

Extraction and Characterization of Bioactive medical textile fabrics using Arisaema Consanguineum (AC) plant root extract

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Abstract

This study examined the application of bioactive medicinal plants of *Arisaema Consanguineum* (CA) species to textile finishes and the functionality of fabrics treated with ethanolic extracts from the root extract of the *A. Consanguineum* plant. The qualitative phytochemical screening method is applied to the extract to observe the presence of some chemical constituents responsible for the bioactivity of the extract. The result shows the presence of terpenoids/steroids, tannin, alkaloid, flavonoid, saponin, carbohydrate, phenolic and volatile oils in the extract. Antibacterial activity was significant in the order of *A. Consanguineum* plant root extract. Antibacterial activity of cotton fabrics treated with *A. Consanguineum* plant root extract was found to be effective against *E. coli* and *S. aureus*. *S. aureus*, on the other hand, was more inhibited before and after washing than *E. coli*. The fabric treated at low concentrations (10%) has good, substantial antibacterial activity, but the sample treated at high doses (20%) has major antibacterial activity. As a result, ethanolic *A. Consanguineum* plant root extract is suggested as a bioactive, eco-friendly antibacterial finish. The FTIR result spectra confirmed the existence of alcohols, phenols, ethers, aromatics, polysaccharides and polyphenols, and alkyl halides in the extract. As a result of this study, the thermal stability of treated cotton fabric is estimated lifetime of medical components. From the observed results, higher decomposition was observed between 130-250°C. Tensile strength and air permeability of the untreated fabrics are slightly higher than those of the treated fabrics without affecting the functional properties of the fabrics.

1. Introduction

Concerns about the environment and public awareness have fostered the development of sustainable products and methods that have a lower environmental and human health impact [1, 2]. Antimicrobial fabrics have become increasingly popular in recent years as a result of their ability to improve home hygiene and provide people with safety benefits [3, 4].

Textiles are widely employed in both dry and wet dressing management due to their attractive and non-allergenic qualities, compatibility, good mechanical capabilities, hydrophilic or hydrophobic features, air and moisture permeability, and other factors. Cellulose is the most prevalent natural polysaccharide, and it has traditionally been employed in clinical settings for bioactive healing. Because its ultrafine fibers provide optimum comfort at a cheap cost, cellulose or its derivatives have also been exploited in the development of nano-fiber materials for biomedical purposes [5].

Because of their high surface area and capacity to retain moisture, textile goods, particularly those made from natural fibers, provide an ideal environment for microbes to thrive [6]. The growth of the microorganism on textiles has several negative consequences that affect both the textile, the environment, and the user. This microbial contamination is a major concern, particularly for textiles used in hospitals as medical equipment or for health and hygiene care, but also athletic apparel, water purification systems, animal feed, and the food sector [7]. In the past decades, people have used several chemicals that have been employed to impart antimicrobial activity to textile goods, like triclosan, quaternary ammonium, triclocarban, inorganic salts, organometallics, iodophors (substances that slowly release iodine), and other

halogenated aromatic compounds. However, the use of chemical products is becoming an increasing problem due to microbial resistance, product withdrawal, undesirable environmental problems, and toxicity on the human body [8]. As a result, antimicrobial-treated textiles based on eco-friendly agents are in high demand, as they help to effectively prevent the negative effects of microbial growth on textile materials [9]. Natural plant compounds have been widely reported for the antibacterial finishing of textiles [10].

Plants have a long history of being used to treat a variety of human diseases. To avoid various diseases, plant parts such as leaves, stems, bark, roots, and flowers are used. Plant herbals can produce a wide range of bioactive chemicals as a result of this process. Nowadays, researchers are looking for natural remedies instead of synthetic medicine and treating various diseases using different parts of plants. Among these medicinally significant plants is the genus *A. Consanguineum*, which contains roughly 250 species, each of which is employed for a particular medicinal purpose [11]. Arisaema species have been discovered in several parts of the world, including Eastern Africa, Central Africa, Asia, and Eastern North America [10, 11]. *Arisaema Consanguineum*, *Arisaema erubescens*, *Arisaema flavum*, *Arisaema tortuosum*, *Arisaema jacquemontii* Blume, *Arisaema leschenaultia*, *Arisaema franchechianum*, and others were among the Arisaema plant species [12]. Some of these plant species are also native in the farmlands of southern Ethiopia in the Gamo Gofa zone, among them *A. Consanguineum* is highly found and selected for these studies to examine its bioactivity on cotton fabrics.

A. Consanguineum is a cellulosic perennial with tubers used for a range of therapeutic applications in the Himalaya and China Fig. 1. All portions of the plant, however, contain oxalic acid and calcium oxalate crystals (raphides), both of which are highly irritating and can cause serious poisoning if consumed without proper preparation [13, 14]. Since antiquity, medicinal plants have been the mainstay of traditional herbal therapy among rural residents all over the world [15]. Natural products have always been an important aspect of traditional medicine to treat wounds, cough, epilepsy, and rheumatism. Traditionally, these plants are used for the preparation of food, wound healing in humans and animals, and rheumatic pain due to their antioxidant, antifungal, and antibacterial properties. The part used is said to be a rhizome, but is more accurately described as a tuber or corm.

This study aims to provide the most up-to-date scientific information on the use of natural *A. Consanguineum* plant roots extract antimicrobials on textiles as effective antibacterial agents. This naturally exists. *A. Consanguineum* plant root extract can reduce the impact that comes from synthetic/chemical antimicrobial agents, as well as being easily available and having low/no toxicity. The present work discusses the extraction and characterization of a bioactive agent from the *A. Consanguineum* plant root. The investigations focused on the screening of phytochemicals and FT-IR analysis, followed by antibacterial tests of the plant extract. The study applies a scientific medicinal plant root extract on fabric to replace traditional use.

2. Methodology

2.1. Collection of plant materials

This study uses native plant roots (*Arisaema Consanguineum*, AC) are commonly available in our country and are not considered a wild species. It was cultivated on the local farm land as a mixed crop is protected from weeds, and the farm lands were protected by a special terracing system to reduce soil erosion. The suitable season for harvesting the mature root was between December to February.

The samples were collected from Southern Ethiopia, with known traditional medicinal properties, and were harvested from Dara is an ancient walled village in the Konso region of southern Ethiopia, located to the east of Karat town under Karat Zurya Woreda. It is located in the southwestern part of the country, with geographical coordinates of 6.36667° N latitude and 37.41667° E longitude.

Prior to sample collection, appropriate permission was formally obtained from the owner/authorized representative of the privately owned farmland. Which is secured to ensure compliance with legal and ethical standards.

The plant roots were washed under running tap water to remove dust and soil. The plant materials were again washed appropriately under tap water.

Water, cut into pieces; pulverized into fine powder in a grinding machine, and air-dried for about ten days, the powder was stored at room temperature with paper labeling in a beaker.

3.2. Standards and reagents

The standard reagents used throughout the experiments to achieve the objective of the study are: methanol, ethanol, acetic anhydride ((CH₃CO)₂O), ferric chloride (FeCl₃), tannic acid; sulphuric acid (H₂SO₄), sodium hydroxide (NaOH), hydrochloric acid (HCl), chloroform and soap/detergent used for analyses and partitions were all purchased from the *Labora International Trading PLC* which present in Addis Abeba, Ethiopia.

3.3. Solvent extraction

Arisaema Consanguineum (AC) roots were pulverized to a particle size of 1–2 nm and extracted with 70 percent ethanol at a weight ratio of AC: ethanol of 1:10, immersing the powder in the ethanol solution for 45–60 minutes with continual stirring by a magnetic stirrer [VEVOR magnetic stirrer SH-2]. For bioactive compounds, the best solvent for extraction or herbal formulation is aqueous and hydro alcohol 70 percent ethanol Fig. 2. Because, in this solvent, herbal products are produced [16, 17]. And we can use or consume those products without fear of high toxicity. It was suggested that ethanol extraction at a higher concentration would include fewer soluble solids and have better antibacterial activity. The rotating vacuum evaporator was used to prepare each extracting liquid utilizing a low-temperature decompression and extraction process at 40–60°C [18]. Finally, we filtered the extract through Whitman No.1 filter paper, and the filtrate was stored in sterile bottles at -4°C for further use.

Figure 2 Schematic representation of *A. Consanguineum* ethanolic extraction and application

3.4. Determination of qualitative phytochemical screening, Antibacterial analysis

Using a standard analytical approach, preliminary qualitative phytochemical analysis was performed to detect the presence or lack of secondary metabolites in *A. consanguineum* root extract by ethanolic alcohol. The preliminary qualitative phytochemical screening was carried out according to the literature for steroids, terpenoids, alkaloids, flavonoids, Tannins, anthraquinones, Cardiac glycosides, Saponins, carbohydrates, anthocyanins, saponin, volatile oil [19, 20], phenolic acid or polyphenols, test for phobatanin, proteins, and amino acids following the standard protocols.

