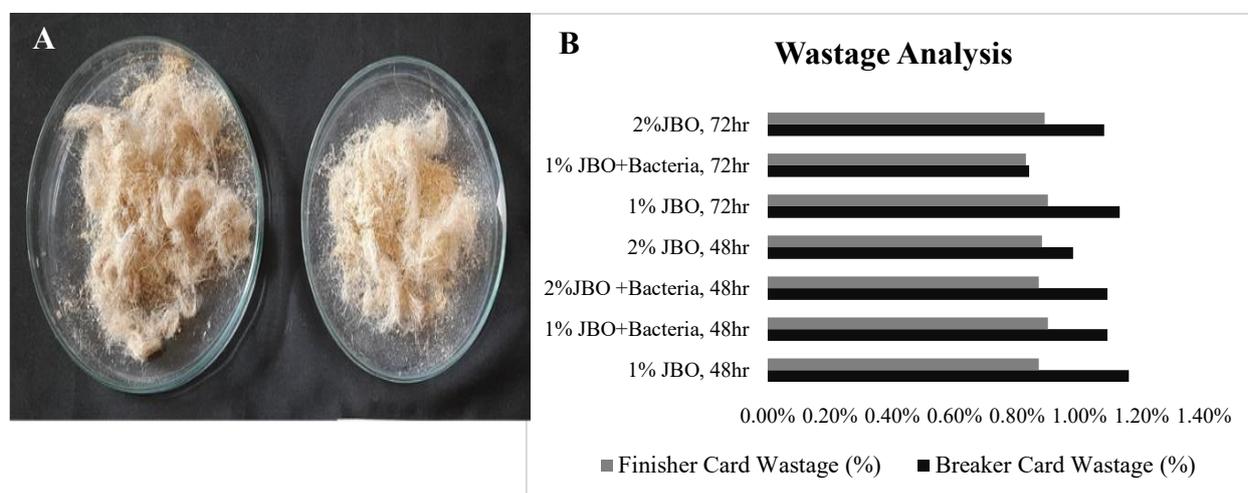


Fig. 6. (A) Wastage at the Breaker card and Finisher card stages (B) Comparison of wastage reduction in jute fiber treated with bacterial consortia across different incubation periods versus the control

3.3.5 Analysis of fiber using Scanning Electron Microscopy

Scanning Electron Microscopy (SEM) analysis was performed on six sample groups from the manufacturing process: untreated jute fiber, treated jute pile, fibers after breaker carding, fibers after finisher carding, fibers at the 3rd drawing stage, and fibers after yarn production. Each group was analyzed across different incubation periods, both with and without bacterial consortia. SEM images of jute fibers treated with bacterial consortia combined with a reduced concentration of JBO emulsion (1%) after a 48-hour incubation revealed a notable increase in bacterial biofilm presence compared to untreated controls (Fig. 7). The rough surface morphology observed in the treated fibers suggests structural modification of the fiber surface, which may be associated with partial removal or alteration of non-cellulosic components such as lignin and hemicellulose, as reported previously, contributing to improved fiber quality. There are some reports like increasing

Eichhornia fibers containing cellulose & other content improved the thermal properties, tensile & bending strength of the composites [23,24]. The SEM analysis also showed the presence of bacterial biofilms on the treated fibers, indicating effective colonization of the bacterial consortia. These biofilms may play an important role in the enzymatic breakdown of lignin and hemicellulose, facilitating the degumming process and further improving fiber quality. Biofilm formation can be particularly advantageous in industrial applications, as it suggests that the bacterial consortia are robust and capable of sustained activity during fiber treatment. The presence of biofilms also indicates that the bacteria are able to survive and function under the harsh conditions typically encountered in jute processing.

