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Research Article

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Development of Antibacterial Cotton Fabric by Application of Fruit and Vegetable Peel Extracts - A Sustainable Approach

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ABSTRACT
The objective of this study is to assess the effect of Solanum incanum fruit (SIFE) and red onion peel (ROPE) extracts treatments on cotton fabric properties. The two factor factorial design was used, the first factor is concentration of the methanolic extract with two levels (3 g/l and 5 g/l) and the second is combination of extracts (25:75 SIFE: ROPE; 50:50 SIFE: ROPE; 75:25 SIFE: ROPE, 100% SIFE, 100% ROPE). Each extract was applied separately and in combination of different proportions on cotton fabric by the pad-dry-cure method using citric acid as a cross-linking agent. After treatment, the physical properties antimicrobial, wash durability and structual properties were determined. Air permeability, water absorbency and tensile strength were decreased for the treated fiber compared with control. Among all treatments, the cotton fabric treated with 50:50 combination was found best in bacterial reduction. This study concluded that, the natural source can sucessfully replace with synthetic chemicals.

Keywords: Antibacterial Activity, Red Onion Peel Extract, Physical Properties, Solanum Incanum Fruit Extract

Introduction

In the hierarchy of human needs, clothing ranks the second priority next to food. The use of textiles for clothing known to humankind from primitive age and gradually extended to household and domestic applications with progressive civilizations [1]. Clothing is an interactive barrier and ensuring thermal balance despite changes in ambient temperature and humidity, metabolic heat production [2]. Since clothing is the second skin of human beings and always touches with the skin, researchers reported that clothing serves as a medium to facilitate the growth of microorganisms such as bacteria and fungi [3-6]. Suitable conditions such as the right temperature, moisture, dust, and receptive surface offers conducive environments for microorganism's growth on the fabric surface [7,8]. In favorable conditions, bacteria and fungi can easily propagate within very short spam. These microorganisms easily obtain sufficient nutrients through perspiration and different body secretions, skin particles, and fats. Although, some of the normal microbial flora can be beneficial; however, they are also seriously unsafe for both the fabrics and humans. In general, the growth of microbes on the textile leads to various problems such as unpleasant odor, degradation of the fabric by the possible loss of functional properties like elasticity and tensile strengths and other aesthetic changes such as stain formation, discolorations [9-12]. Such kind of defects in cloths also causes allergic problems, skin infections, toxic responses, skin irritations for the wearer [13]. For instance, bacteria such as Staphylococcus aureus growth on the inner wares cause odor, Escherichia coli causes odor and ulcers on the skins and fungi like Aspergillus niger cause skin infections and decolorizes the cloths [14]. To overcome this problem, scientists are searching for antimicrobial agents that can help to mitigate the microbial problems in the textiles [15]. Antimicrobial agents destroys or suppresses the growth of microorganisms and their negative effect on the fabrics. Nowadays, researchers paid much attention to the development of antimicrobial agents from natural sources over synthetic antimicrobial agents. Since synthetic antimicrobial agents possess strong biocidal activity towards the non-target microorganisms and potential water pollution [16]. Due to the strict environmental protection regulations enforced by the governmental agencies scientists are concentrated on the development of eco-friendly antimicrobial textile finishers prepared from plant extracts, essential oils, and other natural products [17].

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Plants are rich source of aromatic substances, most are phenols or their oxygen substituted derivatives. The active constituents present in the plant used as plant defense mechanisms against the predation of different pathogenic microorganisms, insects, and herbivores. Soodinvestigated the application of herbal extracts on the fabric used for sanitary napkins by a pad-dry-cure method for antibacterial nature [18]. The results revealed that the methanolic extract of Bauhinia veriagata was showed an inhibition effect on S. aureus and Pseudomonas spp. However, the aqueous extract did not show any activity against the tested bacteria. The antimicrobial activity of the plant extract depends on the type of the active components present in the plant and their concentrations [19]. Today, numerous herbs and plant parts were extracted and studied for antimicrobial activity in textile coatings. Among the numerous natural herbs and vegetables, Solanum incanum and red onion peels are the sources of antimicrobial agents used in the present study. Solanum incanum L. belongs to the Solanaceae family and most important traditional medicinal plant in Ethiopia [20]. S. incanum is a small herb that grows like a weed characterized by thorny leaves, yellow fruits, and blue flowers with yellow pistils, widely distributed in the Horn of Africa. Onion (Allium cepa L) is a common food plant rich in several phytonutrients associated with the treatment and prevention of several diseases [21]. Allium cepa commonly known as onion belongs to the family of Alliaceae and is grown in every part of the world, depends on the growing condition and the location onion exhibit great diversity in color, shape, dry matter content, and pungency [22]. Many researchers concentrated on the technical details of applying individual natural agents, such as neem extract, chitosan, S. incanum fruit, Seabuckthorn leaf, and aloe vera on the textile [23,24]. On the other hand, no study has been undertaken to investigate the combined antimicrobial effect of S. incanum and red onion peel extract on cotton fabric. So, the major objective of the present study is to determine the effect of different concentrations, combinations of the S. incanum and red onion peel extract on physical properties and antimicrobial activities against S. aureus and E. coli.