3.5. Application of Arisaema Consanguineum root extract

The fabric selected for this study was a pretreated woven cotton fabric. 10x5cm samples are prepared from the selected fabrics and immersed in the solution having the required concentrations of extracted *A. Consanguineum* plant root and catalyst (sodium hypophosphite monohydrate) for 1 hour at room temperature and stirred well for 30 minutes with the liquor to material ratio of 1:5 for the pad-air dry-cure method. During padding the samples, a horizontal laboratory padder with two dips and nips process is used to obtain a maximum wet pick-up. Various concentrations of the *A. Consanguineum* extract that had to be used was 10%, 15%, and 20% w/v with 6% catalyst concentration. The treated samples were squeezed by a padding mangle, air-dried, and cured at a temperature of 120°C for 3 minutes. The fabrics treated by the extract were used for microbial treatment to determine the bioactive antimicrobial susceptibility of the extract Fig. 2.

3.6. Physical and Mechanical Characterization of Treated Cotton Fabric

The characterization of some important properties of treated and untreated fabrics are as follows, FTIR (*ASTM E168, ASTM E1252*), TGA (*ASTM E1131, ISO 11358*), stiffness (bending length) (*ASTM test method 1388-96, 2002*), tensile strength (*ASTM D 5035*), air permeability (*ASTM D737*), absorbency (*ASTM D5725-99, 2008*), and thickness (*ASTM D1777-96(2019)*). All tests of fabric characterization are carried out based on international standards.

3.7. Selection of Microorganisms

The microbes used in the study are Gram-positive (*Staphylococcus aureus*) and Gram-negative (*Escherichia coli*) bacteria because this type of bacteria is commonly found on natural plant fibers, where the clinical isolates are obtained from Amhara Public Health Institute (APHI), Ethiopia.

3.8. Assessment of antimicrobial activity (AATCC 147)

The antibacterial activity of the *A. Consanguineum* extract-treated cotton woven fabric, nonwoven fabric, and bandages were tested according to AATCC 147 (Parallel streak method) against the test bacterial culture. The treated samples were taken and cut into rectangular strips of 2.5cm x 5cm. The test organisms will be inoculated with sterile nutrient broth to retrieve a log phase culture, which can be used to determine the zone of inhibition. Sterile AATCC 147 bacteriostasis agar was dispensed in sterile Petri dishes. The log phase culture of the test organisms will be used as an inoculum.

One loop full of culture is loaded and transferred to the surface of an agar plate by making six parallel inoculum streaks approximately 40mm in length and spaced 15mm, covering the central area of the petri dish without refilling the loop. The test specimen should be gently pressed transversely across the six inoculums of the streak to ensure intimate contact with the agar surface. The plates were incubated at 37°C for 18–24 hours. The antimicrobial activity of fabrics will be assessed by the diameter of the zone of inhibition in comparison to the control fabric.

3.9. Experimental design using the design of experiment software

Based on the concentration of the parameter (20–50 g), time (45–90 minutes), and temperature (40–60°C), an antibacterial agent was extracted, and 20 trials were designed and generated using central composite design (CCD), Design-Expert® version 11 software.

3.10. Wash durability of the finished fabric

By utilizing the Launder-o-meter of the ISO: 6330-1984E standard to wash all completed samples, the washing resistance of the finish was evaluated. The washability of the treated cotton fabric was tested on a sample of 10x10cm in length. The test sample was washed 5–15 times at a standard temperature of 37°C and with a standard detergent for 30 minutes, keeping the material: liquor ratio at 1:50, followed by rinsing, washing, and drying. The antibacterial activities of the test and control cotton fabrics were determined after they had dried. The results were assessed after counting the bacterial colonies and calculating the bacterial decrease based on the following formula.

$$R (\%) = \frac{B - A}{B} * 100$$

Where R: % reduction; A: The number of bacteria recovered from the inoculated treated sample; B: The number of bacteria recovered from the inoculated untreated sample.

4. Results and Discussion

4.1. The yield of the Plant Extract

The experimental result of methanol and ethanol extract with the yield of the extract based on three parameters, which are concentration (C), time (T), and temperature (T), as shown in Table 1. To analyze the effects and interactions, analysis of variance (ANOVA) was done for both models. The actual value and model prediction value of the yield showed a good correlation, as shown in Fig. 3. Based on the ANOVA analysis, the linear equation has a p-value of 0.0001 (< 0.05), indicating that the equation model is significant Table 2. From these results, the extraction was dependent on factors like the method of

extraction, the temperature of extraction, the time of extraction, the polarity of the solvent, the concentration of the solvent, and the nature of the solvent.

Table 1
Experimental design

	Factor 1	Factor 2	Factor 3	Response 1
Run	A: Concentration	B: Time	C: Temperature	Yield
	Gram	Minute	Celsius	%
1	50	45	40	38.2
2	35	67.5	50	39.1
3	20	90	60	31.4
4	35	29.6597	50	33.53
5	35	67.5	50	36.72
6	50	45	60	38.3
7	35	67.5	33.1821	34.15
8	50	90	60	38.2
9	50	90	40	37.9
10	35	67.5	50	37.6
11	20	45	40	32.8
12	35	105.34	50	30.5
13	20	45	60	32.5
14	20	90	40	31.3
15	60.2269	67.5	50	39.3
16	9.77311	67.5	50	28.5
17	35	67.5	66.8179	39.3
18	35	67.5	50	36.7
19	35	67.5	50	38.5
20	35	67.5	50	37.4

A 3-D surface plot was used to optimize the extract and yield at the same time, with time and concentration as the parameters that determine the yield. As a result, the optimal ethanol extraction time is 45 minutes with a concentration of 45g/L; temperature 20°C; the predictive yield is 37.394 percent.

The model is significant based on its F-value of 35.06 and p-value of less than 0.0001. Furthermore, as their p-value is smaller than 0.05, both concentration and time have a substantial impact on the extract's yield. In this instance, 14.15 is the point at which adequate precision is reached. The yield's residual vs projected response plot (Fig. 4b) and predicted versus actual plot (Fig. 4a) both attest to the linear fit's high level of satisfaction. The following Experimental formula represents the yield of *A. consanguineum* root extract as a function of temperature, time, and concentration.

$$Yield = +25.429 + 0.209A + 0.0644B - 0.000104C$$

"Adeq Precision" measures the signal-to-noise ratio, which must be more than four. The ratio of this model is 14.15, which indicates an adequate signal. The predicted response values of the model are well in agreement with the actual values, which are shown in Fig. 4a and therefore determine a good fit of the 3FI model. Figure 4b depicts the residual vs predicted response plot, where the residuals are scattered randomly, indicating that the variance is constant for all experiments.

The analysis of variance (ANOVA) was used to evaluate the optimal extraction conditions of *A. Consanguineum* and the relationship between the extraction yields and variables. The results of ANOVA for the two-factorial interaction (2FI) model of phytochemical extraction are presented in Table 2. F-value and p-value can determine the significance of each coefficient. High F-values and small p-values mean that the corresponding variable is significant.

Table 2
ANOVA for the selected factorial model

	Sum of Squares	df	Mean Square	F-value	p-value	
Model	121.39	6	20.23	35.06	< 0.0001	Significant
A-Concentration	111.83	1	111.83	193.77	< 0.0001	
B-Time	8.27	1	8.27	14.32	0.0026	
C-Temperature	0.0156	1	0.0156	0.0271	0.8720	
Residual	6.93	12	0.5771			
Lack of Fit	2.03	1	2.03	4.56	0.0560	not significant

The factors F-values of concentration and time were all more than 5.71, and the p-values were all less than 0.05, but the third factor, which is temperature, had the opposite result. However, there was no significant contribution at the interactive level. That indicated the preceding two factors were significant, and the temperature was insignificant. Meanwhile, the lack of fit|| represents the part of the regression equation that fails to fit. Lack of fit being more than 0.055 indicated that the lack of fit|| of the model was not significant and the experimental errors were small.

The actual and predicted values of the experiment were not significantly different (p < 0.05), Fig.. Contour plots depict that the line yield is constant throughout different times and concentrations. The effect of the

two process variables on the yield, when the third variable was kept at the middle level, is shown on the left side in Fig. 5. The effect of extraction time and solvent concentration on yield at a fixed extraction temperature of 40°C is presented. The yield increased slowly with increasing time and moderately with increasing concentration of the solvent. As the solvent concentration increases, the extraction rate increases as a consequence of the swelling of the plant powder that may happen due to the solvent. An increase in extraction time favors extraction by enhancing both the solubility of solute and the diffusion coefficient of the solvent, but the effect is lower compared to the effect of concentration. Since the temperature is low, the possibility of degradation is very low over a prolonged time. The effect of each significant factor on the yield was also analyzed.

Design Expert (version 11.0.3.0) of the STAT-EASE software was used for simultaneous numerical optimization of the process parameters. The optimum processing conditions were obtained after assigning the solvent concentration in the range of minimum time and temperature for process parameters, and maximized for the response. When constraints in the range were selected, then the optimum conditions were found as 50 g solvent concentration, 20°C extraction temperature, and 45 minutes with the desirability of 0.917. The optimization effect is also further described graphically in Fig. 5.

