

# Antimicrobial and Odor Control Performance of Cellulose Socks Treated with Natural Plant Extracts

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**Abstract:** Foot odor and hygiene issues in socks are primarily due to microbial growth in socks under warm, humid conditions. Antimicrobial treatment reduces microbial growth and improves the comfort of textiles. In the current study, the antimicrobial potential of various plant extracts was explored for cellulosic socks. Natural antimicrobial substances, including lemongrass, mint leaves, aloe vera, holy basil (tulsi), cassia leaves, and neem leaves, were prepared and applied to cotton socks using the padding method. Socks were then assessed for their potential in retarding microbial development and odor formation after use for a few days. Results indicated that all plant extracts exhibited varying levels of antibacterial activity and delayed odor formation in socks. Among the plant extracts used in the study, neem and lemongrass showed the strongest antimicrobial activity. It was concluded that plant extracts can serve as potential alternatives to improve sock hygiene without compromising comfort.

**Keywords:** Antimicrobial Socks, Natural Antimicrobial Agents, Plant Extract Treatment, Cotton Textile Finishing, Odor Control.

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## I. INTRODUCTION

Textile materials that contain natural fibres, such as cotton and linen, create a suitable environment for the growth of microorganisms due to the moisture and warmth they provide, as well as the nutrients from human skin [1, 2]. Microbial growth on textiles may lead to unpleasant odor, fabric deterioration, and potential health problems for the wearer [3]. Warm, humid conditions within footwear further promote bacterial growth, leading to hygiene problems and foot odor [4].

Therefore, antimicrobial finishing has become an important functional treatment for textile materials used in healthcare, hygiene, and consumer products, helping combat the growth of microorganisms [5]. Various studies have been conducted on antimicrobial treatments for textile materials. For example, cotton fabric treated with antimicrobial agents

showed stronger antibacterial activity than untreated fabric [6].

Antimicrobial treatments based on herbal compounds have also been studied previously for textile applications. Herbal compounds combined with copper nanoparticles have shown excellent antibacterial activity and wash durability when used on cotton textiles [7]. Chaion et al. employed the pad-dry-cure method to apply neem leaf extract to cotton socks. They demonstrated excellent antibacterial activity against *Staphylococcus aureus* and *Escherichia coli*, as well as excellent odor management [8].

Other antimicrobial socks made of various fibres have been studied. Socks made of bamboo, cotton, and cellulose fibres were tested for their antimicrobial activity, showing that bamboo fibres have better antimicrobial activity than the others [9]. Eco-friendly fibres such as bamboo are commonly

used in sports socks due to their high moisture absorption, breathability, and antimicrobial properties <sup>[10]</sup>.

In addition to antimicrobial performance, comfort is also important for socks, as they remain in continuous contact with the skin.

Thermo-physiological comfort refers to the interaction between the human body and clothing regarding heat and moisture. Since socks are in direct contact with the skin, they must provide adequate comfort properties during use. In another study, Cimilli et al. investigated socks made from various materials, including viscose, cotton, bamboo, modal, micro-modal, soybean, and chitosan. The study found that chitosan and soybean fibres had better thermal resistance, whereas cotton had better moisture-wicking properties <sup>[11]</sup>.

Microorganisms play both beneficial and harmful roles in human life. On one hand, they contribute positively to natural and industrial processes, including oxygen production through photosynthesis, nitrogen fixation, decomposition of organic matter in the carbon cycle, and the formation of fossil fuels. Microorganisms are also widely used in the production of food and pharmaceutical products such as bread, beer, cheese, and antibiotics. On the other hand, certain pathogenic microorganisms can cause harmful effects due to their virulence. Infection-causing bacteria such as *Staphylococcus aureus* (*S. aureus*), *Escherichia coli* (*E. coli*), and *Enterococcus faecalis* (*E. faecalis*) are known to cause various health problems in humans <sup>[12-14]</sup>.

Although several studies have investigated antimicrobial finishing of textiles using natural and synthetic agents, limited research has compared the effectiveness of different natural plant extracts applied to socks under similar treatment conditions.

Therefore, the present study investigates the application of various natural plant extracts as antimicrobial agents for cotton socks in order to reduce microbial growth and delay odor formation while maintaining user comfort.

## II. EXPERIMENTS

### A. Materials

To do this antimicrobial treatment on something that produces a lot of bad smell after being used for a certain period. The items that absorb or retain perspiration and cause bad smells are mostly socks. So, some socks had been taken that contained 85% cotton, 10% spandex, 5% elastic material.

