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Incorporating neem leaf extract for enhanced sock functionalities: an eco-friendly approach

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Abstract: Socks are necessary items of clothing for everyday use. It is used all year round, not just in the winter, with dress shoes, loafers, athletic shoes, running shoes, and other shoes to increase comfort, keep them from perspiring, and extend their lifespan. After wearing the socks for a certain amount of time, an unpleasant odor emanates from them due to constant perspiration and contamination, which is crummy. The development of fungus, germs, and contamination, a major issue in our day-to-day existence, causes the stench. Anti-odor socks were created to reduce odor and restrict the growth of bacteria. The socks in this study were made entirely of cotton yarn, and they underwent a pad dry cure procedure to treat the fabric with neem leaves. The cotton socks were treated with extracted neem liquid using a padding mangle machine. The treated fabrics underwent a 30-minute drying process at 60 °C and a 3-minute curing period at 140 °C. The absorbency, washing potential, and anti-microbial and odor qualities of socks have been assessed quantitatively. The antibacterial qualities of the neem-treated socks are evident; they also work better at preventing odors from spreading and may be reused multiple times without releasing new ones. While the FTIR test determines the chemical composition of the treated and untreated cotton socks, the SEM examination verifies the deposition of neem particles onto the fabric surfaces.

Keywords**:** Anti-Odor Socks; Cotton Knit Fabric; Neem Leaf; Anti-Microbial Finish; Environmentally Friendly Product.

Introduction

At present, consumer awareness has been considered, particularly about health hygiene, which has prompted clothing producers to use novel chemical finishes and finishing techniques. Sweat from the skin creates an environment where bacteria can grow in the presence of the right nutrients and temperatures. The microbes attempt to cause spoiling and biodeterioration when they come into direct contact with fabric, resulting in an unpleasant odor inside clothing.

Antimicrobial compounds are widely utilized in the textile industry to prevent the growth and spread of pathogenic germs in jogging suits, team uniforms, cyclewear, shoes, socks, and undergarments. These antimicrobial chemicals cause discoloration, skin reactions, textile degradation, and unpleasant odors (Bajaj, 2002). Many people use synthetic antibacterial agents such as triclosan, metals, salts, organometallics, phenols, and quaternary ammonium compounds. These substances have shown promise in the fight against microbes. Nevertheless, they contaminate water and negatively impact creatures that are not their intended targets (Shahid-ul-Islam & Butola, 2019). These factors have raised interest in eco-friendly anti-microbial compounds derived from natural sources in textile applications across the globe. Recently, bioactive, non-toxic, and antibacterial natural antimicrobial agents have been allured by researchers. Examples include chitosan, neem, tulsi extracts, aloe vera, tea tree oil, and eucalyptus oil.

Neem is an extremely fast-growing evergreen plant that reaches heights of up to 35 meters in exceptional circumstances but typically grows to 15 to 20 meters (Ghosh et al., 2021). *Azadirachta indica*, the botanical name for neem, belongs to the tribe Melieae, the subfamily Meloideae, and the family Meliaceae (Akeel et al., 2017). Neem plants thrive naturally in areas with rainfall between 450 and 1200 nm. Neem trees grow well in arid climates and on poor soil since they require little water and direct sunlight. The neem tree is indigenous to Southeast Asia, which includes Bangladesh, India, Pakistan, Myanmar, Sri Lanka, Indonesia, and Malaysia. However, because of its adaptability to the environment, it also thrives in other world regions (Atawodi & Atawodi, 2009). Since the Vedic era, Neem has been used for its anti-tumor, anti-skin infection, anti-ulcer, hypoglycemic, anti-malarial, anti-diabetic, and cardiovascular properties. The neem tree leaves, bark, and seeds contain over 300 compounds; the most commonly found ones include azadirachtin, salannin, and meliantriol. These substances function as insect growth regulators and have antibacterial, antiviral, and virucidal properties (Alves et al., 2009). Due to chemicals in different portions of the neem plant, neem is used to treat inflammatory infections, respiratory disorders, gastrointestinal disorders, and dermatological conditions. Nimbin ($C_30H_{36}0_6$), an anti-inflammatory, antipyretic, antihistamine, and anti-fungal compound, is found in neem tree leaves and comes highly recommended. Neem plants have been shown to have anti-inflammatory qualities in numerous studies. In an experiment using rat models, nimbidin from neem trees was taken orally to assess its anti-inflammatory properties.