4.2. Phytochemical analysis

Phytochemical is a term that refers to plant components that are being studied for their potential health benefits, but are not formally defined as essential nutrients. Carotenoids and polyphenols, which include phenolic acids, flavonoids, and stilbenes/lignans, are two important types of phytochemicals under investigation [21, 22]. To investigate plant phytochemicals by first extracting and isolating substances from the source plant, then characterizing their structure or testing in laboratory model systems such as cell cultures, in vitro research, or in vivo investigations using laboratory animals [23]. Isolating specific chemicals and analyzing their frequently complex structures, as well as distinguishing which phytochemical is responsible for any given biological function, are all challenges in this subject.

Table 3
Preliminary phytochemical constituent screening of *A. Consanguineum* plant roots

<i>Phytochemicals</i>	<i>Ethanol Extract</i>	<i>Phytochemicals</i>	<i>Ethanol Extract</i>
Alkaloid	+	Terpenoid	+
Tannin	++	Steroid	++
Flavinoid	-	Protein	-
Phenol	+	Cardiac glycosides	-
Saponin	++	Carbohydrate	++
Anthocyanin	-	Volatile oil	++

[Symbol (++) indicates present in high concentration, Symbol (+) indicates present in moderate concentration, and (-) indicates possible absence of photochemical constituents.]

This study has observed the presence of phytochemicals within *A. Consanguineum* roots are considered an active medicinal chemical constituent. Among the twelve phytochemical tests performed on the plant root, nine of the test results showed positive, and the remaining three had a negative result. In the test, phytochemicals tannin, saponin, steroid, carbohydrate, and volatile oil were found abundantly, and alkaloid, phenol, and terpenoid are present in a moderate concentration, as shown in Table 3. These important medicinal phytochemicals were investigated by phytochemical screening and qualitative estimation of the *A. Consanguineum* plant root.

Saponins can speed up a variety of biological processes, including hemolysis, antibacterial, antiviral, and antioxidative capabilities, according to [24]. Plants produce alkaloids, which are the most fundamental natural products. They are commonly found in the form of salt-containing organic acids. Among plant compounds, they are considered the most potent medicinal agents. Antimalarial, antiasthmatic, anticancer, analgesic, and antibacterial effects are among the pharmacological activities of pure synthetic alkaloids [25]. Tannin is a therapeutic compound derived from several parts of the plant. The phenolic hydroxyl group found on the surface of tannins is responsible for their medicinal potential. This family of proteins binds to protein adhesins, causing enzyme inhibition, plasma membrane rupture, and microbial substrate shortage. Flavonoids are phytochemicals found in plants that have anti-inflammatory, antibacterial, and antioxidant properties, according to [26].

Medicinal plants and the phytochemical components found in their extracts can be a valuable therapeutic alternative, as well as a valuable tool in combating the threat of multidrug-resistant pathogenic infections. Some phytochemicals are well known for their antimicrobial characteristics, which are essential at the therapeutic level. The wound healing characteristics of different phytochemicals, according to [27], are attributable to their suppression of platelet aggregation, anti-inflammatory, anti-microbial, and antioxidative activities, which reduce the incidence of wound diseases. The qualities of traditional wound therapy formulations, particularly herbal and other therapeutic remedies used around the world, are still being studied scientifically [28].

According to many studies, phytochemical elements such as alkaloids, tannins, saponins [29], and flavonoids, terpenoids, and volatile oils enhance bioactive medicinal therapy and wound healing, mostly due to their astringent and antibacterial qualities, which appear to be responsible for wound healing [30]. Tannins, terpenes, saponins, volatile oils, steroids, terpenoids, and alkaloids were discovered in the *A. Consanguineum* root extract during preliminary phytochemical analysis. The discovered phytochemicals, alkaloids, tannins, saponins, and volatile oils are responsible for the antibacterial action, which is significantly employed for wound healing, according to different research.

The treated textile material is valuable to minimize the agglomeration of the active component and regulate the release rate. Due to the high number of reactive groups (i.e., hydroxyl groups) within each linear glucose ring that are linked by $\beta(1 \rightarrow 4)$ glycosidic bonds on the cellulose surface, it can be readily

functionalized with various functional groups, such as alkaloids, aldehydes, phenolic acids, tannic acid, and amines, leading to diverse properties. During the surface modification of cellulose, the OH from the active component reacts with the OH from cellulose to release water [31]. The oxygen linkage is formed between the phytochemical and cellulose surfaces. As the effect in this case is due to a polyphenolic compound having a good affinity for cellulosic, it is expected to have high durability [32].

4.3. Physical characteristics of A. Consanguineum plant root extract FTIR transmittance spectra of A. Consanguineum extract

The measurement of IR radiation absorption by a sample plotted with the wavelength is known as FT-IR spectroscopy. The correlation of the absorption bands (vibrational bands) with the chemical components in the sample is required for IR spectrum interpretation. This method can be used to identify the phytochemicals and biomolecules found in *Arisaema* root extracts that are responsible for the decrease of specific bacteria. Figure 8 shows the FT-IR spectrum of *A. Consanguineum* root extracts. The results of FT-IR spectroscopic analysis of the extracted agent revealed the presence of alcohols, phenols, carboxylic acids, ethers, aromatics, aryl ketones, polysaccharides and polyphenols, and alkyl halides.

The band at 3253 cm^{-1} in the IR spectrum of *Arisaema* root extract is attributable to stretching vibrations of OH groups in water, alcohol, and phenols, as well as NH stretching in amines. The C = C stretch in aromatic rings and the C = O stretch in polyphenol flavonoids are responsible for the weak band at 1605.9 cm^{-1} . Aromatic amines (C–N stretch) were detected at a peak of 1324.3 cm^{-1} and in polysaccharides, C–O–C stretching produces a band at 1149.5 cm^{-1} and the band at 1077 cm^{-1} showed carboxylic acid O–C stretch, while C–O stretching in amino acids, ethers and primary alcohols produces a band at 1002.71 and 1037 cm^{-1} . Finally, halogen compounds (alkyl halides) like chloro compounds (C–Cl) and iodo compounds (C–I) of functional groups are present within $500\text{--}620\text{ cm}^{-1}$ bands. FT-IR analysis of the solvent extract of *A. The consanguineum* plant root separated the functional groups of the components based on its peak ratio, which identified the chemical compounds, according to the findings of the current study. These chemical components may be responsible for the plant's different medicinal properties.

4.4. Thermogravimetric study (TGA) of A. Consanguineum extract

This analysis was done on the estimated lifetime of medical components related to thermal stability. As observed from the result in Fig. 9 of TGA, the extract (plant) component can have thermal stability until the temperature is up to 40°C . At this point, water and some components present in the plant extract were removed (e.g., volatile oil). The major weight loss occurs at 150°C , which may be due to the removal and decomposition of organic groups present in the sample during extraction at high temperature. The continuous decrease of the slope may be owing to the wettability of the *A. Consanguineum* extract. After 150°C , steady weight loss or almost no variation in weight has occurred [33]. Therefore, the treated fabric should be stored at a temperature of $20^{\circ}\text{C}\text{--}30^{\circ}\text{C}$. Outside of this limit, some active components can lose their activeness. As per the result, it is recommended to extract phytochemicals using the cold extraction

method since it is temperature sensitive, and the pad-air-dry method of application is recommended over the exhaustion method.

4.5. Air permeability of the treated fabric

According to Table 3 and Fig. 10, the air permeability of *A. Consanguineum* root extract-treated fabric is demonstrated. Fabric structure, thickness, density, surface characteristics, and other factors all influence air permeability [34]. The air permeability of untreated cotton fabric is higher (49.6N), followed by a decrease in treated ones; this is consequently due to a decrease in porosity or open space among the fabric treated, which is slightly blocked by the size of the extract particles and has a lower cover factor. As a result, the air permeability of treated cotton fabrics decreases slightly as the concentration rises. As the extract concentration on the fabric increases, the air permeability decreases. As is evident, the *A. Consanguineum* plant root extracts are uniformly embedded and finally disappear as well-dispersed on and penetrating the fiber surfaces in both treated fabrics at different concentrations, giving uniform results of air permeability as the tests are taken from different parts of the treated sample. As a result, the fabric's air permeability was unaffected, indicating that *A. Consanguineum* plant root-treated and untreated cotton fabrics have the same level of breathability.

4.6. Absorbency of the treated fabric

A greater absorbency score indicates that the material can absorb more water and, as a result, is more absorbent [35]. Table 4 shows the absorbency of all test samples using water as the testing liquid. The treated fabric shows better absorbency in water. The absorbency is decreased from low concentration (10%) to high extract concentration (25%). From the result, the sample treated at 10% extract concentration has the best absorption ability, as it has good water circulation in the pore size of the fabric after treatment (35.2%). In a 20% extract concentration, the treated fabric absorbency was 28.33% which is lower than that of 10% and 15% extract concentration. Since proper absorption of water is an important feature expected from plant extract, treated cotton fabrics having high absorbency have been primarily selected. As a result, improved absorbency can tell us that the treated fabrics are highly important for bioactive wound dressing fabrics.