### B. Sample Preparation

At first, all the collected organisms (Lemon Grass, Mint, Aloe Vera, Holy Basil, Cassia Leaves, Margosa Leaves) were washed with cold water to remove dust, sand, etc. Then, the Lemon Grasses, Mints, Holy Basils, Cassia Leaves, and Margosa Leaves have been cut into small pieces and kept separately. On the other hand, the Aloe Vera gel has been collected using a spoon and a knife. All the separated organisms have been blended individually by using a blender. After the blending process was completed, all the blended organisms looked like a paste. All of them were kept separately. The Cassia Leaves have been placed to boil for 40-50 minutes, until the liquor is ready to use. After boiling, the boiling water from the Cassia Leaves was retained by removing the Cassia Leaves from the pot.

By completing all of these processes, Lemon Grass Paste, Mint Paste, Aloe Vera Paste, Holy Basil (Tulshi) Paste, Liquor of Cassia Leaves (Tejpata), Margosa Leaves (Neem) Paste, and a mixture of Aloe Vera, Mint, and Cassia Leaves (Tejpata) have been produced. All of them are ready to use as antimicrobial agents.

Then all pairs of socks were immersed in seven agents at 50% concentration, separately, and properly treated using the Padding Mangle Dyeing Machine. After the socks were soaked in the Padding Mangle Dyeing Machine, they were removed and dried for a few minutes. The dried socks were then ready to be used or tested. First, all the dried socks were kept in a poly zipper packet to prevent air and water from the surrounding environment from entering, ensuring that no further germs or bacteria come into contact with the socks or are born.



Fig 1 Natural Plant Extracts Used as Antimicrobial Agents in this Study.



Fig 2 Mixture of Aloe Vera, Mint, and Cassia Leaves (Tejpata) Extracts Used for Antimicrobial Treatment.



Fig 3 Padding Mangle Machine Used for Applying Antimicrobial Agents to the Socks.

### C. Experimental Design

The experimental procedure was divided into three parts.

#### ➤ Part 1:

Antimicrobial treatment of socks using natural plant extracts, including lemon grass paste, mint paste, aloe vera paste, holy basil (Tulshi) paste, cassia leaf liquor (Tejpata), margosa leaves (neem) paste, and a mixture of aloe vera, mint, and cassia leaves.

#### ➤ Part 2:

Evaluation of odor and antimicrobial effects of the treated socks after six days of usage.

#### ➤ Part 3:

Comparison of the antimicrobial efficiency of socks treated with different natural antimicrobial agents before and after use.

### D. Antimicrobial Testing and Evaluation

The antimicrobial activity of the treated socks was evaluated using the ASTM E2149-01 standard test method,

which is commonly used to determine the antibacterial performance of textile materials. This method assesses the effectiveness of antimicrobial treatments against microorganisms under dynamic contact conditions.

#### ➤ The Main Steps of the ASTM E2149-01 Test Procedure are Summarized as Follows:

- The test microorganism is grown in a liquid culture medium.
- The concentration of the microorganism is standardized before testing.
- The microbial culture is diluted in a sterile buffer solution.
- The treated textile samples are exposed to the microbial suspension to evaluate their antimicrobial activity.

The odor intensity of socks treated with different natural antimicrobial agents was evaluated over a period of six days. The evaluation was carried out using the odor intensity scale described earlier, where lower values indicate less odor formation. The results of the odor evaluation for different treated samples are presented in Table 1.

Table 1 Odor Intensity Evaluation of Socks Treated with Different Natural Antimicrobial Agents During Six Days of Usage.

Antimicrobial Agent (50% concentration)	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Lemongrass	No change of smell	No change of smell	The smell is slightly Changed	Arising of bad smell	Intolerable smell	Intolerable smell
Mint	No change of smell	The smell is tolerable	Slightly significant change of smell	Arising of bad smell	Intolerable smell	Intolerable smell
Aloe vera	No change of smell	The smell is tolerable	Significant change of smell	Arising of bad smell	Intolerable smell	Intolerable smell
Tulsi	No change of smell	No change of smell	Slightly significant change of smell	Arising of bad smell	Intolerable smell	Intolerable smell
Cassia (Tejpata)	No change of smell	The smell is tolerable	The smell is slightly changed	Arising of bad smell	Intolerable smell	Intolerable smell
Neem	No change of smell	No change of smell	Slightly significant change of smell	Arising of bad smell	Intolerable smell	Intolerable smell
Mixture (Aloe Vera+Mint+Tej pata)	No change of smell	The smell is tolerable	Slightly significant change of smell	Arising of bad smell	Intolerable smell	Intolerable smell

- Note: Odor intensity values are based on the evaluation scale described in Table 2.

