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Experimentation of Anti-microbial and Mechanical Properties of Cotton Fabric Treated with Aloe Vera Gel, Basil Leaf Extract and Silver Nitrate Nanoparticles

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ABSTRACT
The textile finishing and processing sector uses a lot of chemicals and releases dangerous elements into the environment. Natural materials, plant components, and plant extracts that can be used to finish textile materials are given top priority in the sustainable concept. They are motivated by a desire for comfort and environmental protection. Single jersey cotton fabrics were finished using Basil extracts and Aloe Vera gel combined with acrylic binder and also from the in situ synthesis of silver nitrate by pad-dry-cure method. The antimicrobial activities of Aloe Vera gel, Basil extract and Silver nanoparticles (AgNPs) were evaluated against Gram positive bacteria (*Staphylococcus aureus*) and Gram negative bacteria (*Escherichia coli*). The appearance of zones of inhibition was used to evaluate the antimicrobial effect. Antimicrobial test showed that Aloe Vera, Basil, and AgNPs inhibited the growth of *S. aureus* (9.0 mm, 7.0 mm and 9.0 mm) respectively and *E. Coli* (0.02 mm, 1.0 mm and 4 mm) respectively. To evaluate the mechanical properties of the treated fabrics, tensile strength and elongation at break tests were done. To confirm the physiochemical qualities of the AgNPs treated sample, a Fourier-Transform Infrared Spectroscopy (FTIR) investigation test was performed. This antimicrobial-treated cloth has a wide range of applications in the medical and modern textile field.

Keywords: Anti-microbial, In situ Synthesis, Mechanical, Nanoparticles, Sustainable.

1. Introduction

Due to the ongoing pollution explosion and the deteriorating environmental pollution, new strategies are essential to improve the health and hygiene qualities of consumer products. Cotton goods are extensively used because of their extraordinary qualities, such as softness, skin-friendliness, hygroscopicity, biodegradation, and regeneration properties [1]. Despite having countless uses, it is important to note that cotton offers the nutrients, moisture, and the appropriate temperature required for the development and spread of pathogenic and odor-producing microorganisms. The development of microorganisms on textiles results in the production of an unpleasant odor, stains and discoloration in the fabric, a decrease in the mechanical strength of the fabric, and a higher probability of contamination. The growth of microbes on textiles should be kept to a minimum during use and storage for the reasons listed above. A fairly large market for antimicrobial textile products has been created by consumers' demand for hygienic activewear and clothing.

It's interesting to note that the World Health Organization estimates that 80% of the global population, primarily in developing nations, still relies on medicinal plants and their extracts for primary healthcare. Plant-based natural antimicrobials have been known for centuries, but they have only recently been scientifically proven. Due to their outstanding antibacterial qualities, natural herbal plant extracts have been studied for use as antibacterial finishing in textiles. These natural antibacterial agents can be used as an antibacterial finish because they are less harmful, irritating, and biodegradable. A monocotyledonous plant, Aloe Vera belongs to the *Liliaceae* family. About 99% of Aloe Vera gel is made up of water, and the remaining 1% is made up of a variety of solid ingredients. The Aloe vera plant has potent anti-inflammatory, antibacterial, and wound- and burn-healing properties. In [2], the authors investigate the antimicrobial effects of *Aloe barbadensis miller* (Aloe vera) on a number of human pathogens, including *Candida albicans*, *Staphylococcus aureus*, and *Escherichia coli* and the aims were to identify the antimicrobial properties of Aloe vera gel and to identify which test microorganisms were most sensitive to the plant extract. The author in [3] conducted research on the phytochemical composition, antioxidant properties, and antibacterial properties of Aloe vera leaf gel extracts made from 95% ethanol and lyophilized leaf gel (LGE). *Ocimum basilicum* L. is known as basil in English, while the French, German, and Spanish names for the plant are basilic, basilikum, and albaca, respectively. It was referred to as the herb of kings by the ancient Gree ks. Basil's anti-cancer, radioprotective, anti-microbial, and anti-inflammatory properties are among its most significant pharmaceutical uses [4]. The combined effect of basil with clove, neem, and karanga to significantly raise the antibacterial activity has been reported in [5]. Authors in [6] has conducted a comparative study of natural and synthetic antimicrobial agents, reporting on the effects of basil as an antibacterial agent on diapers and comparing the effect with synthetic antibacterial agents such as AgNPs, ZnNPs, and TiO_2 powder, concluding that the natural agents have comparable activity to synthetic agents.