Table 4
Properties of plant root extract-treated fabric

Treatment	Air permeability (cm ³ /cm ² /sec)	Tensile Strength (N)		Elongation at break (%)		Absorptivity (%)	Bending length [36]	Thickness
		Warp	Weft	Warp	Weft			
Untreated	49.6	289	245	5.85	15.8	42.8	1.82	0.37
Treated @ 10%	46.2	271	228	6.82	14.5	35.2	2.08	0.40
Treated @ 15%	44.3	263	213	7.33	11.6	31.67	2.2	0.41
Treated @ 20%	43.5	250	187	9.80	9.75	28.33	2.25	0.41

4.7. Bending length (Stiffness) of the treated fabric

Both the handling and tailoring performance of textile fabrics are influenced by their bending qualities. Table 4 shows how the bending length of the treated samples was measured to determine the fabric's hand value. When compared to the untreated sample, the bending length of the samples treated with plant extract rises from 1.82 to 2.25cm linearly in a minimal amount with concentration [37], but it is not significant to affect the handle of fabric when worn on human skin or dress. This could be owing to the presence of cross-linking agents and a high concentration of the extract (10–20% w/v).

4.8. Tensile Strength of the treated fabric

Textile materials' serviceability or durability is an important attribute that is closely related to fiber strength and elongation for their potential usage as apparel fabric [38]. As shown in Table 4, the Tensile strength and elongation at break of *A. Consanguineum* plant root extract-treated cotton fabrics in warp and weft directions are present. Tensile strength is reduced, and elongations at breaks are increased in treated samples as opposed to untreated cotton fabrics. For the treated samples, the Tensile strength of the warp direction appeared to be better than the weft direction in the comparison. The result shows that the tensile strength of the treated fabric gradually reduced as the concentration of *A. The consanguineum* plant root extract was increased. This decrease in strength is most likely due to the extraction binding to fibers and yarn.

4.9. Antibacterial analysis

The plant species reported here are traditionally used in Southern Ethiopia to treat bacterial infections, often addressed by local healers as wound healers. This study aimed to evaluate the antibacterial properties against Gram-positive and Gram-negative bacteria when the extract was applied to cotton fabric

for bioactive medical textile application. There is a great demand for this eco-friendly antimicrobial finished textile.

Table 5
Determination of the antimicrobial activity of the crude extract of *A. Consanguineum* plant root

Treated sample	Extract concentration (%) [Zone of Inhibition (mm)]					
	10	15	20	10	15	20
	Staphylococcus aureus			Escherichia coli		
Untreated	0	0	0	0	0	0
I	17.30	20.60	19.10	16.60	17.50	20.40
II	16.50	18.30	21.80	19.10	18.80	17.50
III	19.20	20.50	20.20	15.80	19.70	18.6

Table 5 and Fig. 11 show a significant inhibition zone in all antimicrobial-treated cotton fabrics. The most sensitive bacterial strain proved to be *Staphylococcus aureus*, gram-positive, followed by *Escherichia coli*, gram-negative, displaying zones of inhibition 16.5–21.80 mm and 15.80–20.40 mm, respectively. The least activity was obtained with 10% extract concentration for both *S. aureus* and *E. coli*, exhibiting a zone diameter of 15.80–19.20 mm. At high concentrations (20% extract), the antimicrobial activities against *S. aureus* and *E. coli* were highest, with zones of inhibition of 21.80 mm for sample II and 20.40 mm for sample I. This suggests that the phytochemicals present in the extract may be responsible for the antibacterial activity. As it was explained, *A. Consanguineum* root extract showed greater activity against nearly all tested bacterial strains. *S. aureus* is the most sensitive microorganism when exposed to plant extracts. From this result, we understood that the antibacterial agent of plant extract was against the bacteria when applied on the cotton fabric, which shows the plant extract has a medicinal property that is recommended for a bioactive medicinal textile, as it might be used on wound healing textile. Furthermore, the antibacterial activity results demonstrated that the extract had a larger zone of inhibition against all bacterial strains at all concentration ranges compared to the control fabric.

The differences in morphological constitution between Gram-positive and Gram-negative bacteria may explain the difference in sensitivity between these microorganisms. Gram-negative bacteria have an exterior lipopolysaccharide membrane that prevents antibacterial chemicals from penetrating the cell wall [39]. Gram-positive bacteria, on the other hand, are more vulnerable due to the lack of an effective permeability barrier in the outer peptidoglycan layer. Gram-negative bacteria have more complex cell walls than Gram-positive bacteria, which act as a diffusion barrier and make them more resistant to antibacterial treatments [40].

Various antimicrobial textile materials are developed using a variety of natural active agents from different parts of plants, such as leaves, seeds, roots, flowers, and stems. They could be effective against both gram-positive and gram-negative bacteria, depending on the type of components present in the plant

extract. Hence, the research on eco-friendly antimicrobial agents and their application to various textile products has gained worldwide importance. Among these, the *A. Consanguineum* plant root extract is applied to textile material for bioactive medicinal applications. In this study, the extract was applied to cotton fabrics that showed the highest antibacterial property, and the treated fabrics have good moisture absorbency.

Each antimicrobial agent's mode of action on the textile will be different. This is determined by elements such as the chemical and structural makeup of the cells, as well as the level of affinity for certain target areas within the cells. The known antibacterial mechanisms of medicinal plants (i.e. *A. Consanguineum* plant root) against gram-positive and gram-negative bacteria were to hinder cell wall construction, accumulate in bacterial membranes, causing energy depletion, or interfere with cell membrane permeability, resulting in increased permeability and cellular constituent loss, membrane disruption causes mutations, cell damage, and death by altering the structure and function of critical cellular elements [41]. Cellulose textile substrates can act as a physical barrier against the deposition and proliferation of microorganisms on the wound bed. Although cellulosic materials are incapable of preventing or treating an infection, surface modification can endow cotton cellulose wound dressings with desirable antimicrobial properties, as was also obtained by [42].

The mechanism is that the bacterial cell wall forms a complex with the surfactant on the surface of the treated textile material. Since the activity of bacteria gets under control, and those of hydrophobic groups further penetrate and interrupt protein activity. The cationic alkaloid and saponin groups can entice the negatively charged cell membrane of bacteria (*E. coli*). This enticed interaction reasons for the formation of the surfactant-microbe complexes, and this can accordingly interrupt the activity of proteins, including all significant roles in the cell membrane and bacterial DNA. In addition to this, the hydrophobic groups can penetrate microorganisms and interrupt all key cell functions. The phenolic acid and tannin could be ionized in water [43]. A similar action of control exists between anionic phenolic acids and tannins in the positively charged cell membrane of bacteria (*S. aureus*).

4.10. Wash durability

The cotton fabric treated with *A. consanguineum* root extract had good wash durability against both *S. Aureus* and *E. coli*, according to Fig. 11. As the number of wash cycles increased from 0 to 15, the antibacterial property declined. Significant antimicrobial activity was actively kept in the fabric for up to ten washings, according to a wash durability test conducted on test cloth treated with *A. consanguineum* plant root extracts against *S. aureus* and *E. coli*. After ten washes, there was less activity in the cloth, and the proportion of bacteria reduced was very low even after multiple wash cycles.

Good antimicrobial qualities against *E. coli* were also demonstrated by the antimicrobial finish's efficacy on the concentration 10 washed fabric for the fabric treated with *A. consanguineum* plant root extract. According to the findings, even after 15 wash cycles, a higher concentration of treated cotton fabric demonstrated good wash durability against *E. coli*. In the case of *S. aureus* and *E. coli*, the antibacterial property declined as the number of wash cycles increased.

5. Conclusion

There has never been a report on the phytoconstituents of the root of *Arisaema* plants. TGA and FTIR spectral analysis of *A. Consanguineum* plant root extract reveals that it contains a variety of functional groups and fatty acids that are responsible for a variety of medicinal activities. It is strongly suggested that further research in the many-sided field of natural products is needed to isolate, typify, and explicate the structure of bioactive molecules, which ensure wound healing trials by applying to textile fabrics, and develop an effective plant-based natural wound healing tissue for various ailments in terms of health security. Treatment of cotton fabric with *A. Consanguineum* plant root extract marginally decreases tensile strength, elongation at break, air permeability, and absorbency, whereas both bending length and fabric thickness slightly increase. Cotton fabrics treated with *A. Consanguineum* plant root extract had good antibacterial action against *E. coli* and *S. aureus*, whereas untreated cotton fabric did not show any antimicrobial activity. *S. aureus*, on the other hand, was more inhibited than *E. coli*, both before and after washing. The concentration of *A. Consanguineum* root extract had a direct association with antibacterial activity. Without the necessity for an antimicrobial test, this relationship can be used to impart the required antibacterial activity based on the concentration of the extract. Overall, cotton fabrics treated with *A. Consanguineum* root extract had better antibacterial activity against *S. aureus* than *E. coli*, and the antimicrobial activity was more resistant to washing. As a result, this research emphasizes the potential of *A. Consanguineum* plant root extract as an antibacterial treatment on cotton fabrics for improving bioactive medical textile applications.

Declarations

Funding statement

The authors declare that no funding was received for this research.

Ethics Statement

This research did not involve human participants or animal subjects. Therefore, beyond each author's approval, no further consent is required for publication.