### III. RESULTS AND DISCUSSIONS

Under favourable conditions of humidity, heat, and nutrients (sweat and urea), bacteria can grow rapidly on human skin and on textiles. They convert sweat into sticky substances, such as acids, aldehydes, and amines, which can cause undesired diseases. *Escherichia coli* and *Pseudomonas aeruginosa* were obtained from the microbiology lab and applied to socks to perform the antimicrobial treatment properly.

#### A. Antibacterial Properties of Selected Natural Antimicrobial Agents

Neem leaves are among the most popular natural sources commonly used as antimicrobial agents due to their broad-spectrum activity and rapid killing rates against gram-positive and gram-negative bacteria. Mergosa Leaves (Neem) possess active antibacterial action against different bacterial pathogen strains. Mergosa Leaves (Neem) exhibit active antibacterial activity against various bacterial pathogens. In addition, the presence in Mergosa Leaves (Neem) of high concentrations of azadirachtin, quercetin, and  $\beta$ -sitosterol could be responsible for stronger antimicrobial, antibacterial, and antifungal activity than in bark and seed <sup>[15]</sup>.

Lemongrass (*Cymbopogon citratus*) bears antidepressant, antioxidant, antiseptic, sedative, nervine, bactericidal, and fungicidal properties. The LGO is effective as a bactericidal agent against several bacterial species,

including *Acinetobacter baumannii*, *Aeromonas veronii*, *Enterococcus faecalis*, *Escherichia coli*, *Klebsiella pneumoniae*, *Salmonella enterica*, *Serratia marcescens*, *Proteus vulgaris*, *Enterobacter aerogenes*, *Corynebacterium equi*, *Staphylococcus aureus*, and so on <sup>[16-18]</sup>.

Similarly, Tulshi demonstrated antimicrobial resistance to *S. Aureus* (including MRSA) and *E. coli*, but was less successful against *P. aeruginosa* [19]. *P. aeruginosa* refers to antimicrobial compounds [19]. Extracts of tulsi demonstrated antimicrobial activity against the Gram-positive bacteria *S. aureus* and the Gram-negative bacteria *E. coli*, as well as the fungus *A. albicans* <sup>[19]</sup>.

Aloe vera is a spiky, green plant that has been used by Egyptians and other civilizations for thousands of years to treat various diseases, and for good reason: it provides powerful antiseptics that can destroy bacteria and viruses <sup>[20]</sup>. The extract of Cassia Leaves was effective against *B. cereus*, *S. aureus*, *S. epidermidis*, *E. coli*, and *K. pneumonia* <sup>[21]</sup>. Similarly, Mint contains antimicrobial agents that are effective against bacteria and viruses, helping reduce odor.

#### B. Antimicrobial Treatment of Socks Using Natural Plant Extracts

The antimicrobial activity of socks treated with different natural plant extracts was evaluated by comparing treated (unused) samples with used samples after testing. The treated specimens showed lower microbial growth than the untreated specimens, indicating that the applied natural extracts exerted antibacterial effects. Fig.4.–Fig.10. illustrate the comparison between treated and used samples for socks treated with different natural antimicrobial agents.