The market for medical and healthcare textiles has grown significantly since the discovery of antimicrobial inorganic nanomaterial and their use in the textile industry. By using physical, chemical, or biological

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methods, nanoparticles can be created. While both chemical and physical methods require the use of hazardous reductants or have high energy requirements, the biological method of synthesizing nanoparticles, also known as the "green synthesis approach," has attracted a lot of attention recently. Silver nanoparticles (AgNPs) are particularly fascinating for biomedical applications due to their well-known antimicrobial and anticancer properties. Scientists working on textiles and polymers have created various ex situ and in situ techniques to create and use silver nanoparticles for textile treatments [7]. Using Aloe Vera gel as a reducing and stabilizing agent for nanoparticle formation, the authors in [8] created AgNPs. These AgNPs demonstrated improved anti-bacterial properties against gram positive and gram negative bacteria. The anti-bacterial activity of the nanocomposite cotton fabrics was examined where in situ generated AgNPs, CuNPs, and bimetallic (Ag/Cu) nanoparticles has been employed in cotton fabric using Aloe vera leaf extract as a reducing agent [9].

In this paper, aloe vera gel and basil leaves-two organic ingredients-were extracted and applied to a cotton knit fabric to evaluate the antimicrobial activity. Aloe vera reduction bath was used for the in-situ synthesis of AgNPs from $AgNO_3$ in cotton. The conventional reduction process can be replaced by a green synthesis utilizing aloe vera to address the sustainability issue. While reporting the functionalization of cotton with AgNPs in numerous pieces of literature, the examination of mechanical properties was neglected. This paper analyzed the finished fabrics' mechanical characteristics in terms of their tensile strength and elongation at break.

2. Materials and Methods

2.1 Materials

100% Cotton Single Jersey bleached fabric of 160 GSM is used for the antimicrobial finishing and testing. Fabric was first treated with wetting and sequestering agent for better absorption and penetration of finishing materials. For anti-microbial finishing, Basil Leaf, Aloe Vera gel were applied along with acrylic binder and Ethanol. In situ synthesis of Silver Nitrate was done and for green synthesis, Aloe Vera gel was used as reducing agent. Fig. 1 provides an outline of the entire procedure.

2.2 Preparation of fabric sample with Basil Leaves Extraction

50 g of Basil leaves were picked freshly from the nature, rinsed thoroughly with distilled water, chopped finely with a ceramic mortar pestle and turned into a paste. Pressing was applied in the paste and Whatman No. 1 filter paper was used for the filtration process to separate the basil leaf extract. Fabric to basil leaf extract ratio 10:6 was taken. For 13 g of fabric, 7.8 ml of basil extract, 7.8 ml of acrylic binder and 84.4 ml of distilled water were taken to a beaker and rigorous stirring was done until an even mixture found. Afterward 13 g of fabric was immersed in the even solution using a glass rod for 15 minutes and then padded with a padding mangle. The sample was taken into oven and dried for 5 minutes at 80^0C and lastly curing was done at 150^0C for 1 minute.

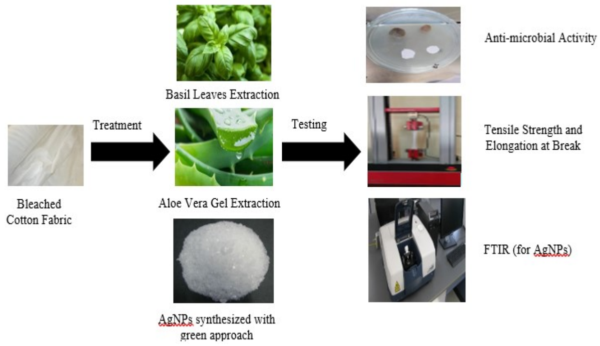


Fig.1 Schematic Representation of the anti-microbial finishing and testing process