Physical Properties of Treated Cotton Fabric

Analysis of variance showed that the concentration of extract and ratio of SIFE and ROPE is highly significant ($p < 0.01$) on water absorbency. The water absorbency in all the treatments was ranged from 4 to 18 s. As the amount of ROPE increased in the treatment, the water repellency also increased. This could be due to the hydrophobic nature of the extracts, which forms a thin coating of film on the surface of the fabric. This trend showed that the hydrophobic nature of the ROPE is greater than the SIFE. Hence, the fabric treated with ROPE showed greater water absorbency time as compared with SIFE. In general, as compared with the untreated fabric the absorbency values were not altered much after treatments. The results of the present study are aligned with previous reports as 7.75 s 26 s, and 7.6 s [25-27]. A significant difference ($p < 0.05$) was observed in weight add on percentage. The weight add-on percentage range of 2.09-9.44% was observed in the study. This study observed that, significant differences between fabrics treated with only SIFE and ROPE also significantly different with the fabric treated with different ratios of SIFE and ROPE. The weight add-on percentage increased as the concentration of extracts increased, since more extract was attached to the fabric during the finishing process. The weight gain percentage of the combination of the extracts were higher than the pure extract, this may be the degree of extracts affinity towards the fabric, difference between the two extracts. In the case of the weight add-on percentage of the fabric treated with a single extract, the fabric finished with only ROPE had reported a better weight gain percentage than SIFE at the same concentration. This is maybe due to the high affinity of red onion peel extract to the cotton fabric. The present finding is in agreement with Mondal and Saha, reported that weight add-on percentage increased with an increase in the concentration of chitosan and aloe vera extracts. The present finding also supported by Sood, reported that the application of different herbal extract on the cotton identified the increase in weight gain percentage [28]. Analysis of variance showed that the concentration of extract and the ratio of SIFE: ROPE are highly significantly ($p < 0.01$) effected on the air permeability of the treated fiber. The range of the 37.85–46.67 cm3 /cm2 /s air permeability was observed in all the treated samples in this study. The air permeability was decreased as the amount of ROPE increased in both the tested concentration. This may be due to the increase in the fabric thickness due to the methanolic extract application. The maximum air permeability was observed for the fabric treated with 100% SIFE at 3 g/l concentration. This trend may be due to the better affinity of ROPE towards the fabric than SIFE and the coating layer thickness was may be thicker in the case of ROPE treated fabric compared to SIFE treated fabrics. The result of the present study is similar to the finding of El-Shafei et al. and Mondal and Saha, they reported that by the application of herb extract on the fabric surface does not significantly alter the air permeability [28]. This also can be evident from this study by observing the air permeability (46.667 cm3 /cm2 /s) values of untreated fabric, which are similar to the treated samples. The weight loss of treated fabric showed a highly significant difference ($p < 0.05$) as SIFE concentration increased from 25% to 75%. The range of weight loss reported in this study was 7.54–15.72%. The results showed that the maximum weight loss due to the soil degradation was reported in untreated fabric, this is attributed to the microorganisms in the soil attacked on the untreated cotton fabric quickly, due to the no application of any extarct [29]. On the other hand, weight loss of the fabric treated with 100% ROPE and SIFE was 15.98% and 15.72%, respectively. Thus, SIFE had the strongest antibacterial effect in the underground test. Thilagavathi et al., reported the development of eco-friendly antimicrobial textile finishes using herbs, with both the antimicrobial and less biodegradable nature of the fabric is possible by plant extracts. Although, the treated samples showed soil degradation moderately, so they are environmental friendly. The findings of the present study are comparable with the finding of Mondal and Saha [30]. A significant difference ($p < 0.05$) was observed in the bending length in which the fabric was treated with the different ratios of SIFE and ROPE. However, the concentration of the extract and the interaction between the ratio and concentration are not significant. Data obtained show that there is a maximum of 4.76% change in the bending length of the fabric treated by onion peel extract at 5 g/l concentration as compared to the untreated, and bending length is directly related to the flexural rigidity of the fabric. This trend is observed due to the presence of a cross-linking agent. Without a cross-linking agent, under stress, the hydrogen bonds between adjacent cellulose chains can break and allows the chains to slip each other [31]. However, after cross-linking of cellulose hydrogen bonds are converted to covalent bonds, therefore, the bending length is increased in the treated samples [32]. The same author studied the effect of the cross-linking agent on bending length and observed that the bending length of the treated cotton fabric increased in both warp and weft direction and this was attributed to the formation of covalent bonds, their role in cellulose molecules integrity. Also, different studies also revealed that the presence of resin cross-linking agents and herb extract could cause an increase in the bending length of cotton [33]. The result of the analysis of variance showed that the interaction of the concentration of the extract and the ratio of SIFE and ROPE is highly significant ($p < 0.01$) on tensile strength. The maximum strength loss happened to the fabric treated with 100% ROPE in the warp and weft direction of the fabric for both studied concentrations. The range of the tensile strength loss was reported as 12.16-43.96% wrap direction and 10.40-23.57% in the weft direction. The maximum percentage loss of strength was 43.96% in the warp and 23.57% in the weft direction at 5 g/l concentration and 19.93% in the warp and 14.60% in the weft direction at 3 g/l concentration observed in fabric treated with the 100% ROPE. In contrast, the minimum strength loss was observed in the fabric treated with 100% SIFE in warp and weft direction for both concentrations. The minimum percentage loss of strength was 10.40% in the weft and 12.166% in the warp direction for 3 g/l concentration and 20.03% and 13.58% in the warp and direction for 5 g/l concentration of the SIFE treated samples, respectively. The loss of strength is mainly due to the stiffening of the molecular backbone after cross-link formation [34]. The decrease in tensile strength could be attributed to the formation of intermolecular and intramolecular cross-links, which reduce the possibility of equalizing the stress distribution, causing a reduction in the capacity to withstand the load, as well as prevent the movement of the fiber molecules causing severe tensile strength loss as reported by Edwin Sunder and Nalankilli. With increasing in the antimicrobial agent concentration, the tensile strength of the treated fabric decreased in all the treatments. However, the loss in strength was not significant. The results of Ali et al. Nalankilli and TadesseSathianarayanan et al. and Sood were reported similar trends with the present finding.

