Antimicrobial Activity of Cotton Fabric Treated with Solanum Incanum Fruit and Red Onion Peel Extract

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Abstract. The majority of the antimicrobial compounds used for treating textiles are synthetic based and are not considered to be environmentally friendly. Therefore, solanum incanum fruit and onion peel were selected for the current study based on their potent antimicrobial activity. The active substance was extracted from fruit and peel by using the maceration extraction technique for 7 days with mass to solvent ratio of 1:10. The Solanum incanum fruit and red onion peel extracts were applied alone and together, on the cotton fabric samples by the pad-dry-cure method, using citric acid as a cross-linking agent. The antibacterial activity and the wash durability of the treated cotton fabrics were assessed by the American Association of Textile Chemists and Colorists 100-2004 method. Among all treatments, the cotton fabrics treated with 50:50 combinations were found to be more in bacterial reduction. It was 100% and 99.92% bacterial reduction in cotton fabric with 5 g/l concentration for S. aureus and E. coli respectively. The wash durability of fabric treated with 50:50 combinations was 85% for S. aureus and 84.17% was for E. coli bacteria after 15 wash cycle. After treatment, the tensile strength, air permeability, bending length, water absorbency, and soil degradation were tested. Air permeability, water absorbency, and tensile strength were decreased. Soil degradation tests proved the biodegradability of the treated sample. The result recommended that the use of herbal extract could potentially be used as a substituent to a synthetic agent.

Keywords: Antimicrobial · Cotton fabric · Solanum incanum fruit · Red onion peel · Fabric comfort

1 Introduction

The growth of microorganisms on textiles had negative effects not only on the textile itself but also on the wearer. Most of these negative effects are a reduction of mechanical strength in fabrics, discoloration of the fabric, likelihood contamination, generation of bad odor, allergic response, and skin irritation [1–4]. Such a bottleneck problem forced attention towards developing advanced textile-based medical products. The rapid growth in medical and functional textiles provides many opportunities for the application

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of innovative functional finishes [5]. Antimicrobial finishes can be applied to textile substrates by the exhaust, pad-dry-cure, coating, spray method, or spinning dope [2, 6]. The growth of microbes on the textile can be controlled by applying antimicrobial agents by various mechanisms like preventing cell production, blocking of enzyme reaction within the cell membrane to the destruction of the cell wall, and poisoning the cell from within [6, 7].

Mostly the textile sector utilized a synthetic antimicrobial agent against bacteria and fungi. But, most of the synthetic antimicrobial agents such as triclosan, formaldehyde have the potential to cause skin irritation, non-biodegradability, and bioaccumulation effect [8]. However, the herbal antimicrobial finishes overcome the disadvantages of the chemical finishes because they are eco-friendly, non-toxic, and non-allergic [9, 10]. The antimicrobial effectiveness of the plant depends on the chemical structure of the active component present in the plant and their concentration [11–13]. Today, numerous herbs and vegetables have been studied to extract the antimicrobial agent. Among the numerous natural herbs and vegetables, Solanum incanum and onion peel are a source of antimicrobial agents.

Solanum incanum L. is one of the most important traditional medicinal plants which belong to the Solanaceae family [12, 14]. Solanum incanum is a plant characterized by thorny leaves, yellow fruits, and blue flowers with yellow pistils which mostly distributed in the Horn of Africa as described by Nalankilli & Tadesse [12].

Onion (Allium cepa L) is a common food plant rich in several phytonutrients associated with the treatment and prevention of several diseases [15]. Allium cepa commonly called onion belongs to the family of Alliaceae and is grown in every part of the world where plants are farmed and exhibit great diversity in a form including color, shape, dry matter content, and pungency [16]. The variety also affects the antimicrobial activity, since the secondary metabolite present in each variety (red variety, green variety, and white variety) are different. The bioactive compound from onion exhibited antibacterial and antifungal activities [15].

The majority of the synthetic antimicrobial agents utilized in the textile industry are leaching type; result in decreasing their concentration and fail to inhibit the growth of harmful microbes and the release of these agents acts as a poison to a wide spectrum of bacteria and fungi [17]. On the contrary, the textile industry looks for non-toxic, non-allergic, and eco-friendly natural antimicrobial agents that do not adversely affect the quality of the textile material and the ecosystem as a substitute for synthetic toxic chemicals [17].