It depicts that inflammatory stimulus markedly inhibited macrophage migration to their peritoneal cavities and that phagocytosis was suppressed. Since ancient times, neem leaves have been utilized extensively. Neem leaves have been shown in the literature to be physiologically active and commonly utilized in hepatoprotective, neuroprotective, nephrotoxic, immunomodulatory, cardioprotective, and wound healing applications. Neem is used with textiles for two purposes. To begin with, it is a great source of colorant for dying the textile substrate and a bio-mordant that improves the color fastness. Second, it is a naturally occurring antimicrobial ingredient that strengthens the textile substrate's antibacterial qualities when applied (Prajapati et al., 2022). Neem is typically used on cotton as an antibacterial agent but is also applied to silk, wool, hemp, bamboo, polyester, and cotton blends (Ali et al., 2010; Babu & Ravindra, 2015; Badr, 2018; Hooda et al., 2013). Joshi et al. (2007) investigated the antibacterial properties of neem-seed extract applied to polyester and cotton blends. The following tests were run in this study: cross-linking, fastness, strength, antimicrobial, and whiteness index (Joshi et al., 2007). Arafa Badr (2018) examined mechanical characteristics, antibacterial activity, and other functional aspects of knitted socks made of Egyptian cotton and regenerated fibers like bamboo and Tencel (Badr, 2018). Erana (2017) demonstrated the anti-microbial activity of specific microorganisms and concentrated on developing an antibacterial treatment for socks and kitchen supplies using neem leaves (LA, 2017). To generate antimicrobial textiles, Patel et al. (2014) focused on a project where medical textiles were grafted with neem leaf extract. They discovered some specific microorganisms exhibit antibacterial activity (Patel et al., 2014). Research by Lopez-Romero et al. (2015) showed the antibacterial activity of certain particular microorganisms (Lopez-Romero et al., 2015). According to Khurshid et al. (2015), neem impacts antimicrobial activity; compared to aloe gel and neem alone, the hybrid of neem and aloe gel was an excellent antifungal and antibacterial agent. Additionally, after washing, it showed good durability (Khurshid et al., 2015). Anjali et al. (2012) removed the neem leaf and examined the natural dye's antibacterial properties on cotton textiles: antimicrobial activity and dye extract from the leaf (Anjali et al., 2012).

Odors are primarily a mixture of organic and inorganic substances, such as hydrogen sulfide, ammonia fatty acids, and lactic acids, sensed by receptors of the nose and identified by the olfactory bulb in the human brain. The compounds secreted by human sweat glands, urine, feces, expiration, saliva, breasts, skin, and genital organs are used by bacteria for their metabolic processes, resulting in an unpleasant odor. Textile goods must be created with antimicrobials or odor-absorbent properties to control malodor (Karolia & Khaitan, 2012; R H McQueen, 2011; Rachel H McQueen & Vaezafshar, 2020). An innovative technology by British scientists to reduce odor in socks was reported in February 1997 by the British daily ‘The Daily Mirror’ (Mandal & Mandal, 2011). Because silver nanoparticles have antibacterial qualities that prevent the growth of microorganisms that generate odors, they may be applied to socks. Even if most of the particles were removed during the initial wash, numerous writers agreed that nanoparticles are still released (Gulati et al., 2022). Scientists are becoming concerned about this phenomenon because it affects cells through cell penetration (Geranio et al., 2009). Joshi et al. (2010) created eco-friendly antimicrobial textiles by applying neem seed extracts to polyester/cotton blend fabrics. They investigated the antibacterial properties of five natural dyes against Escherichia coli and Staphylococcus aureus: turmeric, neem leaves, tea leaves, pomegranate rind, and myrobalan. They contrasted the wash endurance of the dyes and microbiological activity (Joshi et al., 2007). Shastri et al. (2012) used chemical and biological procedures to create nanoparticles, which were put into sock textiles to test the material's antibacterial qualities (Shastri et al., 2012). l

Most researchers utilized neem leaf, bark, fruit, and seed to create antimicrobial finishes, pesticides, and medications (Mollick et al., 2023). Neem leaf was applied c to textile materials by certain researchers to use the product as an antimicrobial or antibacterial. Some utilized neem leaves as an all-natural coloring and antimicrobial finish. Neem leaf was employed in a study on kitchen fabric and socks to demonstrate the anti-microbial qualities of some specific bacteria, such as *E. Coli*, *S. aureus*, etc. To produce anti-odor socks, some researchers employed silver nanoparticles. However, this raised specific environmental issues. However, no one can manufacture an anti-odor product using neem leaf, bark, or oil. Only some people can demonstrate the analytical measurement of the finished neem product after usage. This project intends to develop natural anti-odor finishing environmentally safe technology, evaluate certain physical features, and improve anti-odor products such as socks.

Materials and Methods

Materials

Throughout the investigation, 102 (g/m^2) rib-structured cotton knitted textiles with a yarn count of 30 Ne, a yarn crimp of 5%, a fabric cover factor of 21, and a loop density of 10 were employed. The neem was extracted with the use of ethanol as a solvent. Citric acid is utilized in this instance as a binding agent.

Table 1. Identification of samples.

Sample Name	Identification
Sock sample without treatment	SW
Sock sample with 5% treatment	ST1
Sock sample with 10% treatment	ST2
Sock sample with 15 % treatment	ST3
Sock sample with 20% treatment	ST4

Techniques

2.2.1 Plant matter

Neem leaves were collected from Jashore University of Science and Technology, Jashore, Bangladesh. To create an efficient powder for solvent extraction, neem leaves were allowed to dry at room temperature in the shade and then blended with a dry blender. Neem leaf powders were kept in a tight-fitting glass bottle.