Competing interests: The authors declare no competing interests

Author contributions statement

All authors reviewed and approved the final version of the manuscript. The publishing of this study, including the primary text and supporting data, has been approved by all authors.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. The datasets generated during and/or analyzed during the current study are generated from experimental data and Design Expert Software.

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Figures



Figure 1

A. Consanguineum plant leaf and its roots

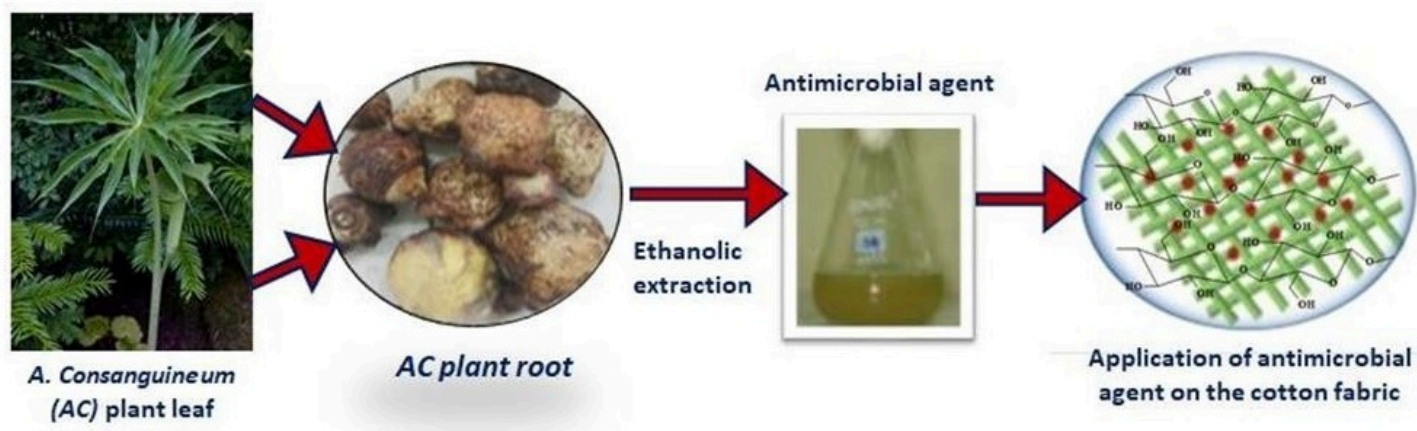


Figure 2

Schematic representation of *A. Consanguineum* ethanolic extraction and application

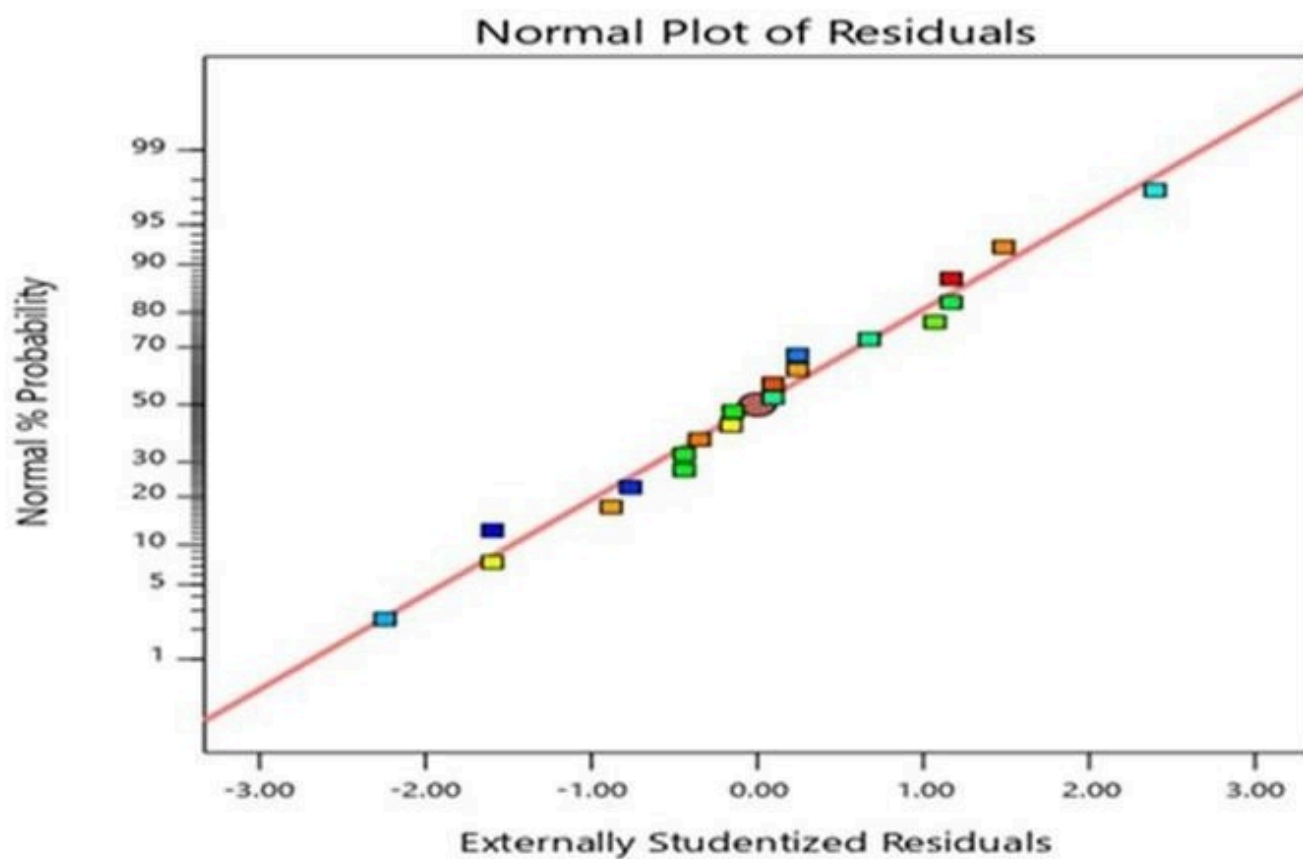


Figure 3

Normal plot of residuals

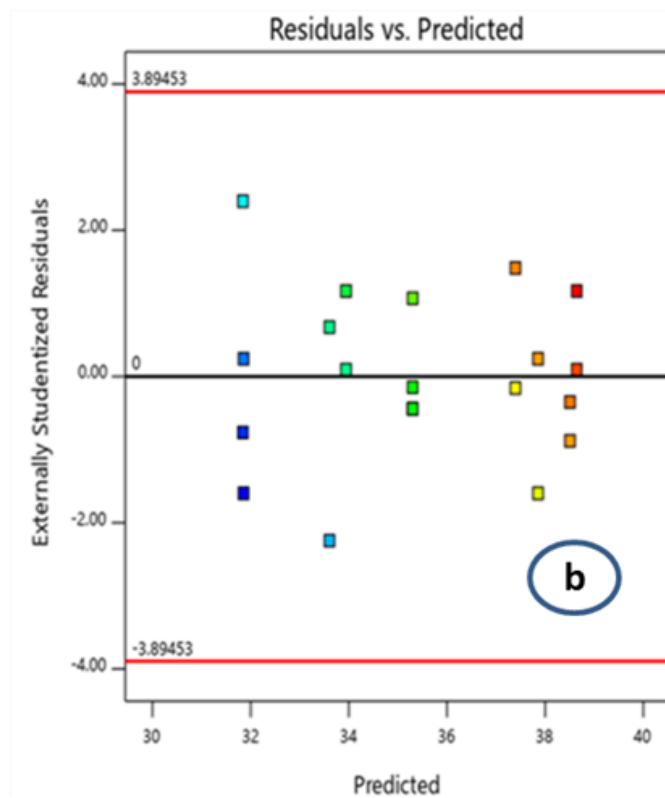
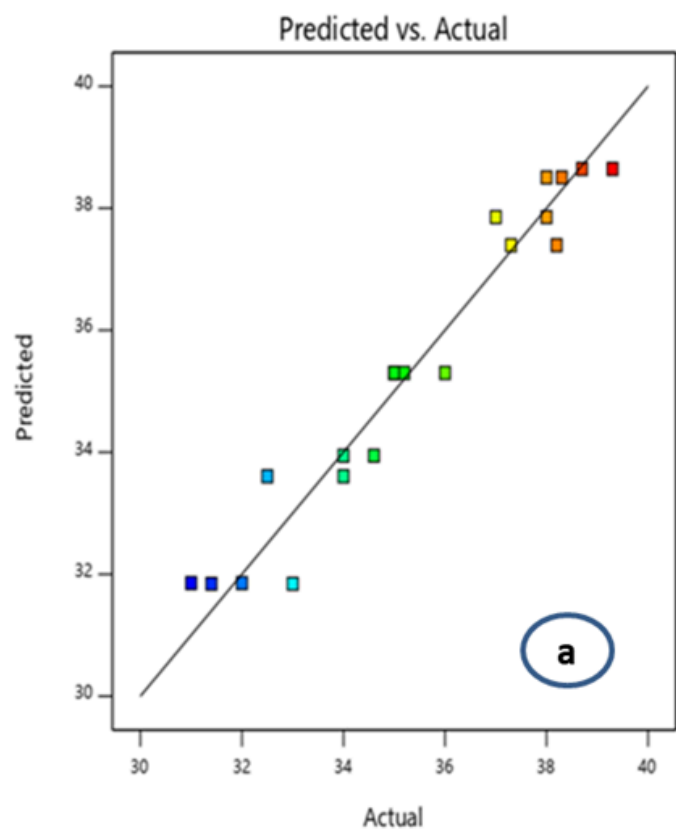