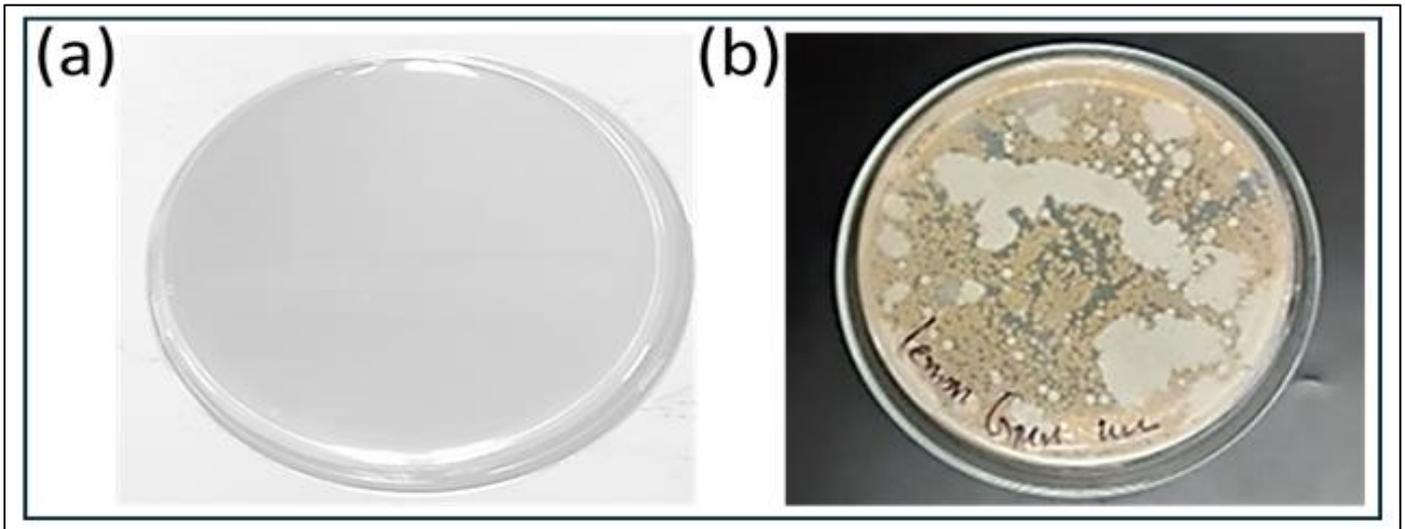


Fig 4 Lemongrass-Treated Sock Samples: (a) Treated/Unused Specimen, (b) Used Specimen After Testing.

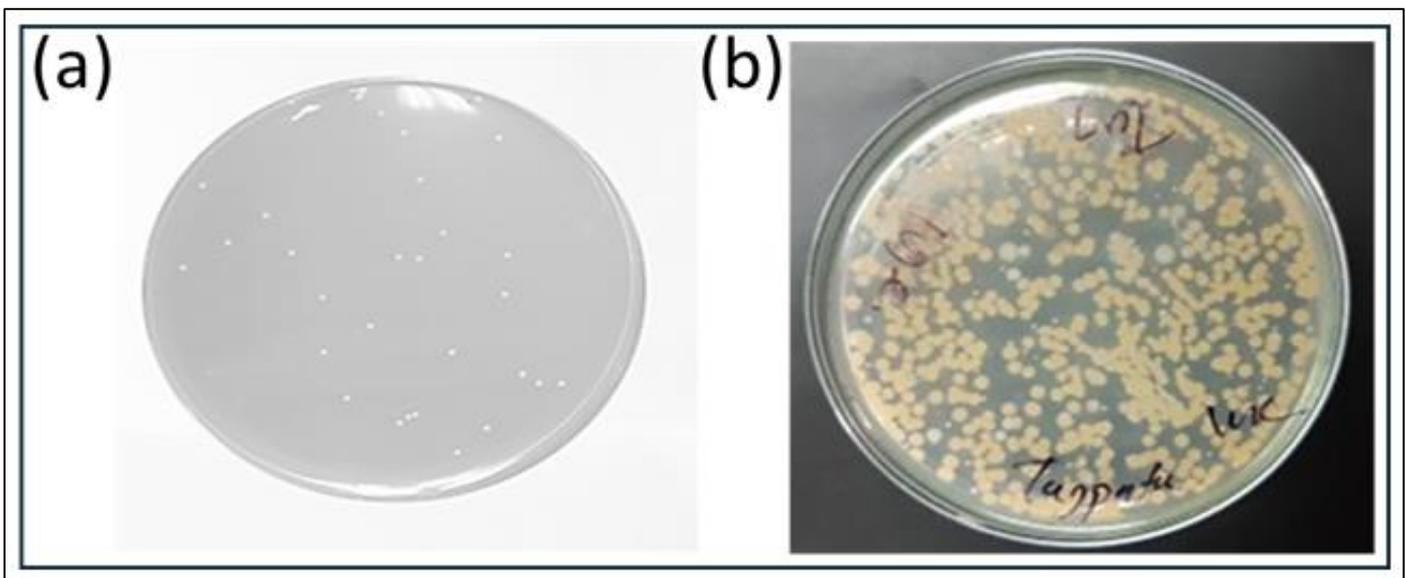


Fig 5 Cassia Leaf (Tejpata) Treated Sock Samples: (a) Treated/Unused Specimen, (b) Used Specimen After Testing.