2.2.2 The extraction of neem

Before being weighed and recorded, the neem leaves were carefully cleansed with distilled water. 50 ml of 100% ethanol was combined with 25 g of fresh neem leaves. The mixture was allowed to dissolve for one to two minutes, after which the hard residue was removed using silk cloth filtration. The same procedure was used to separate the coarse residue. However, alcohol was used this time. These pieces that had been collected were mixed and then filtered again using fast filter paper. A total of 25 ml of extract was collected after the alcohol was removed, and the remaining extract was then transferred to an airtight bottle with an amber tint.

Figure 1. Procedures for extracting neem and preparing samples.

2.2.3 Using an antibacterial coating

The introduction of plant-based ethyl alcohol extracts to pre-treated cotton fabric was addressed through the pad-dry-cure procedure. 5 g of sock fabric was coated with 50 ml of extracted oil. The cloth was put through a pneumatic padding mangle at a speed of 3 m/min and a pressure of 1 kg/cm^2 to remove the excess solution after being submerged in a plant extract containing 6% citric acid (a binding agent) for 10 minutes. Three pads and three nips were used for padding, and the squeezed fabric sample was dried for three minutes at 60 °C and then cured for three minutes at 140 °C (Shastri et al., 2012; Zhang et al., 2009).

2.2.4 Methods of testing

Test for odor properties

SNV 195651 is used to measure the odor test (SNR 195651:2015, 2015). First, the sample was added to a 500 ml lidded container on top of the sodium carbonate solution. After that, the container was kept in an oven for fifteen hours at a consistent temperature of 37± 20 °C. According to Table 2, six persons evaluated each sample separately.

Table 2. Value rating for the odor test.

Grading	Parameters
Grade 1	Odorless
Grade 2	Weak odor
Grade 3	Tolerable odor
Grade 4	Annoying odor
Grade 5	Intolerable odor

The average of the odor intensity grades must be less than four.

Evaluation of antibacterial efficacy

The antibacterial activity of treated samples (SW & ST3) against two different bacterial species (*Escherichia coli* and *Staphylococcus aureus*) was assessed in accordance with the ASTM E2149-01:2001 standard (ASTM E2149-20, 2020). One gram of sample was weighed and ready for antibacterial testing. The bacteria were cultured in broth before being cultivated on agar. After this resuscitation, one gram of cloth was placed in a 50 ml liquid solution containing roughly 28×10^5 CFU/ml of bacteria. The glass jars containing 50 milliliters of bacterial solution were kept in an incubator shaker set at 37 °C for one hour. The glass jars containing the fabric and bacterial solution were taken out of the incubator. The liquid samples were then diluted 10-1000 folds, and 100 µl was placed on nutrient agar plates and incubated for 24 hours at 37 °C. As a result of this application, bacteria were counted on Petri dishes, and bacteria reduction rates were computed using the following formula:

$$\text{Reduction Percentage (R \%)} = \frac{A-B}{A} \times 100 \qquad \text{(i)}$$

A represents the initial (CFU/ml) bacterial count, and B represents the final (CFU/ml) bacterial count following an hour.

Test of cleaning ability

A durability wash is a method of testing clothing that consists of one cycle of fifteen washes in a standard household washing machine. This technique offers prompt input on the performance of the dress, making it possible to identify opportunities for improvement early in the manufacturing process (Wylie & Merrell, 2022).

Test for water absorbency

The ability of a fabric to absorb moisture is implied by its absorbency features, which include shrinkage, water repellency, static build-up, wrinkle recovery, and comfort for the skin. The ASTM 4772 test method was utilized to assess the absorbency of materials (ASTM D4772-14:2019, 2019; Hu et al., 2006). A drop of water was allowed to fall onto a 20 by 20 cm piece of fabric. A syringe manages the drop water height, and 60 seconds are kept to determine the water absorbency region.

Test for air permeability

Air permeability is the flow rate per unit area that passes perpendicularly. The structure, the fabric's pores, and the finishing methods alter the airflow path of the fabric (Mishra et al., 2019). Every sample was examined in light of EN ISO 9237:1997. With a head area of 20 cm^2 and a differential pressure of 100 Pa/mm H_20, GT N44 numerical air permeability was employed (ISO 9237:1995, 1995). For the air permeability test result, no special formula is required. The development appears automatically on the machine display once you push the start button. Five examples of each fabric are displayed here.

Test for water vapor permeability

Clothing kinds are distinguished by a critical feature called water vapor permeability (Saville, 1999). For example, high water vapor permeability is advantageous.

$$WVP=\frac{24M}{At}\ g/m^2\ /Day \qquad \text{(ii)}$$

Where M = loss in mass (g), t = time between weighing (h), and A = internal area of the dish (m^2).

$$A=\frac{\pi d^2\times 10^{-6}}{4} \qquad \text{(iii)}$$

Where d = internal diameter of the dish (mm).

Test of tensile properties

As per ASTM D5035-11, the tensile property of the sock fabric was measured. The tensile tester MESDAN TENSO was utilized in this experiment to assess the elongation (%) and breaking force (N) (ASTM D5035-11:2019, 2019).