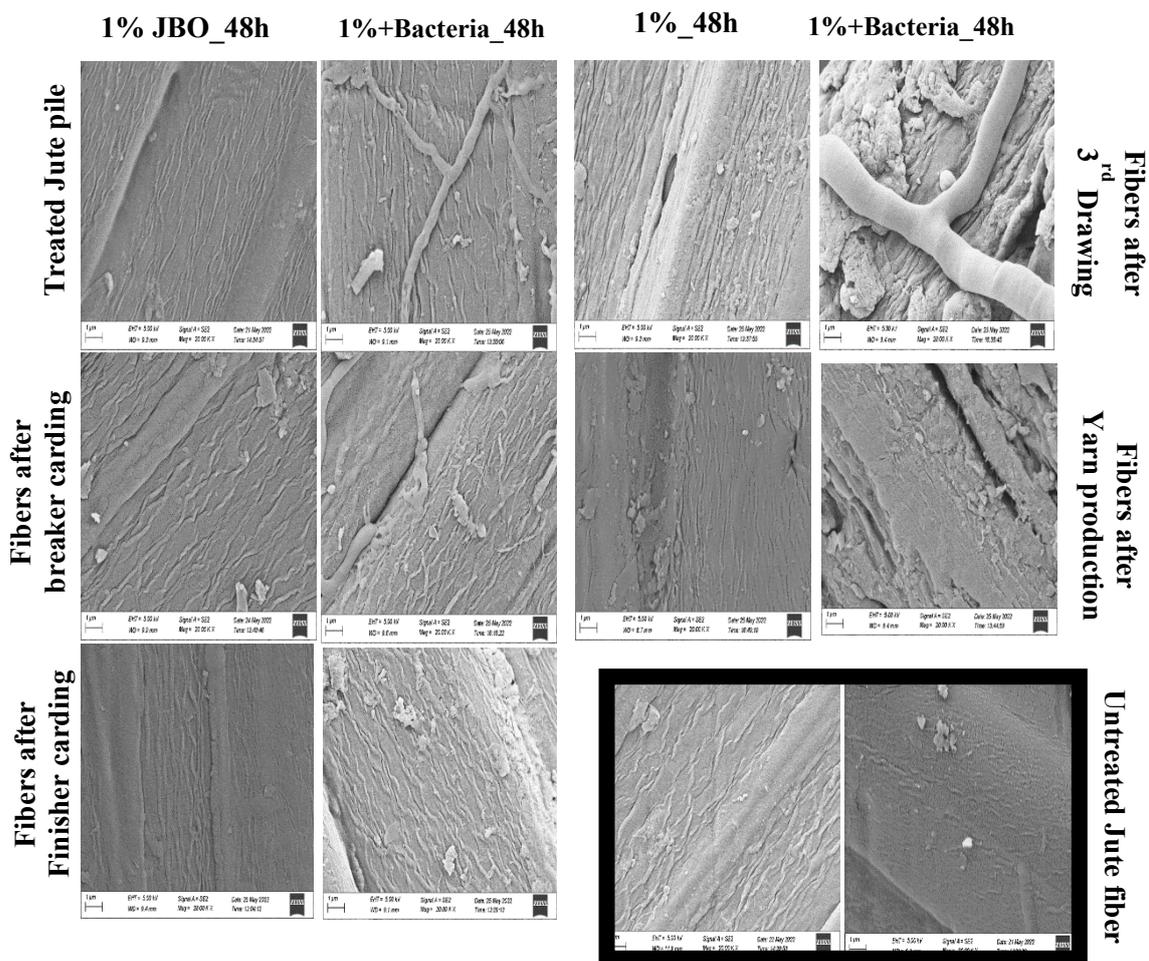


Fig. 7. SEM analysis of jute fiber of six sample groups: untreated jute fiber, treated jute pile, fibers after breaker carding, fibers after finisher carding, fibers at the 3rd drawing stage, and fibers after yarn production

In addition to improving mechanical properties and reducing wastage, the microbial consortia offer significant environmental and economic benefits. By reducing the concentration of JBO from 2% to 1%, the treatment not only lowers the cost of raw materials but also minimizes the environmental footprint associated with petroleum-based JBO. JBO has been reported to migrate into food grains when used in jute packaging, posing significant health risks [25]. The ability to reduce or eliminate JBO use without compromising fiber quality represents a major

advancement in the sustainability of jute production. By partially replacing JBO with a microbial treatment, manufacturers can achieve enhanced fiber quality while promoting sustainability. This approach aligns with global efforts to reduce reliance on harmful chemicals and move towards more sustainable production practices. Given the growing consumer demand for eco-friendly materials, the development of microbial treatments for natural fibers like jute offers a timely and important solution for the textile industry.

Furthermore, the reduction in incubation time from 72 hours to 48 hours observed in this study is another important finding. Reducing the time required for fiber maturation can lead to significant energy savings and increased production efficiency. The shorter incubation period, combined with the reduced concentration of JBO, makes the microbial treatment not only more environmentally friendly but also more economically viable for large-scale industrial applications.

Future research should focus on optimizing the composition of the bacterial consortia to further enhance their efficacy. This could involve identifying additional bacterial strains with specific enzymatic activities that could improve fiber quality even further. Additionally, long-term studies should be conducted to assess the impact of microbial treatment on fiber properties across different stages of the jute production process. Exploring the application of microbial consortia to other natural fibers, such as hemp or flax, could also broaden the utility of this approach within the textile industry.

4. Conclusion

Microbial consortium treatment provides a sustainable and cost-effective alternative for jute processing. By reducing jute batching oil (JBO) usage from 2% to 1%, this method addresses environmental concerns and lowers production costs. The improved fiber quality, seen through enhanced tensile strength and elasticity, leads to stronger, more durable yarn, while a reduction in fiber wastage increases production efficiency. These advantages make this approach both eco-friendly and commercially competitive, offering jute manufacturers the opportunity to enhance output while minimizing reliance on petroleum-based JBO.

Future research should aim to optimize the bacterial consortia used in this process and explore its potential application to other natural fibers. Expanding the use of microbial treatments beyond jute could further promote sustainable practices across the textile industry. By reducing harmful chemical use and improving fiber processing, this method paves the way for environmentally friendly, cost-efficient solutions in natural fiber production.

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CRedit authorship contribution statement

Md. Rezaul Karim Rana: Data curation, Formal Analysis, Methodology, Validation, Visualization, and Writing – original draft, Review & Editing; **Rabeya:** Data curation, and Methodology, Writing- Original draft, Review & Editing; **Al Amin:** Data curation, Formal Analysis, and Validation; **Farjana Haque Shaon:** Methodology, Formal Analysis, Visualization, and Writing – original draft; **Farhana Tasnim Chowdhury:** Validation, and Investigation; **Haseena Khan:** Conceptualization, Investigation, Resources, and Supervision; **Mohammad Riazul Islam:** Conceptualization, Funding acquisition, Investigation, Project administration, Resources, Supervision, and Writing – review & editing.

Declaration of Competing Interest

The authors declare no competing interests.

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