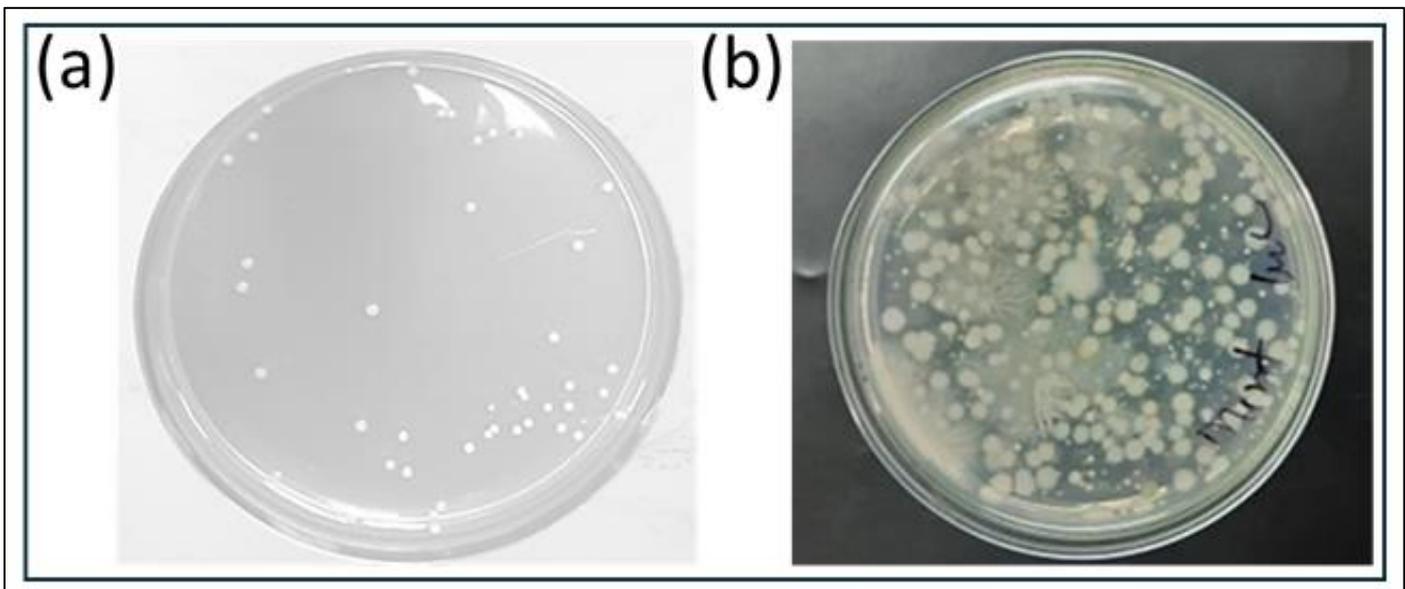


Fig 6 Mint-Treated Sock Samples: (a) Treated/Unused Specimen, (b) Used Specimen After Testing.

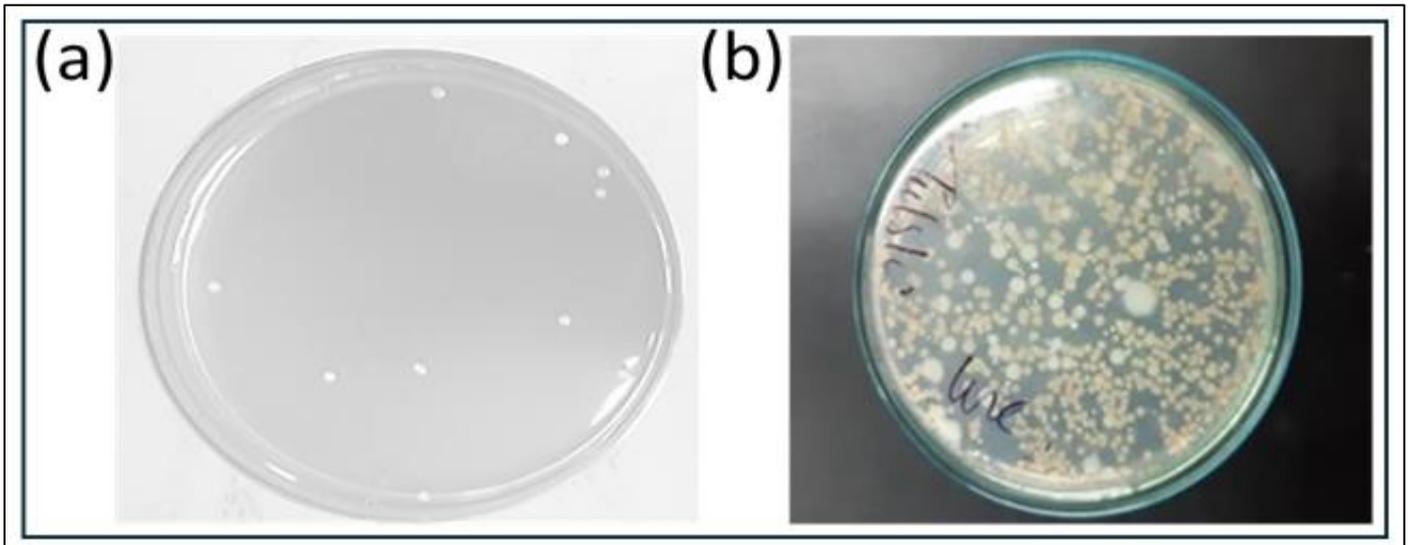


Fig 7 Holy Basil (Tulsi) Treated Sock Samples: (a) Treated/Unused Specimen, (b) Used Specimen After Testing.