Test for shrinkage

The ISO 6330:2021 standard measures the shrinkage test of sock fabric (ISO 6330:2021, 2021). After conditioning, the shrinkage of the neem-treated samples was measured using a shrinkage test board and ruler. A raw fabric sample of 35 cm by 35 cm was measured.

$$\text{Shrinkage (\%)} = \frac{\text{Length before wash} - \text{Length after wash}}{\text{Length before wash}} \times 100 \qquad \text{(iv)}$$

FT-IR examination

The FTIR spectra of cotton fabrics treated with neem and those without were analyzed using a NicoletTM iSTM 10 FTIR Spectrometer (Germany), as Mollick et al. (2023) mentioned (Mollick et al., 2023).

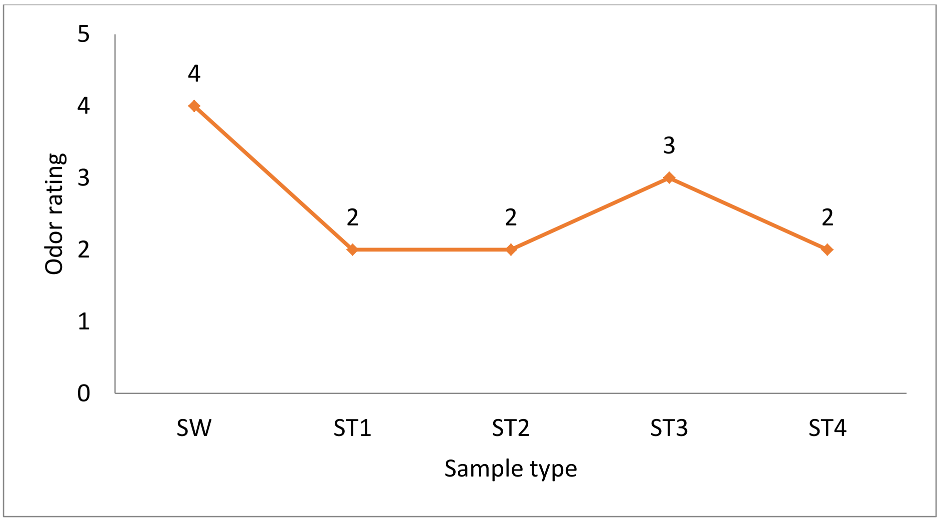
SEM examination

FESEM (ZEISS Sigma, Germany) was used at the Genome Center of Jashore University of Science and Technology in Jashore, Bangladesh, to perform scanning electron microscopy (SEM). The samples were subjected to a 5 kV accelerating voltage and examined at magnifications of 300X and 1500X.

Findings and Discussion

Analysis of odor properties

Figure 2. Test of the odor properties.



Before applying neem to socks worn by various individuals, Figure 2 illustrates that we discovered a distinct odor scale, such as 2, 2, 2-3, and that it was then left on ethanol & sodium carbonate for 15 hours in a microwave oven. After that, an odor test yields 3, 3, 3, and 4 results. Thus, a 3–4 on the mean odor scale. According to the analysis, the average odor rating when neem is used as an antimicrobial agent is 3–4/4; the odor rating is 2 when no antibacterial finish is used. Lastly, odor production is inhibited by using neem as an antibacterial finish (Figure 3). Therefore, this study offers a different, environmentally friendly method of sanitizing textile materials to prevent the spread and retention of odors.

Figure 3. Photographs of two sock samples, (a) untreated, and (b) treated.

Antimicrobial activity test (colony count reduction)

Table 3: Antimicrobial activity test of sock sample.

Sample	Reduction in colony count (%)	
	S. aureus	*E. coli*
Untreated (SW)	TNTC	TNTC
Neem-treated (ST3)	94	98

The bacterial culture 28×10^5 CFU/ml was applied to the sock samples, and the resulting count was used to determine the percentage decrease in bacterial colonies. The % decrease in colony count is displayed in Table 3. Within *S. aureus*, the typical decrease in colony count is 94%, whereas *E. Coli* has a noteworthy decrease of 98%. As seen in Figure 4, the colony count of the untreated samples was too high to count (TNTC).

Figure 4. Antimicrobial activity of sock fabrics (gram-positive A, B, and C; and gram-negative D, E, and F).

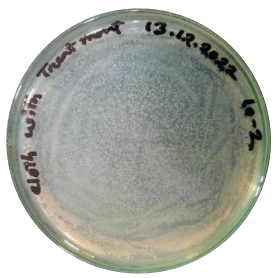
A. Only Bacteria (Initial Count (Cfu/ml))

B. Untreated Cloth

C. Treated Cloth

D. Only Bacteria (Initial Count (Cfu/ml))

E. Untreated Cloth



F. Treated Cloth

Durability of washing (decrease in wicking rate)

Table 4. Washability of sock samples.

