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Application of Coriander to Medical Cotton Bandage for the Development of Antimicrobial and Wound-Healing Properties

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ABSTRACT
The aim of the research is to create a medical bandage utilizing an eco-friendly herb extract that is both antibacterial and wound-healing without the use of external dressing materials. The goal was accomplished by solvent extraction of the coriander herb (Coriandrum sativum). Ten layers of extracted solution were combined with one cotton bandage to create it using the pad-dry-cure technique. Following the same process, a second sample was created with a single layer using a ten-fold more concentrated coriander extraction solution. The K/S value measurement, SEM analysis,ATR analysis, and antimicrobial test were performed on treated materials. Implementations of the samples were made on a rabbit's wound site to demonstrate their ability to recover. The second sample's K/S value was remarkably similar to that of the first sample's tenth layer which was 0.89. The second sample's SEM picture showed that a significant amount of coriander extract had been deposited on the fibre surface. The presence of coriander extract's phytochemicals in the treated sample was confirmed by ATR analysis. Samples that had been padded with coriander extract had zones of inhibition (ZOI) against Gram-positive and Gram-negative bacteria that were 14 mm and 12 mm, respectively, in terms of antibacterial activity. Healing of the wound showed good results when the bandages were removed after seven days. The wound had fully recovered. Environmentally friendly products are in high demand in the medical industry. Therefore, these modified samples are marketable for use as medical bandages.

KEYWORDS
antimicrobial properties, wound-healing, medical bandage, coriander extract, coriandrum sativum

INTRODUCTION

Wound dressings encourage the ideal conditions for wound healing while safeguarding the wound from harm, pathogens, and extra infection. Textile wound dressings can be made from both natural (cotton, silk, and linen) and synthetic (polyester, polyamide, polypropylene, and polyurethane) polymers. Even if synthetic polymers have the right mechanical and thermal properties, they can be toxic to wounds. Natural polymers, on the other hand, frequently promote cell growth and are biocompatible. Cotton cellulose, the finest form of cellulose, has the highest molecular weight and is highly crystalline, oriented, and fibrillary [1]. Cotton has been used for medical applications for its moisture control, insulation, comfort, and hypoallergenic properties as well as adaptable and effective three primary sterilization methods (steam, ethylene oxide, and gamma radiation). It is one of the safest fibres on the planet with both absorbent and non-absorbent cotton varieties. It has shown promising effects in the management and maintenance of patients' health. The best example of cotton in the medical field is cotton bandages in the form of woven, knit, non-knit, elastic, and non-elastic varieties. Natural healing takes a long time, and there is a possibility that the wound will develop into a chronic state if not treated properly [2]. The majority of clothing and pharmaceutical products on the market are chemical-based, and extremely bad for the environment. With eco-friendly herbal finishes, and sustainable goods on fabrics, medical bandages can take the place of standard chemical-based dressing materials, but there is a vast area for research, and improvement [3].

Cristian Dima et al. examined a study on encapsulated coriander essential oil in -CD (Beta-Cyclodextrin) matrix to determine and assess the antioxidant and antibacterial characteristics. They showed that a wide range of bacteria are inhibited by coriander essential oil. Especially, more sensitive strain *S. cerevisia*e MIUG D9 showed higher antifungal activity against the *A. niger* MIUG M5 and *P. glaucum* MIUG M9 strains (9.0 mm) [4]. Silva et al. studied the antibacterial effects of coriander extract oil on food preservatives and showed antioxidant activity, broad antimicrobial effectiveness, and bactericidal activity within 30 minutes of contact against several foodborne pathogens. Its safety as an ingredient in food makes it an appealing and valuable choice for the development of natural-based food preservation techniques [5]. Ketema et al. discovered that nettle leaf extract, which crosslinks with cotton fibres in the presence of citric acid, has a higher antibacterial capability. On textile substrates, especially cotton, it demonstrates a strong antimicrobial finish with fine stability and fastness with the highest bacterial reduction percentage against S. aureus and E. coli [6]. El-Shafei et al. investigated the effects of sage, chamomile, and green tea extracts on cotton fabrics to discover their antibacterial capabilities in the presence of crosslinking agents. The sample extract-treated fabric demonstrated good disinfection characteristics with increased degradation in colonies generated. The treated fabric showed no degradation of related Physical characteristics [7]. Similar antimicrobial finishes have been applied using Curry Leaves oil and Ginger extract by Zaghloul et al. with four distinct solutions that were then infused with carrier oil. The extract content increased the antimicrobial resistance proportionally with no negative impact on the fabric's physical characteristics [8]. Similarly, the Aloe vera and neem leave mixture also showed good antibacterial and antifungal qualities with a great wash fastness [9]. A tulsi extract on children's apparel, socks, bedspreads, cotton gloves, diapers, cotton head caps, and innerwear, the herbal-washed fabric can reduce the incidence of bacterial and fungal infections [10]. Pomegranate rind and tulsi leaf extract also demonstrated a significant zone of inhibition to gram-positive and gram-negative bacteria to be applied for single uses, such as surgical cloth, bandage gauze, and uncleansed sanitary napkins [11].