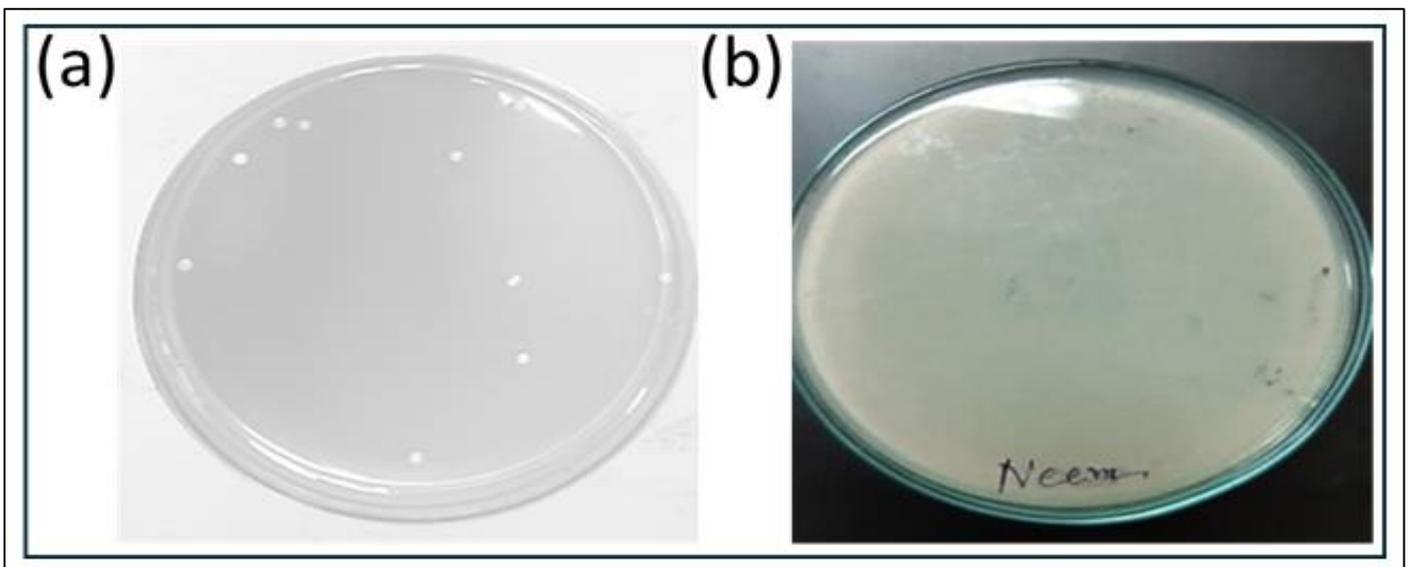


Fig 8 Neem (Margosa) Leaf Extract-Treated Sock Samples: (a) Treated/Unused Specimen, (b) Used Specimen.