Samples	After 3 washing cycles	After 5 washing cycles
Neem-treated (ST3)	98.99%	94.67%

The reduction in wicking rate for each set of samples was used to measure the washing durability twice, i.e., after three and five washes. The results are presented as a percentage and are displayed in Table 4. The antibacterial activity of neem leaves against *S. aureus* and *E. coli* is shown in Table 4. *S. aureus* and *E. Coli* and their ability to be cleaned quickly. Cleaning neem leaves greatly lowers bacterial colonies for some species (Lombi et al., 2014; Periolatto et al., 2012). After five wash cycles, the antibacterial activity decreases by 2% on average for each concentration, although the concentration increases.

Test for absorbency

Figure 5. Test for the absorbency of sock samples.

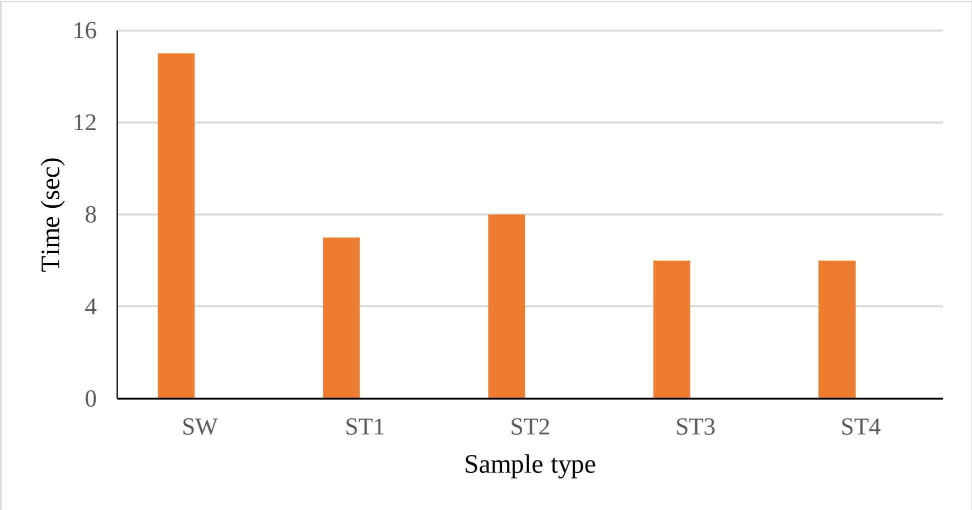
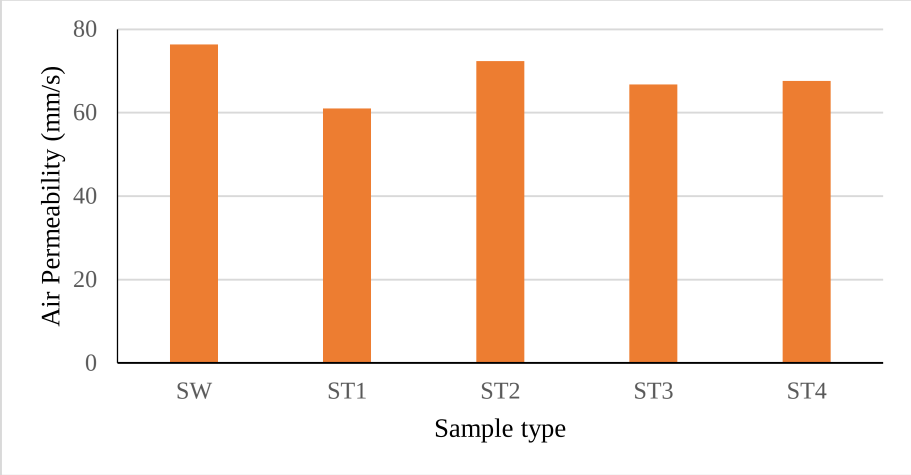


Figure 5 shows the results of an absorbency test conducted to evaluate the water absorbency characteristics of cotton knit fabric treated with varying concentrations of neem. Neem-treated samples had an absorbency of around half that of untreated sock samples. Compared to untreated neem cloth, the absorbency time lowers by 53%, 46.66%, 60%, and 60% for ST1, ST2, ST3, and ST4 at concentrations of 5%, 10%, 15%, and 20%. The sample order was ST2> ST3> ST1> ST4. The cloth becomes softer, and the friction between the water droplet and the fabric changes after the neem finishes soaking (Shahidi et al., 2010).

Air permeability

Figure 6. Test for the air permeability of sock samples.