Qualitative and Quantitative Antibacterial Activity of Treated Fabric

The analysis of variance showed that the concentration of the extract and ratio of SIFE and ROPE is significantly inhibited the S. aureus and E. coli. Figures 1 show the result of the disc diffusion test for antimicrobial of untreated and treated fabric against E. coli and S. aureus. It is evident from the figure that there was a clear zone of inhibition around the fabric treated with SIFE and ROPE against the two-tested organism in contrast to the controlled fabric, which allowed the growth of these test organisms. It is also observed that zone of inhibition increased as the concentration of SIFE and ROPE increased. All the treated fabric showed the zone of inhibition ranging from 30 to 47 mm for gram-negative bacteria and from 36 to 70 mm for gram-positive bacteria. Among all the treatments, treatment 2 (S2) at 5 g/l showed maximum zone of inhibition against both S. aureus (70.00 ± 1.00 mm) and E. coli (51.00 ± 1.00 mm). From the results, it is evident that the fabric treated with 100% SIFE had maximum bacterial reduction compared to 100% ROPE in case of both tested bacteria. This may be due to the presence of specific antimicrobial agents in SIFE like high number of flavonoids, which has known to exhibit a remarkable degree of antibacterial activity. Ewais et al. reported better antimicrobial activity of SIFE (methanolic) on E. coli and S. aureus. However, it is found that showed that the fabric treated with a combination of SIFE and ROPE had maximum bacterial reduction than the 100% single extracts at different concentrations. This is maybe due to the synergic effect of the different chemical compositions of SIFE and ROPE. The reduction of 100% and 99.92% observed for S. aureus and E. coli, respectively, for SIFE and ROPE treated with 5 g/l. From the result, it was observed that gram-negative bacteria were more resistant than gram-positive bacteria. Sood has been reported that the major differences between Gram-positive and Gram-negative bacteria are the composition of the cell wall [34]. The lipopolysaccharide content in the cell walls of Gram-negative bacteria is very important and the low-efficiency antibacterial agents have more difficulties in crossing the cell wall of Gram-negative bacteria in comparison to Gram-positive bacteria. The present findings are similar to the reports of Sathianarayanan et al., who reported that the application of tulsi leaf and pomegranate fruit extract on cotton fabric (paddy-dry-cure) reduced 99.9% S. aureus. Summarized literature is reported by different authors. Wash durability test The ANOVA results showed that the wash durability was a highly significant difference ($p < 0.01$) in several wash. As the wash cycle increased, the percentage of bacterial reduction gradually decreased. The decrease in antibacterial activity may be attributed to the slow removal of the extract, due to the breakdown of cross-links between the finishing agent and the cellulose material. It has been found that the bacterial reduction of the fabric treated with 50:50 combinations of SIFE and ROPE at 5 g/l showed reduction after 15 wash cycles for both Gram-positive (S. aureus) and Gram-negative (E. coli) test bacteria, whereas the bacterial reduction of the fabric treated with 100% SIFE and ROPE had a significant change after the 15-wash cycle at the same concentration. It is found that wash durability of the synthetic antimicrobial agent (silver nitrate) decreases after 10 wash cycles. Fabric treated with 50:50 combinations of SIFE and ROPE had better wash durability than fabric treated with the synthetic antimicrobial agent (silver nitrate). This was due to the leaching property of synthetic agents. The present result was supported by the study conducted by Unango and Ramasamy, which reports an investigation of biologically active natural compounds on cotton fabrics as an antibacterial textile finishing. Wash durability test result of the present study on antibacterial activity are similar to the study conducted by Nalankilli and Tadesse and Singh et al. SEM analysis The surface morphological structure of the controlled (untreated) and tread cotton fabric was analyzed by SEM. Among all the treatments, the fabric treated with 50:50 combination of SIFE and ROPE at 5 g/l was taken for SEM analysis. This is due to the better effectiveness of the test microorganism in both qualitative and quantitative assessment against S. aureus and E. coli. The SEM photograph of untreated and treated cotton fabric is shown in Figure 1.

As it can see from the figure, the photograph of untreated cotton fabric is in white color. As shown in the photograph, the morphological structure of the treated cotton fabric is wrapped. This is maybe due to the acidic reaction of the extract on the fiber. In Figure 1, agglomerated granulars were clearly visible on the treated fabric, which is evident from the antimicrobial agents successfully attached to the fabric. The present study is in accordance with Singh et al. Mondal and Saha.

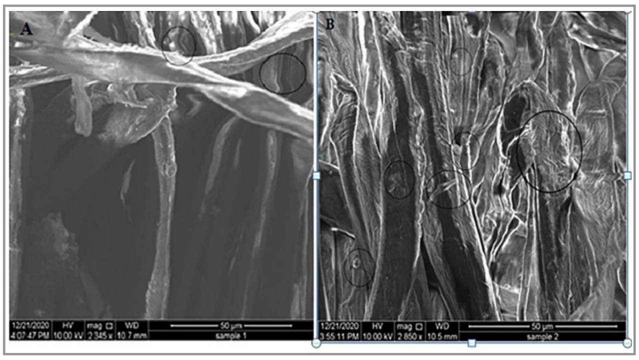

Figure 1: Scanning electron microscope images (A) untreated fabric, (B) treated fabric

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Conclusions

SIFE and ROPE treated cotton fabric showed good microbial reduction percentage on both S. aureus and E. coli microbes for all treatments. The fabric treated with a 50:50 combination of SIFE and ROPE with 5 g/l concentration showed a maximum bacterial reduction. The wash durability of the fabric treated with combined extract exhibited the good durability in terms of bacterial reduction percentage even after 15 wash cycles, whereas fabric treated with single extract showed less durability after 15 wash cycles. The fabric weight and bending length of the fabric increased after the application of extract, whereas the tensile strength, air permeability, and wetting property of the fabric decreased after the application of extracts. Finally, by considering all, the Fabric treated with 50:50 combination of SIFE and ROPE with 5 g/l concentration recommended for the fabric treatment.

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