Figure 4

Predicted vs actual (a) and residual of experiment (b)

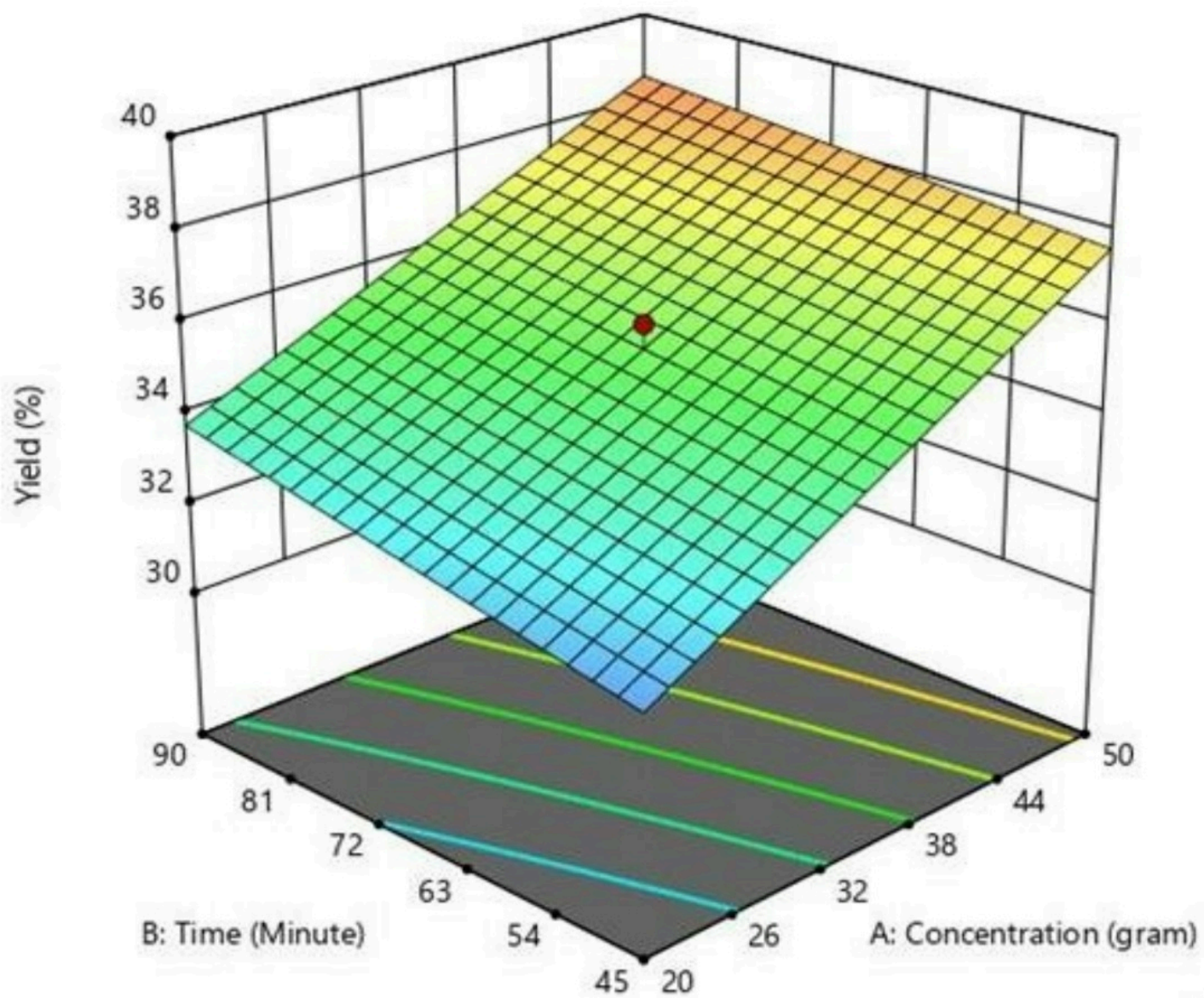


Figure 5

The effect of concentration, time, and temperature on the yield of the extract.