In Ethiopia, cooks will usually use red onion for their kitchen, which results in discarded underutilized parts of the vegetable, and it may cause an environmental problem like a source of unpleasant odor. However, the onion peel has high phenolic and flavonoids content, which act as antimicrobial agents. On the other side, no study has been undertaken to investigate the combined antimicrobial effect of solanum incanum fruit and onion peel extract on cotton fabric. Thus, to overcome these bottles' necked problem applying herb extract on the cotton fabric was taken as an immediate solution. For this study, the two herbs were applied by varying their proportion to examine the combined effects of the antimicrobial agent on the antibacterial activities, wash durability, and physical properties of cotton fabric.

2 Materials and Methods

2.1 Materials and Chemicals

Solanum incanum fruit and red onion peel were used for antimicrobial agent source. The citric acid (99.5%) was used as a cross-linking agent. Chloroform (99.8), hydrochloric acid (37%), ferric chloride (99%), ammonia (35%), aluminum chloride (99%), sulfuric acid (98%), acetic acid glacial (99.5%), potassium iodide (98.5%), phosphoric acid (85%) and sodium hydroxide (98.8) were used for phytochemical analysis. Gallic acid (99%), Folin- Ciocalteau reagent, and sodium carbonate (99.5%) were used for total phenol content determination. Methanol (99.8%) was used for extracting the active component from the peel and fruit of solanum incanum and red onion. Quercetin acid (99.8%), sodium nitrite (99.5%), aluminum chloride, sodium hydroxide was used for total flavonoid content determination. All chemicals used in the current study were analytical grades.

2.2 Equipment Used

Test tubes were used for solution preparation of phenol and flavonoid analysis, padding mangle (Mathis made in Switzerland) for imparting antimicrobial agent onto cotton fabric. Oven dryer was used for removing excess water from the fabric after applying finishing agent, multifunctional grinder (RRH-100g) for reducing the size of the solanum incanum fruit and onion peel into powder form. Universal strength tester (Mesdan, Italy) was used for measuring the tensile strength and elongation of break of the treated fabric, Rotary evaporator (Rota-vapor, RE300, UK) for concentrated the filtrate of the extract, oven (Bernareggio, M40-VF, Italy) for drying of sample, electronics balance for weighing the sample, orbital shaker (Unimax2010, Germany) for extraction.

2.3 Methods

Sample Collection and Pretreatment

The plant material, solanum incanum fruit was collected from Abay Mado, kebele 11, around Gihon secondary and preparatory school, Bahir Dar, Amhara regional state, Ethiopia. The red onion peel was collected from Bahir Dar institute of technology student cafeteria. The collected sample from the available area was washed in tap water and rinsed in distilled water to remove dust and other impurities. Then the rinsed samples were dried in shade; Solanum incanum fruit for five days and onion peel for 14 days by cutting it into the smaller piece-using knife until its moisture content was reduced to 14%.

The dried samples were subjected for size reduction to powder (finely) by high-speed multifunctional grinder (RRH-100g, Hongtaiyang Electrical & Mechanical Service Co. Ltd of the Yongkang City of Zhejiang Province) purchased from the local market, Bahir Dar, Ethiopia. After that, the powder was sieved with a sieve size of 0.5 mm to remove the oversized particles. Finally, the perspective-powdered samples were stored in an airtight glass container at room temperature until used.

Extract Preparation

Extraction was done using a method described by [18]. The dried powder, 50 g of each sample (Solanum incanum fruit and red onion peel) was soaked in 500 ml of absolute methanol with a continuous shaking with an orbital shaker at 172 rpm for one week at room temperature. After a week, the perspective sample was filtered through what man filter paper (125 mm, No.1) using a suction filter apparatus, while the residues were allowed for a second extraction. After filtration, the filtrates were concentrated under reduced pressure using a rotary evaporator at a temperature of 50 °C. The crude extracts were collected and dried in an oven at a temperature of 35 °C for 72 h. The dried concentrate was weighted and scooped into a well-labeled plastic bottle and stored in a refrigerator at 4 °C waiting for bioassay.

Phytochemical Analysis/Screening

Chemical Test: The chemical analysis of both the extracts was performed by following the protocol of [19–22].