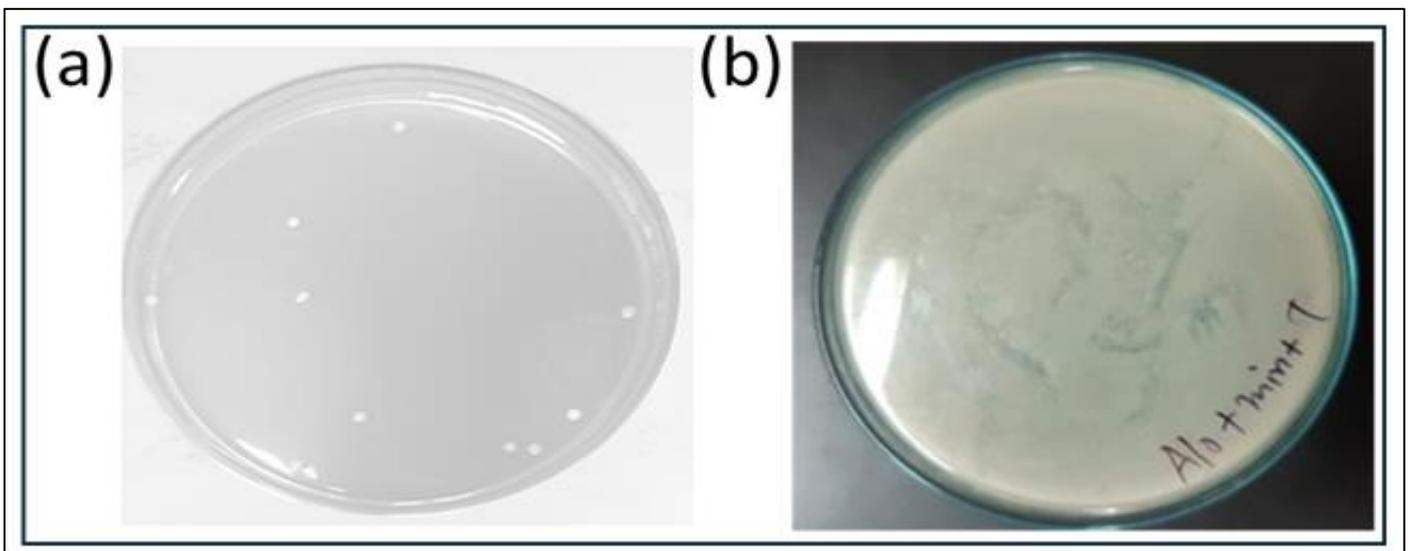


Fig 9 Mixture-Treated Sock Samples (Aloe Vera + Mint + Cassia): (a) Treated/Unused Specimen, (b) Used Specimen After Testing.

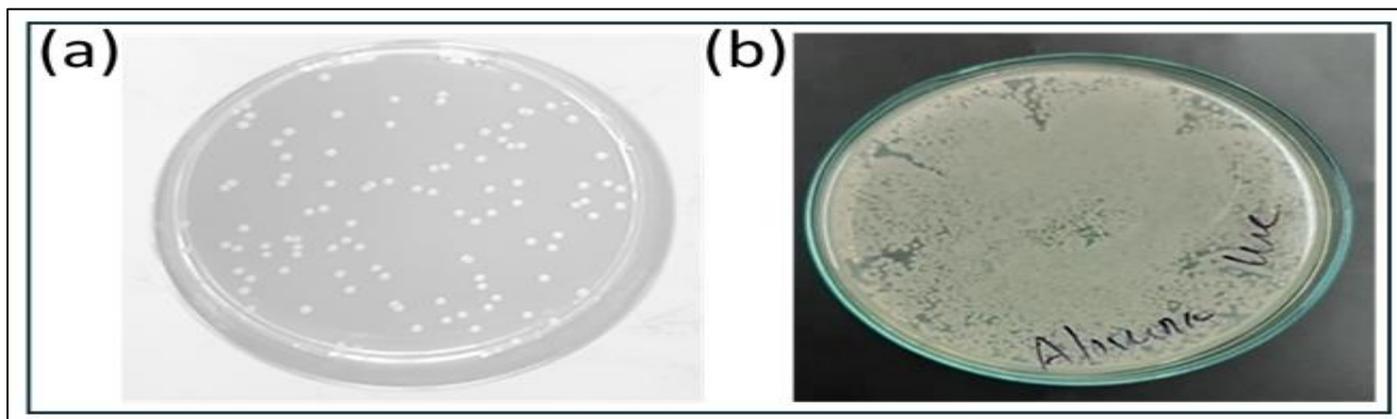


Fig 10 Aloe Vera-Treated Sock Samples: (a) Treated/Unused Specimen, (b) Used Specimen After Testing.

The comparison indicates that the treated samples exhibited greater resistance to microbial growth than the untreated samples, demonstrating the effectiveness of the natural antimicrobial agents applied to the socks.

*C. Evaluation of Odor and Antimicrobial Performance After Six Days of Use*

The odor and antimicrobial performance of the treated socks were evaluated after 6 days of continuous use. The evaluation was conducted by observing changes in odor intensity resulting from microbial activity. A numerical scale was used to classify odor levels from undetectable to intolerable. The scale used for the odor evaluation is presented in Table 2.

Table 2 Odor Evaluation Scale used to Assess Antimicrobial Performance of Treated Socks.

Odor Observation	Scale Value
No change of smell	0
Slightly significant change of smell	1
The smell is tolerable	2
Significant change of smell	3
Arising of bad smell	4
Intolerable smell	5

Fig.11. shows the variation in odor intensity of socks treated with different natural antimicrobial agents over 6 days. On the first day, no noticeable odor was observed for any treated samples. However, the odor intensity gradually

increased with time due to microbial activity. Among the tested agents, lemongrass and neem extracts showed comparatively slower odor development, indicating better antimicrobial performance than the other treatments.