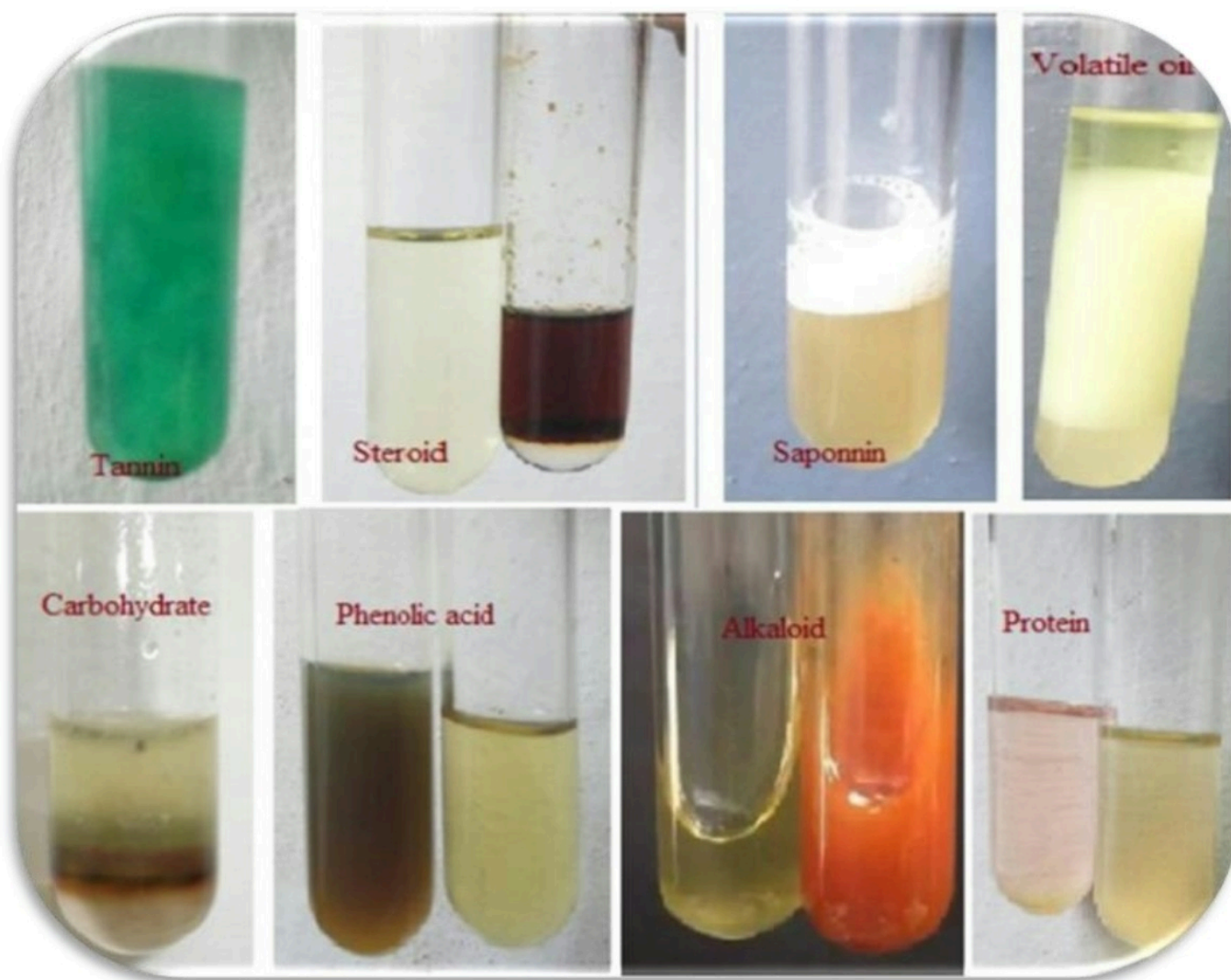


Figure 6

Phytochemical screening of *A. Consanguineum* root extract



Figure 7

The existence of a variety of functional groups

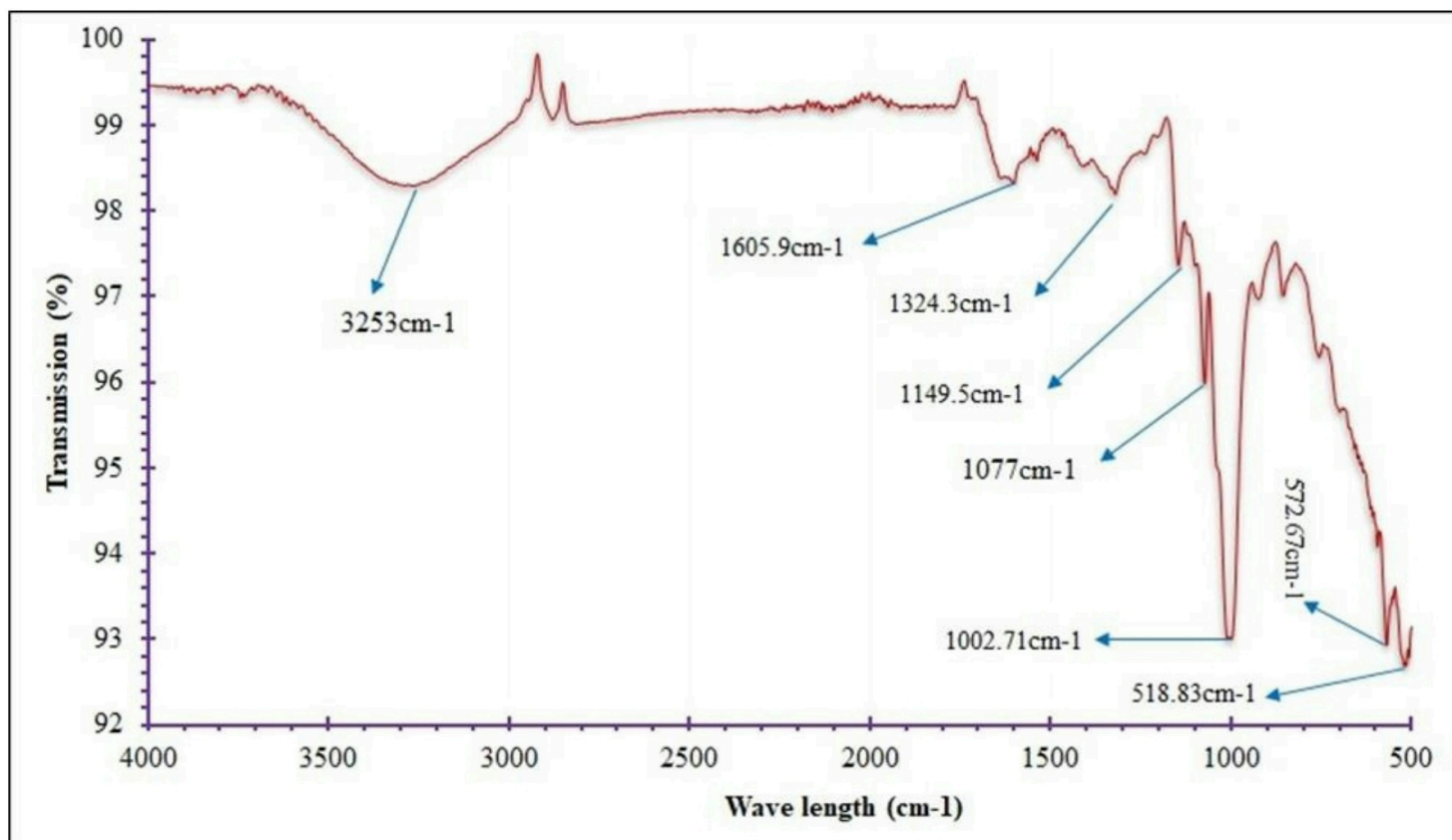


Figure 8

FTIR Spectrum of *A. Consanguineum* plant root extract

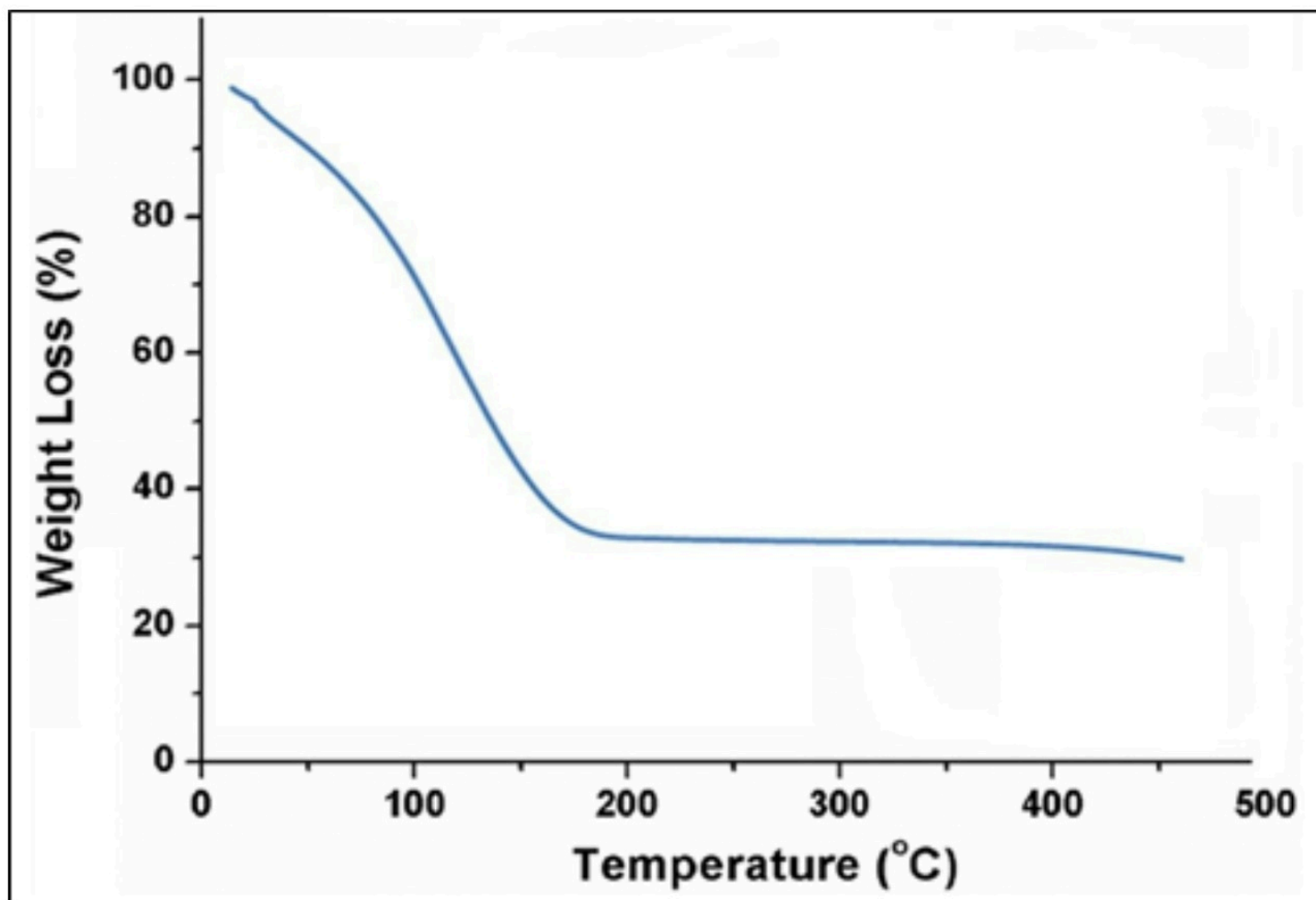


Figure 9