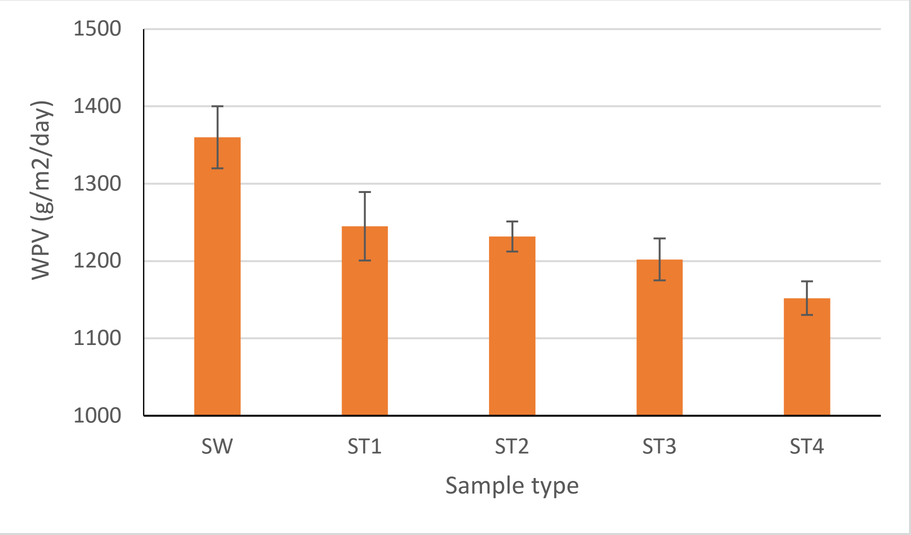


For knitted fabric, a minimum acceptable quality guideline for air permeability is 25 mm/s. The ability of cotton knit fabric with varying concentrations of neem treatment to flow air was tested using an air permeability test, and the relevant results were summed and shown in Figure 6. The sample order was found to be ST2> ST3> ST4> ST1 at concentrations of 5%, 10%, 15%, and 20%. Compared to untreated neem fabric, the air permeability decreased by 20.16%, 5.23%, 12.57%, and 11.52% for ST1, ST2, ST3, and ST4. Figure 6 demonstrates the good air permeability of the neem-finished sock fabrics. The liquid moisture in the body and water vapor can readily diffuse and evaporate from the fabric into the surrounding air, lowering the relative humidity inside the clothes. The body has cooled due to this process, and breathability has risen (Inprasit et al., 2018; Vaideki et al., 2009).

Water vapor permeability

Sweat transmission capacity is influenced by the parameters of water vapor permeability (WPV). The ability of cotton knit fabric with varying doses of neem treatment to flow water was tested using a water vapor permeability test; the related data was summarized and shown in Figure 7. Neem-treated samples have around half the water vapor permeability of untreated sock samples. The sample's order was determined to be ST1> ST2> ST3> ST4 at concentrations of 5%, 10%, 15%, and 20%. Compared to untreated neem fabric, the water vapor permeability decreased by 8.46%, 9.44%, 11.61%, and 15.29% for ST1, ST2, ST3, and ST4, respectively. Every sock sample did exceptionally well in the water vapor permeability test, as shown in Figure 7. Any cloth that receives a finishing treatment contributes to its increased water vapor permeability (Gericke et al., 2021; Inprasit et al., 2018; Vaideki et al., 2009).

Figure 7. Permeability to water vapor of sock samples.



Tensile properties

Table 5. The tensile characteristics of socks.

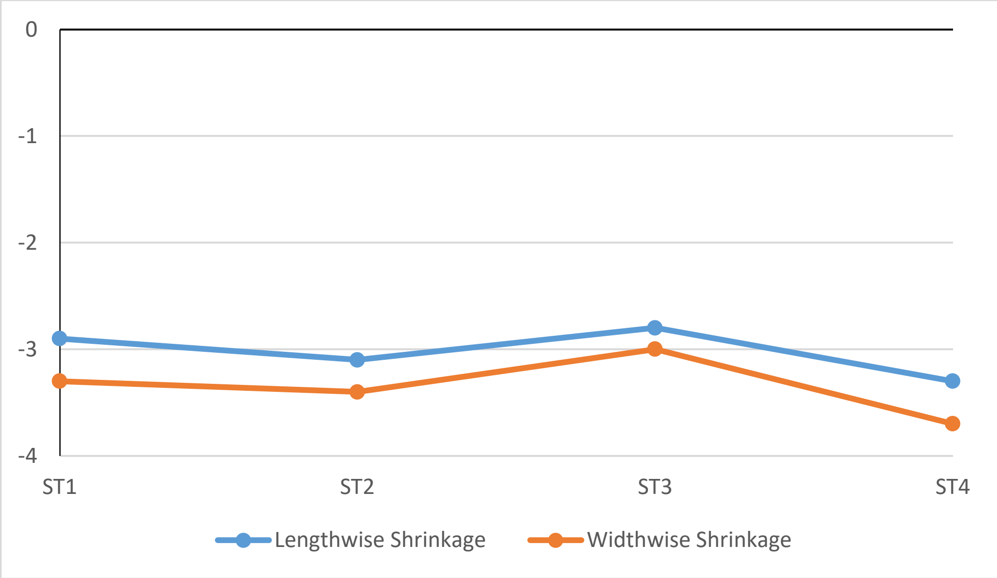
Socks Sample	Lengthwise		Widthwise	
	Max. breaking force in	Elongation (%) at break	Max. breaking force in N	Elongation (%) at break
SW	277	146	89	521.5
ST1	276	118.5	75	602.5
ST2	281	113.3	79	658.5
ST3	277	124.5	72	712.5
ST4	270	120.5	83	588.5

The difference in tensile strength between fabrics treated with neem and those that are not is seen in Table 5. It is discovered that treatment reduces the tear strength of the sock samples in both the length and width directions. The rate of decline is 7% width-wise and about 25% length-wise. Tensile strength is likewise decreasing concurrently with tear strength. In terms of tensile strength, there is a 25% lengthwise decline and a 41% widthwise decline (Gericke et al., 2021).