Quantification of Total Phenol and Flavonoid Content

Phenol Content Determination: The quantity of total phenolic contents in each extract was determined accordingly to the Folin-Ciocalteau reagent (FCR) method described by [23] using Gallic acid as standard. The absorbance of the reaction mixtures was measured at 765 nm using a UV– Vis spectrophotometer (PerkinElmer UV-Vis spectrometer, Lambda 35) against the blank. The experiments were done in triplicate. The absorbance of the extract was compared with a Gallic acid standard curve using concentrations of 0, 0.050, 0.100, 0.150, 0.200, 0.250, and 0.300 mg/ml for estimating the concentration of phenol content in the sample. The phenolic content was expressed as mg of Gallic acid equivalents (GAE) per ml of sample.

Flavonoid Content Determination: The total flavonoid contents in each extract were determined by the well-known aluminum chloride colorimetric method [24]. The sample absorbance was read at 510 nm using a UV/Vis spectrophotometer. The absorbance of the extract was compared with a quercetin standard curve using concentrations of 0, 0.050, 0.100, 0.150, 0.200, and 0.250 mg/ml for estimating the concentration of flavonoid content in the sample. The flavonoid content was expressed as mg of quercetin equivalents (QE) per ml of sample.

Application of Extract on Fabric Using a Pad-Dry-Cure Method with Standard Combination

Pad-Dry-Cure Method: The cotton fabric was treated with 3 g/l and 5 g/l concentration of Solanum incanum fruit and red onion peel extract and with their standard combination as described in Table 1. The citric acid (6% w/v) was used as cross-linking with a mass liquor ratio of 1:10 (1 g of fabric in 10 ml of active ingredient solution). A two-bowl vertical laboratory padder (pressure 2 bar, speed 1.5 m/s, Mathis made in Switzerland) was used with a two dip and two nip process to get a wet pick up of 95% on the weight of the fabric. After padding, the treated samples were dried at 80 °C for 3 min and cured at 150 °C for 3 min on the lab model-curing chamber. Five solutions were prepared for each concentration and designated sample as shown in Table 1.

Table 1. Fabric treated with different concentrations

Concentration	Type of treatment	Sample code
3 g/l and 5 g/l	25:75 v/v Solanum incanum fruit to red onion peel	S1
	50:50 v/v Solanum incanum fruit to red onion peel	S2
	75:25 v/v Solanum incanum fruit to red onion peel	S3
	100% Solanum incanum fruit	S4
	100% red onion peel	S5
	Unfinished	Untreated

Performance Evaluation of Treated Cotton Fabrics

Tensile Strength Test (ES ISO13934): The tensile strength of fabric was determined on the paramount universal tensile tester (Mesdan, Italy) using the ES ISO 13934 test method. The samples of template size "16 × 5" from the warp and "20 × 5" centimeter from the weft directions of the fabric were cut and mounted between the jaws with approximately 2.54 cm of fabric protruding from each side of the jaws at the distance of 8 cm. The instrument was started; the upper jaw was moved in an upward direction until the sample break. The readings were taken from the digital display at sample break. Two readings of the specimen from both the directions (warp and weft) were taken and the average was calculated.

Bending Length (BS 3356): The fabric stiffness (bending length) was determined according to the method described by BS 3356.

Air Permeability (ES ISO 9237): The air permeability of a fabric is the volume of air, measured in cubic centimeters passed per second through one square centimeter of the fabric at a pressure of 1 cm of water. Air permeability was tested using air permeability tester (FX 3300, Zurich Switzerland) and the result was noted as $cm^3/cm^2 \cdot S$.

Water Absorbency Test (AATCC Test Method 79): The water absorbency of both treated and untreated fabrics was evaluated by the water drop method as per AATCC 79-2000 standard. In brief, a drop of distilled water was dispensed from a dropper onto the fabric surface from a distance of 1 cm. Time was recorded until the water drop absorbs completely. Four readings were taken for each fabric sample and the mean was calculated.

Biodegradability of Finished Fabrics

The soil degradation test was conducted by the burial soil testing method described by [13] with slight modification. Both treated and untreated samples were kept inside the microbial active soil at 10–15 cm depth. The samples were carefully removed from the soil after two weeks and washed with water gently off soil particles, then dried in the sunlight. The degradation (weight loss) of the prescribed samples after two weeks was determined by the following equations.

$$\text{Weight loss}\,(\%) = \frac{\text{w1} - \text{w2}}{\text{w1}} * 100 \tag{1}$$

Where w_1 is the initial weight in (gm) and w_2 is the after-burial weight (in gm).