2.3 Preparation of fabric sample with Aloe Vera gel Extraction

Collected from the nature, Aloe Vera leaves were rinsed thoroughly and gel was taken out from the leaves using knife. 150 ml of Aloe Vera gel was stirred at 1000 rpm for 30 minutes and taken to the Soxhlet extraction machine. For over a century, Soxhlet machine has been a standard analytical practice, and it is inarguably the most widely used and accepted technique for separating semi volatile organic compounds from solid samples [10]. Ethanol was taken as an extraction solvent in the distillation flask of the machine and the amount of Ethanol was 200 ml. The machine was run at 100^0C for 120 minutes, the extraction was collected and filtered using Whatman No. 1 filter paper. Ethanol was removed from the extraction by exposing it to open air as it is highly volatile. Following previous basil leaf extraction process, Fabric to Aloe Vera extract ratio 10:6 was taken. 16 g of fabric was taken and immersed with 9.6 ml of Aloe Vera extract, 9.6 ml of acrylic binder and 80.2 ml of distilled water solution. Padding, drying and curing were done with the same process.

2.4 Preparation of fabric sample with *in situ* synthesis of Silver Nanoparticles

0.225 mol/L AgNO3 solution was prepared first. The fabric was immersed in water at 80^0C for 30 minutes for hydroxyl group activation and then squeezed to extract extra water from the fabric. Afterward the fabric was treated with AgNO3 solution for 35 minutes at 60^0C with liquor-to-fabric ratio of 30:1 (v/w) which allows the Ag^+ to be absorbed and spread on the cotton fabric and again squeezed to extract extra solution. The treated fabric was finally treated with previously extracted Aloe Vera gel reduction bath for 35 minutes at room temperature maintaining a liquor-to-fabric ratio of 15:1 (v/w) and pH was kept at 7-8 by using NaOH. The fabric sample was then washed with detergent and dried.

2.5 Evaluation of Anti-microbial activity using Agar Diffusion method

In the agar diffusion method, bacterial and fungal isolates (*Staphylococcus aureus, Escherichia coli*) were cultured in newly made nutrient agar slants after being maintained on agar slants stocks. The pathogenic strains were adjusted to 10^7 CFU/ml by adding aseptic DW and 100 µl of the particular tested pathogen was inoculated on the surface of the nutrient agar plate. The pathogenic strains were grown in nutrient broth for 24 hours at 37^0C. Fabric samples were laid over the nutrient agar plate in intimate contact and incubated for 24 hours at 37^0C. Uninoculated nutrient broth (NB) was placed in one well as a control. The plates were examined for the bacterial growth underneath the fabric samples and immediately around the fabric edges (zone of inhibition). The clear zones diameter was measured and the diameter of the observed inhibition zones was photographed.

2.6 Mechanical Properties of treated fabrics

According to British Standards (BS 6F 100:1998), the tensile strength and elongation at break were measured using a Universal Tensile Strength Tester (M350-5 CT Testometric, UK). The samples were cut into 200mm×50 mm swatches and were held in place by the top and bottom jaws. It was equipped with cell load of 500 kg and a constant rate of extension (CRE) of 400 mm/min. A total of 5 samples were evaluated and mean value of the samples are recorded.

2.7 Finish Durability to Washing

The finished fabric samples were hand washed with detergent. Persoclean STN (Origin: Taiwan) was used for washing the samples which was nonionic detergent. The samples were washed using 2 g/L detergent with 60:1 liquor ratio in room temperature and dried for 60 minutes at 60^0C. The antimicrobial effect was evaluated using the above-mentioned procedure after 5 wash cycles.

2.8 Characterization of Silver Nanoparticles

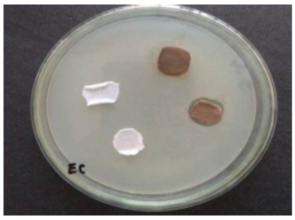
The alteration in color served as visual confirmation that AgNPs were produced through the green synthesis method using Aloe vera leaf extract. Using a Fourier Transform Infrared Spectrophotometer (FTIR Spectrum 2000, Perkin Elmer, USA), chemical compositions of the *in situ* synthesized AgNPs in the 4000-500 cm^{-1} spectral range were examined.