Percentage of shrinkage

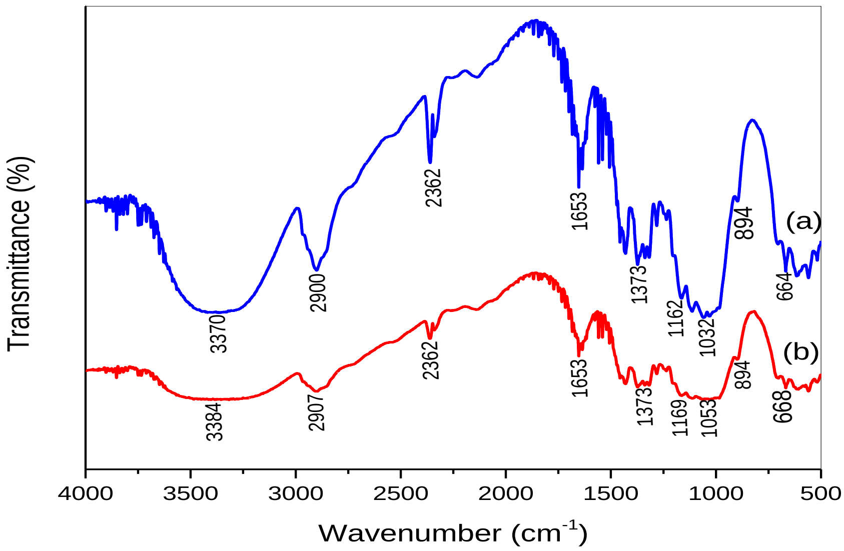
The shrinkage of the neem-treated cloth in the warp and weft directions is shown in Figure 8. Using samples of untreated socks, the lengthwise shrinkage of neem-treated samples is calculated. The sample was in the following order at concentrations of 5%, 10%, 15%, and 20%: ST4> ST2> ST1> ST3. Neem treated at concentrations of 5%, 10%, 15%, and 20% showed the following widthwise shrinkage in sample order: ST1> ST2> ST3> ST4. The proportion of shrinkage in the widthwise direction of sock textiles is greater than the percentage in the lengthwise direction, which can be attributed to the rib knit construction. Additionally, spandex yarn for sock fabric shrined more than regular cotton yarn, and this value is suitable for meeting client needs (Gericke et al., 2021).

Figure 8. Proportion of sock fabric shrinkage.



FT-IR examination

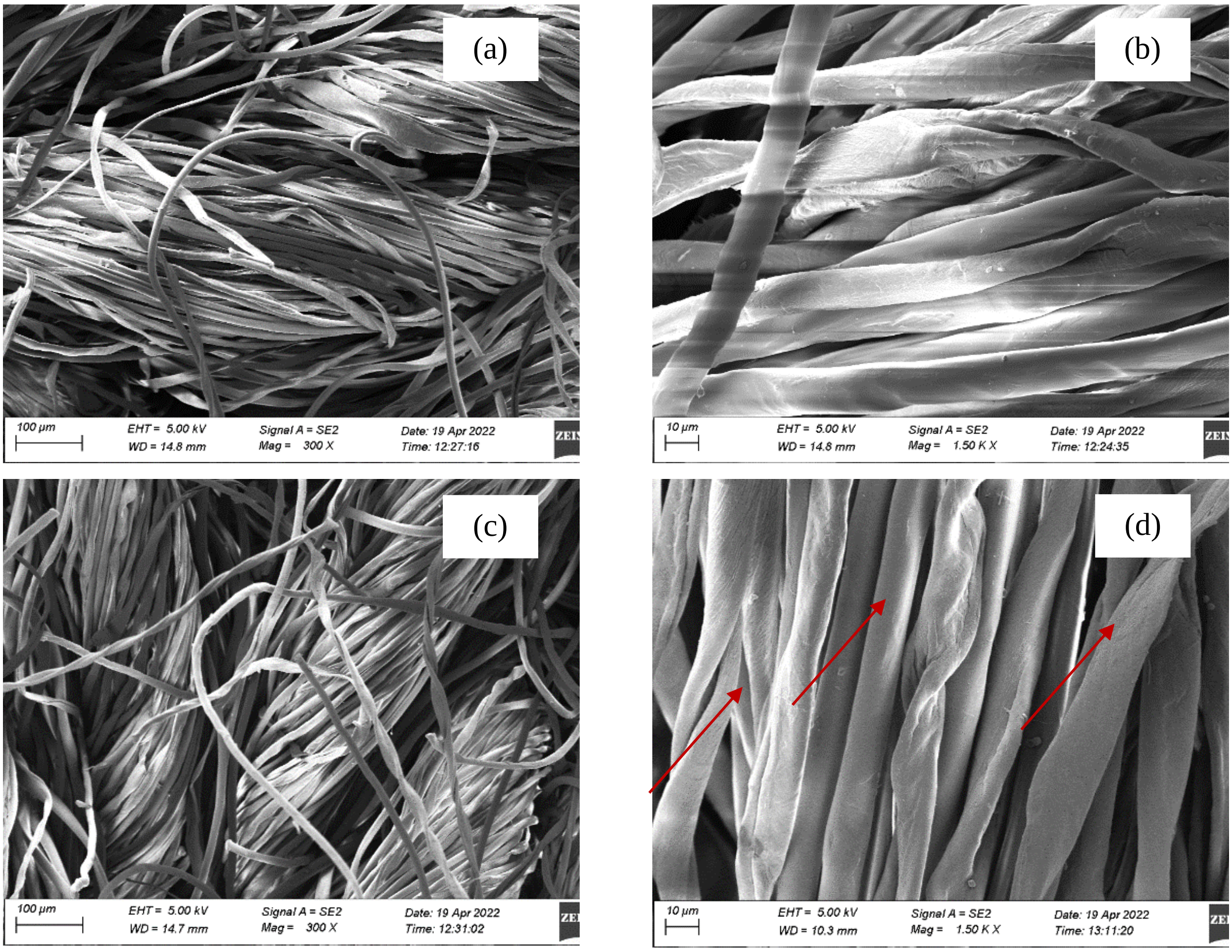
Figure 9. *Azadirachta indica* leaf treatment (b) and untreated cotton fiber (a) in socks using FT-IR.