Antibacterial Activity Testing

Antibacterial testing was done by AATCC test method 100:2004 for a quantitative assessment of the antibacterial effectiveness of the antimicrobial agent against Gram-positive bacteria (Staphylococcus aureus) and Gram-negative bacteria (Escherichia coli). Half gram (0.5) of swatches was weighted from the test fabric. The weighted swatches were stacked in 250 ml wide-mouth glass jar with a screw cap followed by sterilization at 121 °C for 15 min. To the sterilized glass jar containing the test fabrics, 1 ml of bacteria culture solution with a cell concentration of 1×10^6 CFU/ml and inoculated individual swatches for 18 h at 37 °C. The inoculated samples were incubated for 24 h at 37 °C. After 24 h incubation, 100 ml of the neutralizing solution prepared by sterilized distilled water was added and shaken vigorously for 1 min. 1 ml of samples were spread on to the agar plate and plates were incubated at 37 °C for 24 h. After incubation, bacterial colonies were counted by a colony counter unit, and the antibacterial activity was determined as follows.

$$\%\,\text{Reduction} = \frac{\text{A} - \text{B}}{\text{A}} * 100 \tag{2}$$

Where "A" is the number of surviving cells (CFU/ml) for untreated cotton fabric (control), and "B" is the number of surviving bacteria (CFU/ml) for the treated fabrics.

Wash Durability Test

In the present study, the wash durability of the antimicrobial activity of the treated cotton fabric was evaluated at different wash cycles. The treated cotton fabric was washed in a launder –o-meter according to ES ISO 3759 test method with a 5 g/l neutral soap solution at 50 °C for 5 min. The finished fabrics were tested for the retention of antimicrobial activity after 5, 10, 15 launderings by the AATCC-100 test method as described in the above section.

3 Result and Discussion

3.1 Chemical Test Analysis

In the present study, the chemical test analysis was conducted to evaluate the presence of active constituents such as alkaloid, flavonoid, steroid, glycoside, protein, resin, quinone, tannin, anthraquinones and phenols.

The data presented in Table 2, the results of the phytochemical analysis indicate the presence of flavonoids, steroids, glycoside, tannin, protein, quinone, alkaloid, terpenoids, saponins, phenol and the absence of anthraquinone and resin in methanolic fruit extract of Solanum incanum. Whereas the chemical test analysis of a methanolic extract of onion peel indicates the presence of steroids, terpenoids, alkaloids, flavonoids, quinone, anthraquinones, phenols, saponins, tannin, resin but the absence of protein.

Table 2. Chemical test analysis of a phytochemical component of red onion peel and solanum incanum fruit

Phytochemical	Test	Color change observed	Red onion peel	Solanum incanum fruit
Saponins	Frothing test		+	++
Resins	Sulfuric acid test	Violet	+	–
Glycosides	Alkaline reagent test	Yellow	+	+++
Tannins	Ferric chloride test	Blue-black	+++	++
Terpenoids	Salkowski test	Reddish-brown	++	+++
Steroids	Salkowski test	Red	+++	++
Phenol	Ferric chloride test	Blue-black	+++	++
Flavonoids	Alkaline reagent test	Intense yellow	+	++
	Ammonium test	Yellow	+	++
	Aluminum chloride test	Light yellow	–	+
Quinone	Hydrochloric acid test	Yellow	–	+
Anthraquinones	Ammonia test	The red color in the ammonia layer	++	–
Protein	Xanthoproteic	Yellow	–	++
Alkaloid	Wagner's reagent test	Reddish/brown precipitate	++	+++

Key (+++) strongly present, (++) moderately present, (+) weakly present and (–) absent

3.2 Quantification of Total Polyphenol and Total Flavonoid Content

Total Polyphenol Content

The levels of total phenol were quantified from the equation of the regression line: A = 0.006C + 0.045 with R^2 = 0.969 from calibration curve where A = mean absorbance, C = concentration in mg/L.