3. Results and Discussion

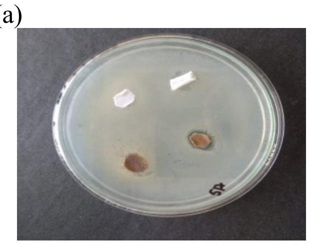
3.1 Anti-microbial Activity

Against gram positive bacteria *Staphylococcus aureus* and gram negative bacteria *Escherichia coli*, the anti-microbial activity of basil, Aloe vera, and AgNPs treated fabric and fresh fabric (without treatment) was examined without washing and after washing. Three agar media plates were prepared. In plate no. (a), *S. Aureus* bacteria was used for unwashed basil, Aloe vera and silver nanoparticles treated samples. The diameter of the zones of inhibition around the disk were 7 mm, 9 mm and 9 mm respectively. In plate no. (b), *E. Coli* bacteria was used for the unwashed treated samples in the similar way. The diameter of the zones of inhibition were 1 mm, 0.02 mm and 4 mm respectively. There was no inhibition zone against either bacterium on the untreated, fresh fabric. It is evident that the treated fabric has developed a significant amount of antimicrobial properties shown in Fig.3. AgNPs and basil treated fabric demonstrated maximum and some anti-microbial activity against both bacteria respectively. The anti-microbial activity of fabric treated with aloe vera was highest when *S. aureus* was present, but it was least effective when *E. coli* was present. Compared to other bacteria, *S. Aureus* has a simpler wall structure. *E. Coli* has a three-layer cell wall that includes a barrier-forming peptydoglycan, lipoprotein, and outer membrane. The sensitivity of Aloe vera gel to gram-positive and gram-negative bacteria varies as a result of this structural difference [11].

(a)



(b)



(c)

Fig.2 Anti-microbial activity of (a) unwashed treated samples against *S. Aureus* (b) Unwashed treated samples against *E. Coli* and (c) Washed treated samples against *S. Aureus*

Additionally, evaluated was the antibacterial activity's resilience to repeated washings. In plate no. (c), *S. Aureus* bacteria was used for 5 times washed basil, Aloe vera and silver nanoparticles treated samples. The zones of inhibition around the disk were 2mm, 3mm and 4mm respectively. The findings unmistakably show that subsequent washing has a negative impact on anti-microbial property. However, the finished fabric still exhibited significant antimicrobial activity demonstrated in Fig.3. The permanency of the finish is anticipated to be enhanced by the proper use of a binder or cross-liking agents.

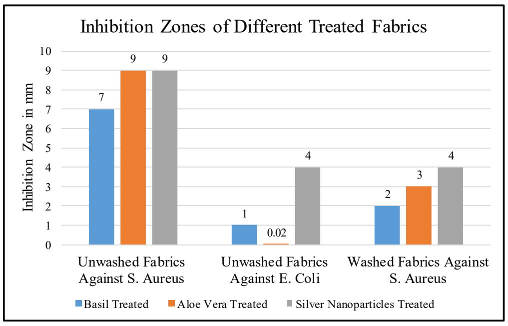


Fig.3 Graphical representation of the inhibition zone against *S. Aureus* and *E. Coli* of basil, Aloe vera and AgNPs treated fabrics before and after wash

3.2 Effect of Mechanical Properties

3.2.1 Tensile strength

A reduction in tensile strength is visible in Fig.4 after 5 samples of treated fabrics were taken to assess the mean tensile strength. The thickening of the molecular backbone during cross-link formation is the primary cause of the strength reduction. Basil causes a strength loss of around 7.44%, aloe vera treatment causes a strength loss of about 5.84%, whereas silver nanoparticle treatment causes a strength loss of about 3.48% compared to untreated fabric. Basil results in the highest loss of strength, whereas silver nanoparticle-treated fabric loses strength the least. This may be because AgNPs fall within the nano range in size, they can easily pierce the fabric's polymer structure and are therefore likely to be used as a crosslinking or filler ingredient. While applying the load to the fabric, this phenomenon helps with load sharing as well which results in less strength loss [12]. When it comes to functional textiles, a percentage loss of nearly 15% is acceptable, but any larger percentage could result in the degradation of the textile's structure [13].