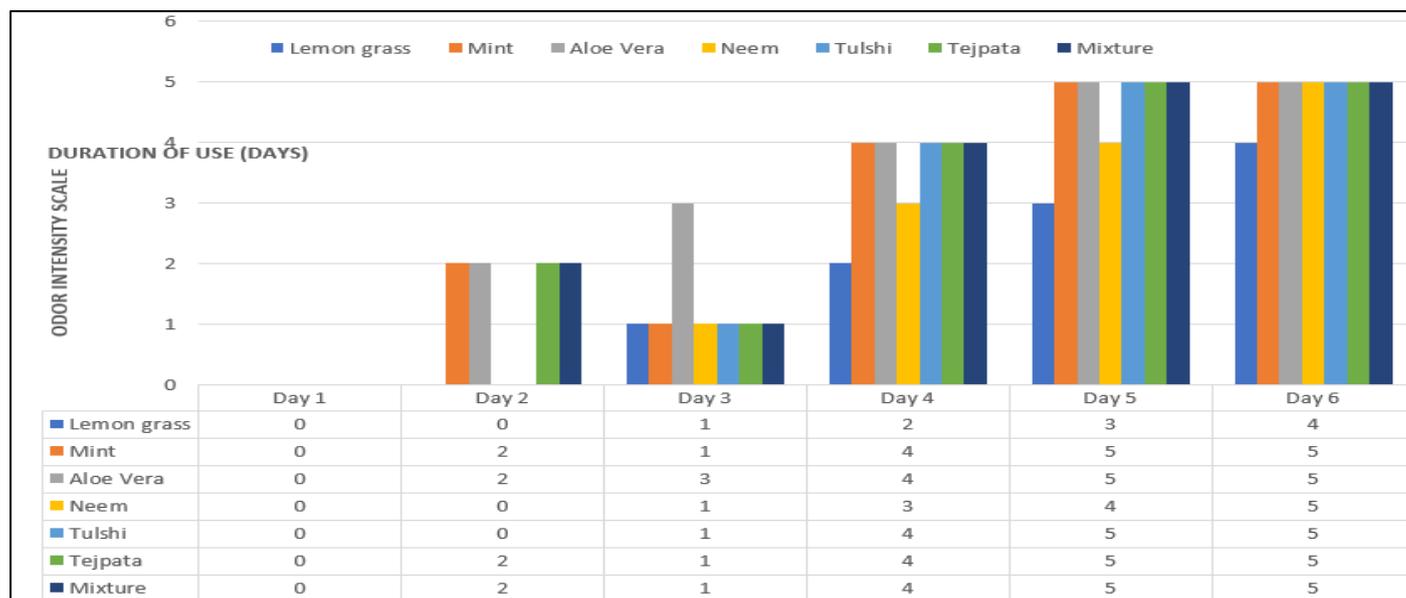


Fig 11 Change in Odor Intensity of Socks Treated with Different Natural Antimicrobial Agents Over Six Days of Use.

The results indicate that the odor intensity increased gradually with the duration of sock usage due to microbial growth under warm and humid conditions. Among the tested natural antimicrobial agents, neem and lemongrass treated socks showed comparatively lower odor intensity values during the initial days of use. This suggests that these plant extracts possess stronger antimicrobial activity compared with the other natural agents used in this study. The mixture of aloe vera, mint and cassia also demonstrated moderate antimicrobial performance.

#### IV. CONCLUSIONS

The antibacterial finish of Socks was done by using Lemongrass Paste, Mint Paste, Aloe Vera Gel Paste, Holy Basil (Tulshi) Paste, Liquor of Cassia Leaves, Margosa Leaves (Neem) Paste, and a Mixture of Aloe Vera, Mint & Cassia Leaves (Tejpata).

These agents are highly effective against the microorganisms, as expected. These natural antimicrobial agents have been selected for their medicinal value, ease of availability in the surroundings, and other properties, such as antioxidant activity and UV ray resistance. The reason is that socks are mostly affected by coccus species bacteria and sometimes by Pseudomonas. These agents are collected from nature and from our surroundings. So, the cost of the antimicrobial agents is not so much. From the results, it can be concluded that although the antimicrobial-treated socks inhibit bacterial growth, the inhibition is low. This is associated with a low concentration of all the agents listed below, which were found to be inhibitory in the study. With the appropriate use of the appropriate concentration of all the antimicrobial agents, it is possible to enhance the antibacterial property of the treated cotton fabrics beyond what has been obtained in this study. Thus, with the availability of an appropriate selection of antimicrobial agents, proper technology for the extraction of these natural ingredients, and appropriate testing facilities, it is commercially viable to produce antibacterial socks and other fabrics for the betterment of health and the environment from these blessed agents.

This research will enhance knowledge of the use of natural products as antibacterial agents, which is still in its early stages. Further studies are required to meet this target.

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