The total phenol content can be determined using the formula $TPC = \left(\frac{\text{mgGAE}}{\text{ml}}\right) = C$ where C = Concentration of Gallic acid in mg/ml and TPC = Total phenol content in mg of Gallic acid equivalents per ml of sample. The level of the total phenol contents of the methanolic extracts of Solanum incanum fruit and red onion peel were presented in the table below (Table 3). It appeared that the methanolic extract of red onion peel had

Table 3. Total phenol content of methanolic extract of red onion peel and solanum incanum fruit

Extracts (mg/ml)	Total phenol content (mg GAE/ml sample)			
	Red onion peel		Solanum incanum fruit	
	Current study	Previous study	Current study	Previous study
1	0.857 ± 0.00078	0.71433 ± 0.06609	0.515 ± 0.00136	No studied

Key, **GAE = Gallic Acid Equivalent (conventional unit for phenolic compound)
All values are mean of triplicate experiments.

the highest phenol content compounds (0.857 ± 0.00078 mg GAE/ml) than that of the same extract of solanum incanum fruit (0.515 ± 0.00136 mg GAE/ml).

Ifesan [25], reported that the total phenol of ethanolic extract of red onion skin was 0.714.33 ± 0.06609 mg GAE/ml from 1 mg/ml concentration. The total phenol content in the present study was 0.857 ± 0.78 mg GAE/ml from 1 mg/ml was higher than that of the total phenol content has been reported by Ifesan [25] which was 0.714.33 ± 0.06609 mg GAE/ml from 1 mg/ml concentration of the sample.

Total Flavonoid Content

The levels of total flavonoid were expressed in terms of quercetin equivalent (QUE), determined by the well-known aluminum chloride colorimetric method described by Viera et al. [24] and quantified from the equation of regression line: $A = 0.0007C+0.026$ with $R^2 = 0.935$ from calibration curve where A = mean absorbance, C = concentration quercetin in mg/L. The total flavonoid content of the extracts can be determined using the formula $TFC\left(\frac{\text{mgQUE}}{ml}\right) = C$ where C = Concentration of quercetin in mg/L of quercetin equivalence and TFC = Total flavonoid content in mg of quercetin equivalence.

Table 4. Total flavonoid contents of methanolic extract of Solanum incanum and red onion peel

Extracts (mg/ml)	Total flavonoid content (mg QUE/ml sample)			
	Red onion peel		Solanum incanum fruit	
	Current study	Previous study	Current study	Previous study
1	0.266 ± 0.0294	0.17733	0.849 ± 0.0067	No studied

Key, **QUE = Quercetin Equivalence (the conventional unit for flavonoid compound)
**All values are mean of triplicate experiments.

The level of the total flavonoid contents of the methanolic extracts of Solanum incanum fruit and red onion peel are presented in the table below (Table 4). It appeared that the methanolic extract of Solanum incanum fruit had the highest flavonoid content compounds (0.849 ± 0.0067 mg QUE/ml sample) than that of the same extract of red onion peel (0.266 ± 0.0294 mg QUE/ml sample).

Ifesan [25], reported that the total flavonoid of ethanolic extract of red onion skin was 0.17733 mg QUE/ml from 1 mg/ml concentration. The total flavonoid content in the present study which was 0.266 ± 0.0294 mg QUE/ml sample from 1 mg/ml was higher than that of the total flavonoid content has been reported by Ifesan [25] which was 0.17733 mg QUE/ml from 1 mg/ml concentration of a sample.

This may due to the type of solvent used, solvent strength, the technique of extraction, and time of extraction. It can be observed that the color change observed for the flavonoid test in solanum incanum fruit extract is confirmed moderately presence of flavonoid compound in solanum incanum fruit extract than the presence of flavonoid compound in red onion peel extract (weakly present). This result reveals that the quantification result from the UV-Vis spectrometer supports the qualitative test.

3.3 Physical Properties and Biodegradability of Treated Cotton Fabric

In the present study, 100% bleached cotton fabric was treated with Solanum incanum fruit and red onion peel extract in the presence of citric acid as a cross-linking agent. The data depicted in Table 5, it was a 4.76% change in the bending length of the treated fabric as compared to the untreated one and the bending length is directly related to the flexural rigidity of the fabric. Thus, the flexibility of the fabric is not changed too much even after the treatment process. [26] Studied the effect crosslinking agent on bending length and observed that the bending length of the treated cotton fabric increased in both warp and weft direction and attributed such an increase in the formation of covalent bonds that held the cellulose molecules together. However, after cross-linking of cellulose, some hydrogen bonds get converted to covalent bonds, therefore, bending length increase. The result published by Mortazavi & Esmailzadeh [27] and Mukthy et al. [26] support the result obtained in the present study.