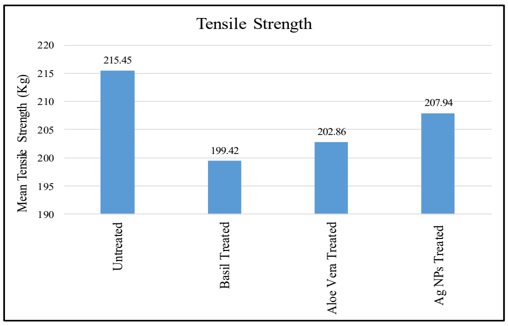


Fig.4 Effect of mean tensile strength on treated fabrics

3.2.2 Elongation at break

Fig. 5 shows an increase in elongation at break following the evaluation of the mean elongation at break using 5 samples of treated textiles. AgNPs-treated fabric exhibits the least amount of breaking elongation of 123.849 mm, whereas Basil-treated fabric exhibits the greatest breaking elongation of 126.1898 mm. The action of the linkages between the molecular chains of the fibers may, however, be used to explain the elongation enhancement for the treated fabrics in the interim [12].

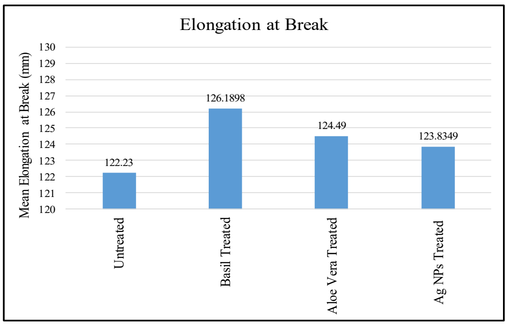


Fig.5 Effect of mean Elongation at break on treated fabrics

3.3 Fourier Transform Infrared (FTIR) Spectroscopy analysis of AgNPs

Fig.6 displays the findings from the FTIR analysis. FTIR spectrum shows peak shifts with intense absorption bands at 550, 1085, 1600, 2330, 2870, 3385 and 3720 cm^{-1}. The peak at 3720 cm^{-1} indicates the presence of O-H stretching while 3385 cm^{-1} corresponds to the presence of N-H stretching of aliphatic primary amine. The peaks of 2870 cm^{-1} ascertain the presence of C-H stretching and 2330 cm^{-1} of O=C=O stretching. Again, the peaks of 1600 cm^{-1} indicate the presence of C=O stretching, 1085 cm^{-1} of C-O stretching and 550 cm^{-1} of C-I stretching of halo compound. It is confirmed that the Aloe vera extract reduces and stabilizes silver nitrate due to the presence of numerous functional groups in the FTIR analysis.

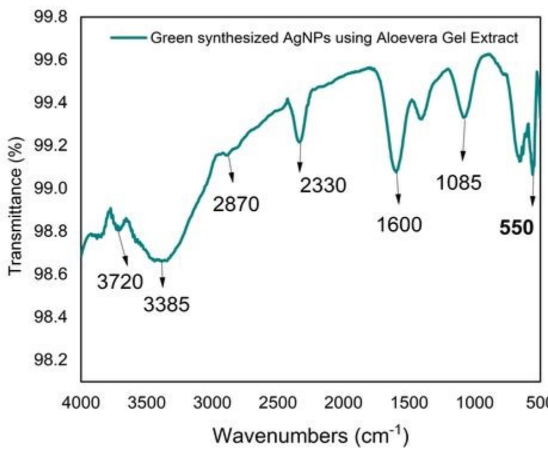


Fig.6 Spectrum of FTIR analysis of AgNPs treated fabric

4. Conclusion

Cotton fabric was treated with Basil leaves extract, Aloe Vera gel extract and AgNPs successfully and shown enhanced anti-microbial activity against *S. Aureus* and *E. Coli* bacteria. Antimicrobial tests revealed that S. aureus (with a growth rate of 9.0 mm, 7.0 mm, and 9.0 mm, respectively) and E. coli (with a growth rate of 0.02 mm, 1.0 mm, and 4 mm, respectively) were inhibited by Aloe Vera, Basil, and AgNPs. The presence of AgNPs was verified by FTIR spectrum analysis during the green synthesis of $AgNO_3$ using the reducing and stabilizing properties of Aloe Vera gel. This paper reports a decrease in tensile strength for fabrics treated with basil, aloe vera, and AgNPs, with values of 7.44%, 5.84%, and 3.48%, respectively. In addition, a rise in elongation at break is noted. The results of this study may contribute to the development of bacterial and eco-friendly textile products, as well as improve the necessary characteristics of clothing and textiles for medical use without compromising comfort.

5. Acknowledgement

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6. References

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