TGA graph of *A. Consanguineum* plant root extract

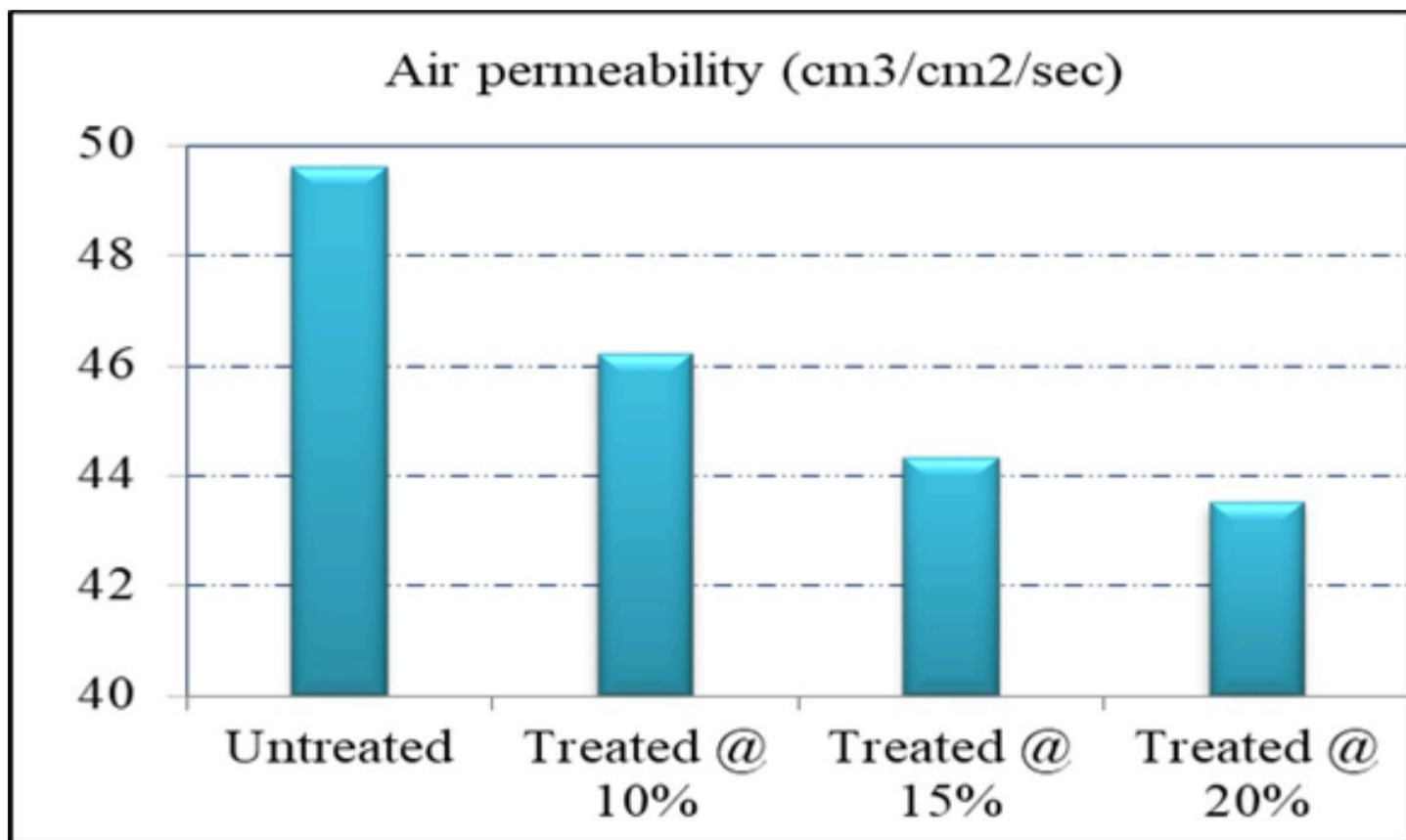


Figure 10

Air permeability of untreated and *A. Consanguineum* extract-treated cotton fabric.

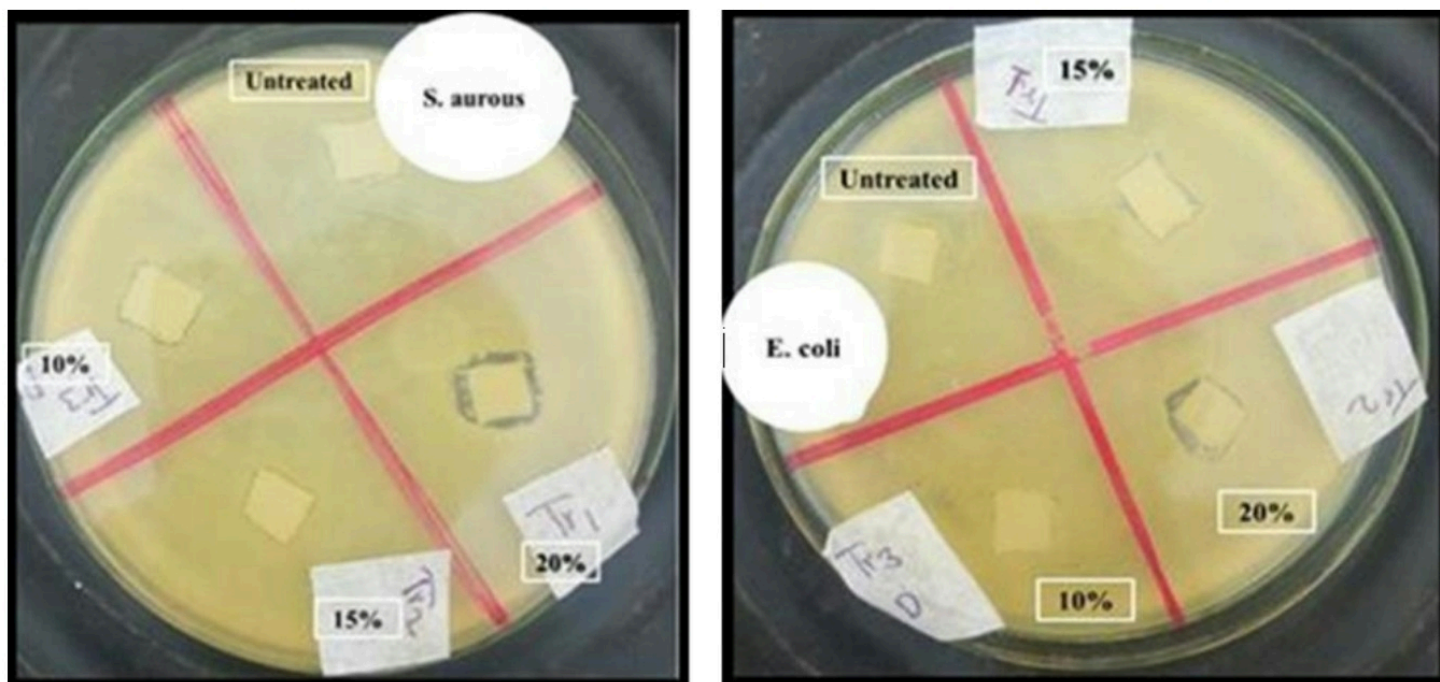


Figure 11

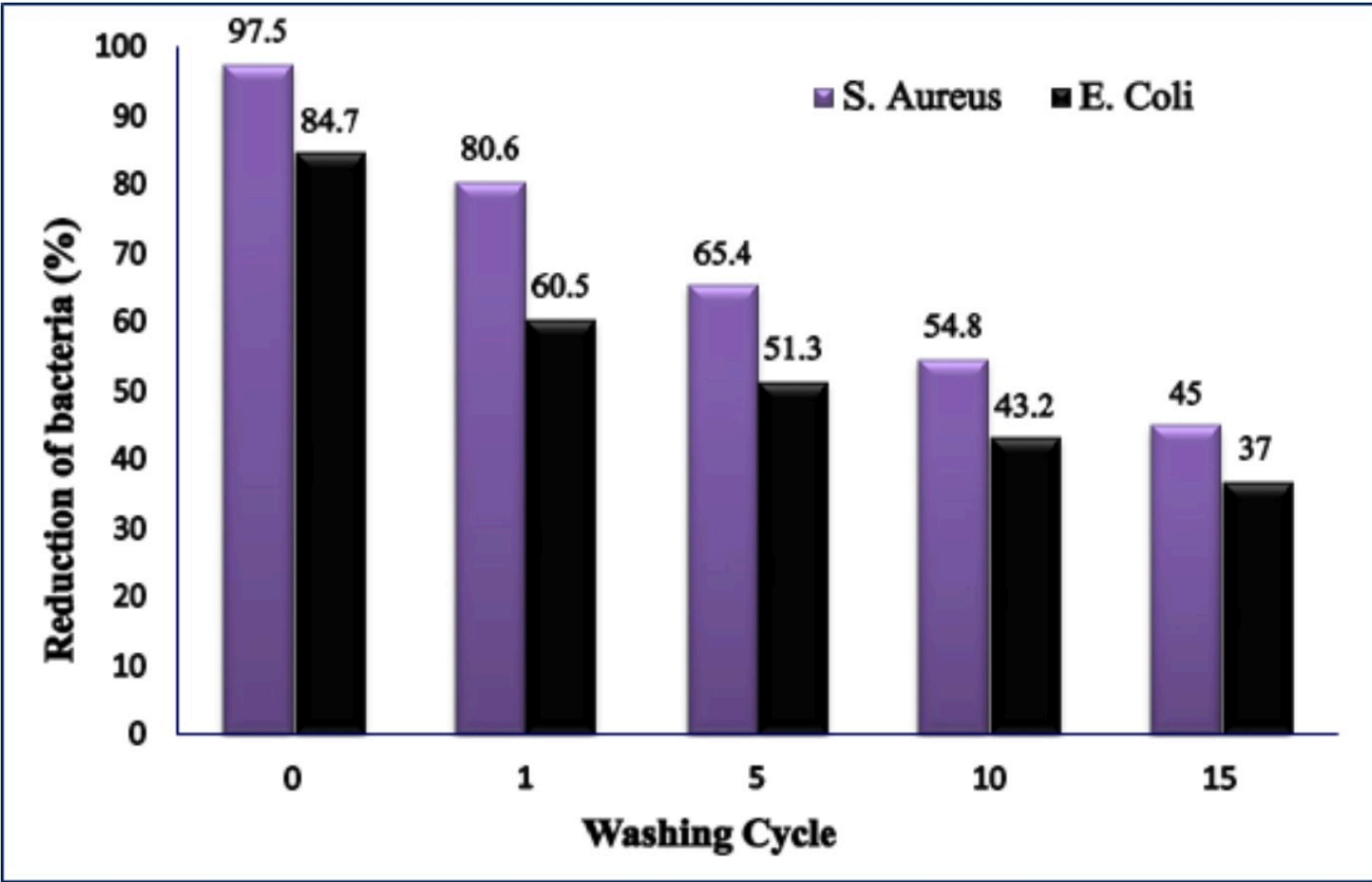


Figure 12

Wash durability of *A. Consanguineum* plant root extract-treated cotton fabric