Air permeability is an indication of the rate of airflow through the fabric. By increasing the concentration of the antimicrobial agent, from 3 to 5 g/l, applied on the cotton fabric, the thickness of the fabric was increased. As a result, the air permeability was slightly decreased.

The test result presented in Table 5 provided that, solanum incanum fruit and red onion peel extract finished fabrics had lower air permeability than that of unfinished fabrics. This is because Solanum incanum fruit and red onion peel extract treatments fill the pore of the fabric. As compared to the air permeability of pure extract finished fabric, fabric treated with pure Solanum incanum fruit extract (S4) had better air permeability than that of pure red onion peel extract finished fabric (S5).

This is due to the better affinity of red onion peel extract towards the fabric than Solanum incanum fruit extract and the coating layer thickness was larger in the case of red onion peel extract-treated fabric compared to Solanum incanum fruit extract treated fabrics.

The result of the present study was similar to the finding of El-Shafei et al. [9] and Mondal et al. [28] who reported that applying herb extract on the fabric surface did not much significantly alert the air permeability of the fabric.

The weight loss of the fabric due to digging soil test after two weeks was calculated by using the Eq. (1). From Table 5, the maximum weight loss because of soil degradation

Table 5. Water absorbency, weight loss (%), stiffness (bending length), and air permeability of Solanum incanum fruit and red onion peel.

Coc. (g/l)	Treatment combination (SIFE: ROPE)	Water absorbency (sec)	Weight loss (%)	Bending length (cm)	Air permeability ($cm^3/cm^2/s$)
3	S1 (25:75)	8.33 ± 0.57	14.55 ± 0.10	2.05 ± 0.07	38.75 ± 0.30
	S2 (50:50)	7.33 ± 0.57	9.19 ± 0.03	2.02 ± 0.00	40.25 ± 0.69
	S3 (75:25)	5.33 ± 0.57	11.24 ± 0.06	2.01 ± 0.01	40.027 ± 0.870
	S4 (100:0)	4 ± 0.01	15.72 ± 0.27	2.01 ± 0.01	43.42 ± 027
	S5 (0:100)	15.33 ± 0.56	15.98 ± 0.70	2.07 ± 0.02	39.77 ± 0.78
5	S1 (25:75)	12.33 ± 0.57	12.47 ± 0.13	2.09 ± 0.02	38.27 ± 0.01
	S2 (50:50)	10.33 ± 0.54	7.54 ± 0.13	2.04 ± 0.01	37.85 ± 0.09
	S3 (75:25)	10 .1 ± 0.9	10. 12 ± 0.24	2.02 ± 0.02	41.05 ± 0.04
	S4 (100:0)	8 .0 ± 0.01	14.22 ± 0.20	2.02 ± 0.03	41.6 ± 0.97
	S5 (0:100)	18 .0 ± 0.01	15.55 ± 0.24	2.10 ± 0.01	39.32 ± 0.20
	Control	1.33 ± 0.57	30.22 ± 0.04	2 ± 0.00	46.67 ± 0.05

was that of the untreated fabric, this is because microorganisms in the soil attacked the untreated cotton fabric quickly, in the absence of any treatment to inhibit them.

It can be seen from the table (Table 5), the least degradation (7.54%) occurred in the 5 g/l of fifty-fifty combination of Solanum incanum fruit and red onion peel extract-treated fabric, and the second least degradation occurred in the fabric treated with 50% combination with 3 g/l concentration. This proves the strong antibacterial activity of the combinatorial extract of solanum incanum fruit and red onion peel. The present finding was supported by Mondal et al. [28].

As presented in Table 6, the maximum strength loss happened in the fabric treated with pure red onion peel extract in the warp and weft direction of the fabric for both concentrations. The maximum percentage loss of strength was 43.966 ± 2.262% in the warp and 23.576 ± 1.074% in weft direction at 5 g/l concentration and 19.933 ± 0.00% in the warp and 14.6 ± 2.1074% in weft direction at 3 g/l concentration. Whereas the minimum strength loss has happened, the fabric treated with pure Solanum incanum fruit extract in warp and weft direction for both concentrations.