Functional groupings in treated and untreated sock samples are shown in Figure 9. There is a prominent peak at 3330/cm for the cellulose, lignin, and water hydroxyl (OH) groups. The C-H stretching vibration found in cellulose and hemicellulose is responsible for the peak at 2896/cm, whereas water in the fibers may be the band's origin at 1622/cm. The presence of the carboxyl group in the hemicellulose is indicated by the lack of a peak in 1730/cm. The absorption bands at 1360/cm and 1315/cm, respectively, indicate the bending vibrations of the C-H and C-O groups in the aromatic rings of cellulose polysaccharides. The significant peak vibrations at 1032/cm are caused by the polysaccharides (CO) and (OH) stretching vibrations. A peak at 894/cm shows the presence of monosaccharide-monosaccharide-glycosidic connections. After being treated with an ethanol extract of *Azadirachta indica* leaves, the bands near 1156/cm, which represents the anti-symmetric bridge stretching of the C–O–C groups, near 1312/cm, which represents $–CH_2–$ wagging vibrations, and near 894/cm, which represents linkages, stayed unchanged. The bands of about 3351/cm correspond to vibrations in the -OH plane. The noticeable peak between 3400 and 3200/cm results from hydroxyl groups, mostly formed when cellulose undergoes -OH stretching. The -CH stretching in -CH_2-groups produces the peak at 2917/cm (Patel et al., 2014).

Analysis with FESEM

Figure 10. SEM of sock samples: untreated (a), and (b); treated (c), and (d) with *Azadirachta indica*.



Scanning electron microscopy images (a) and (b) of the structure of untreated cotton fabric are shown in Figure 10. It illustrates how, in contrast to woven materials, the surface pictures of the weft-knit fabric provide the impression of a far more open form (Hooda et al., 2013). The SEM pictures of the cotton fabrics treated with neem are displayed in pictures (c) and (d), which indicate how the neem-treated effect, a scale of small particles accumulating on the surface of cotton fabrics with minor macroscopic flaws, has caused differences in the surface morphology. Consequently, it is possible to conclude that the neem sheets and small particles are securely contained between the yard structures. Similarly, following treatment, there was a notable increase in fiber diameters and filament tightness (Babu & Ravindra, 2015; Hooda et al., 2013).

Conclusion

Cloth has been a significant component of technology and creativity throughout history. The defense applications of textiles have shown to be the most creative textile arena for unexpected developments. The importance of hygiene has increased recently. The existence of smell has grown to be important. Perspiration and other physiological fluids include chemicals that can build up and produce unpleasant smells. The results showed that neem with an antibacterial finish received an average odor rating of -2, whereas neem used as an antimicrobial agent received an average odor rating of 3-4/4. Consequently, this study offers a different, ecologically friendly technique for treating textile materials to stop the spread and retention of odors. However, the study demonstrates that fabrics treated with neem had lower permeability to water vapor and air while still having acceptable absorbency qualities. Neem-treated fabrics are poised to offer an eco-friendly solution, demonstrating superior antibacterial performance, although characteristics may diminish with increased washing cycles.

Conflict of Interest

The authors have no conflict of interest in publishing this research article.

Funding

None.

Declaration of Ethics

The subjects consented, and the studies complied with accepted ethical standards.

Data accessibility

All information, including samples, tables, figures, and experimental outcomes, is available.

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