The minimum percentage loss of strength was 10.403 ± 1.074% in the weft and 12.166 ± 0.989% in the warp direction for 3 g/l concentration and 20.033 ± 1.131% and 13.586 ± 1.074% in warp and weft direction for 5 g/l concentration respectively. The loss of strength is mainly due to the stiffening of the molecular backbone after cross-link information Ali et al. [5].

3.4 Antibacterial Activity of Treated Fabric (AATCC Test Method 100-2004)

The bacterial resistance of the fabric finished with pure Solanum incanum fruit and red onion peel extract and their combinations with two different concentrations i.e. 3 g/l

Table 6. Tensile strength of the fabric in warp and weft direction

Concentration in g/l	Treatment combination	Loss of tensile strength (%) (Mean ± SD)	
		Warp direction	Weft direction
3	S1 (25:75)	15.200 ± 1.131	13.620 ± 1.074
	S2 (50:50)	12.700 ± 1.131	12.716 ± 1.074
	S3 (75:25)	15.633 ± 1.131	11.310 ± 1.074
	S4 (100:0)	12.166 ± 0.989	10.403 ± 1.074
	S5 (0:100)	19.933 ± 0.000	14.600 ± 2.142
5	S1 (25:75)	42.333 ± 1.131	23.386 ± 2.138
	S2 (50:50)	36.066 ± 1.131	15.903 ± 1.074
	S3 (75:25)	28.566 ± 2.262	16.610 ± 1.074
	S4 (100:0)	20.033 ± 1.131	13.586 ± 1.074
	S5 (0:100)	43.966 ± 2.262	23.576 ± 1.074
	Control	Nil	Nil

and 5 g/l by pad-dry-cure method, the growth of E. coli (Gram-negative bacteria) and S. aureus (Gram-positive bacteria) was counted quantitatively by the standard test method AATCC 100. As presented in Table 7, after treating the cotton fabric by a pad-dry-cure method with 3 g/l and 5 g/l concentration of red onion peel separately, percentage reduction values were 97.17% and 97.67% for E. coli and 97.50% and 98.00% for S. aureus, respectively.

Table 7. Antibacterial activity of cotton fabric treated by Solanum incanum fruit and red onion peel against S. aureus and E. coli.

Concentration in g/l	Bacteria	Bacterial reduction	Type of treatment				
			Solanum incanum fruit	Red onion peel	Combination of Solanum incanum to onion peel extract		
					50:50	25:75	75:25
3	E.coli	%	97.83	97.17	99.63	98.08	99.00
	S. aureus	%	97.92	97.50	99.83	98.42	99.25
5	E.coli	%	98.00	97.67	99.92	98.92	99.42
	S. aureus	%	98.83	98.00	100	99.08	99.75
Untreated	Confluent growth						

Data (Table 7) also revealed that when Solanum incanum fruit extract was applied by the pad-dry-cure method, percentage reduction values were 97.83% and 98.0% for E. coli and 97.92% and 98.83% for S. aureus. Data (Table 7) also depicted the bacterial reduction against various combinations of Solanum incanum fruit and red onion peel extracts. It was found that 50:50 v/v combinations of Solanum incanum fruit and red onion peel extract had better bacterial reduction i.e. 99.63% for E. coli and 99.83% for S. aureus with 3 g/l.

With 5 g/l concentration of the same extract i.e. combination of Solanum incanum fruit and red onion peel, the bacterial reduction values increased to 99.92%, 99.42%, and 98.92% using 50:50, 75:25 and 25:75 v/v standard combinations on cotton fabric for E. coli bacteria.

The bacterial reduction of the fabric treated with combined extract of solanum incanum fruit and red onion peel was found better than the fabric treated with alone. This is maybe due to the cumulative effect and different chemical composition of Solanum incanum and red onion peel extract in combinatorial treatment. As comparing the bacterial reduction of fabric treated with pure extract, the fabric treated with pure Solanum incanum fruit extract had maximum bacterial reduction than that of red onion peel extract against S. aureus and E. coli test bacteria. This is due to the chemical composition of solanum incanum fruit extract i.e. the presence of a high number of flavonoids, which has known to exhibit a remarkable degree of antibacterial activity.

3.5 Wash Durability Test

As data depicted in Fig. 1, the bacterial reduction of the fabric treated with 50:50 combinations of Solanum incanum fruit and red onion peel extract at 5 g/l concentration shows a slight change after 15 wash cycle for both Gram-positive (S. aureus) and Gram-negative (E. coli) test bacteria. Whereas the bacterial reduction of the fabric treated with pure Solanum incanum fruit and red onion peel had a significant change after a 15-wash cycle at the same concentration.

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, which explains the bonding between the finishing agent and the fabric structure. As comparing the wash durability of fabric treated with pure extract, the fabric treated with pure Solanum incanum fruit extract had better efficacy than that of red onion peel extract against S. aureus and E. coli test bacteria. Data also presented in the figure below the wash durability of the synthetic antimicrobial agent (silver nitrate) decrease after 10 wash cycle. Fabric treated with 50:50 combinations of Solanum incanum fruit and onion peel extract had better wash durability than fabric treated with the synthetic antimicrobial agent (silver nitrate). This was due to the leaching property of synthetic agents.

These results are supported by the study conducted by Unango et al. [29] who report on the investigation of biologically active natural compounds on cotton fabrics as an antibacterial textile finishing. Thus, the wash durability test of the present study on antibacterial activity also suggested the study conducted by Singh et al. [30] and Nalankilli & Tadesse [12].

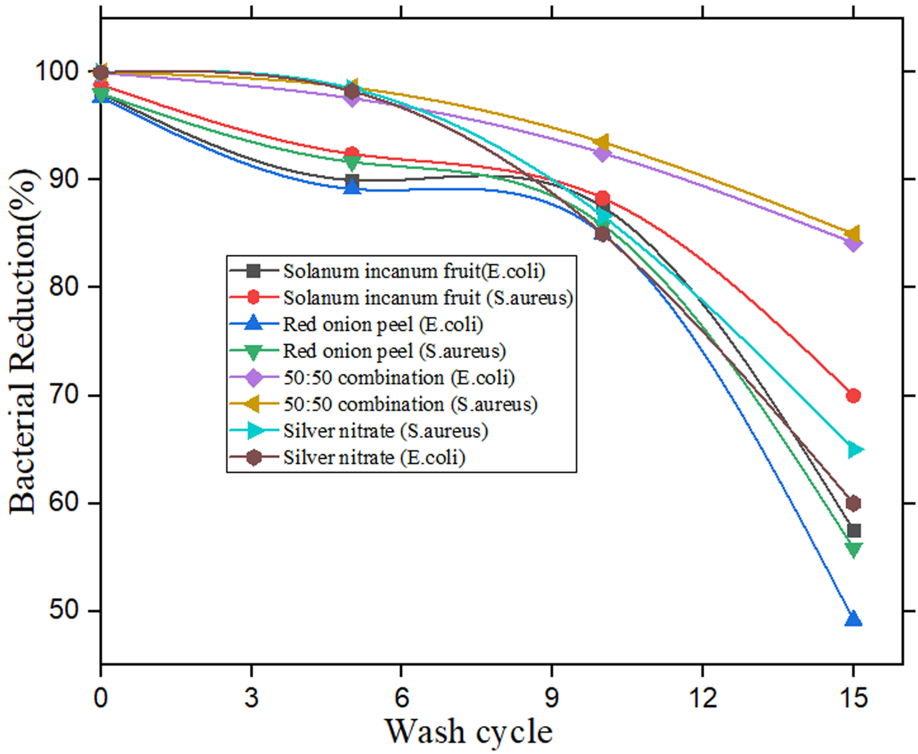

Fig. 1. Effect of wash durability on antibacterial activity of cotton fabric against S. aureus and E. coli

4 Conclusion

Based on the experimental results, it was concluded that the methanolic extract of solanum incanum fruit and red onion peel exhibited a good microbial reduction percentage in both Staphylococcus aureus and Escherichia coli microbes for all treatment. The high antimicrobial effect on cotton fabric was achieved with fifty-fifty combination at 5 g/l concentration for both bacteria. The wash durability of the fabric treated with combined extract exhibit good durability in terms of bacterial reduction percentage even after 15 wash cycles. However, fabric treated with pure extract showed less durability after 15 wash cycles. The physical properties fsuch as weight and bending length increased after the application of extract. Whereas the tensile strength, air permeability, and wetting property of the fabric decreased after the application of extracts.

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