Several attempts have been conducted for wound healing bandages with natural plant extracts with antimicrobial properties, but still, there are plants to be analysed for wound healing applications. The study introduces a novel approach to wound healing and antimicrobial application of cotton medical bandage with natural extract as there has been no such application till now as per the authors' knowledge. Thus, the study's primary goals are to create cotton bandages with a herbal finish using aqueous coriander (*Coriandrum sativum*) extracts and to assess the effectiveness of wound healing by using these bandages to cover a rabbit's wound.

EXPERIMENTAL

Materials and Methods

Cotton medical bandages of woven gauge were used according to the specifications mentioned in Table 1. To perform this research, a variety of substances, including ethanol, H_2O_2, enzyme, Na_2SO_4, CH_3COOH, and NaOH, were used. Coriander was utilized. Coriander (*Coriandrum sativum*) often known as Chinese parsley, is a feathery annual plant in the Apiaceae family that is used as a spice and herb (Figure 1). Table 2 shows the part of the herbs used in the research.

Table 1. Specification of cotton bandage (woven gauze)

Features	Description
Fabric type	Woven
EPI (Ends Per Inch)	19
PPI (Picks Per Inch)	16
GSM	26
Count	40 Tex

Figure 1. Coriander (Coriandrum sativum) herbs

Table 2. Specification of natural herb

General Name	Binomial Name	Used portion as a colourant
Coriander	*Coriandrum Sativum*	Leaf

Solvent Extraction Process

The leaves were first cleaned with water to get rid of any dust. Then the leaves were dried. The dried leaves were then cutwith a scissor into smaller pieces. The leaves were almost reduced to powder. A sieve was employed to filter out the large particles. The dried leaves were dissolved in ethanol using a 1000 mL conical flask. Before dissolving 100 g of chopped leaves in one litre of ethanol, they were weighed (1:10 ratio). The conical flask's open end was wrapped with aluminium foil sheets to prevent ethanol evaporation. This remedy was then maintained for 7 days. The extracted liquor was filtered with filter paper after 7 days. The ethanol was then evaporated from the extracted liquor by heating it to 30–40 °C (Figure. 2). It was then prepared for usage [12].

Phytochemical Screening of Coriander (Coriandrum sativum) Herbs

To conduct the phytochemical analysis, a small amount of the methanol extract was used. Alkaloids, flavonoids, tannins and phenols, saponins, steroids, terpenoids, carbohydrates, amino acids, and proteins are among the phytochemical assays (Table 3). For, Alkaloids, A few drops of Mayer's reagent were added to 1 ml of extract. A few drops of Wagner's reagentwere applied to 1 ml of extract. For Flavonoids, one millilitre of the extract was heated for a short time after which a few drops of HCl were added. After adding a few drops of sodium hydroxide. For Tannins, to 2 ml of extract, mild ferric chloride (1–2 drops) and 10% lead acetate were added. For Saponins, 3 mL of aqueous extract was combined with 10 mL of distilled water. The solution was vigorously shaken for 5 minutes. It took around 30 minutes for the effect to become apparent. For Steroids, 2 ml acetic anhydride and 2 ml concentrated H_2SO_4 were added to 1 ml aqueous extract. Any colour variations were observed. For Terpenoids, 2 mL chloroform and 3 mL concentrated H_2SO_4 were added to 1 mL extract respectively. Any colour differences were seen. For Carbohydrates, one millilitre of the extract was added to a few drops of Benedict's solution, which was then heated. The result was evident. For Amino Acids, one millilitre of the extract was mixed with a 10% Ninhydrin solution. For Proteins, to 1 mL of extract, a few drops of FC reagent were added [13].

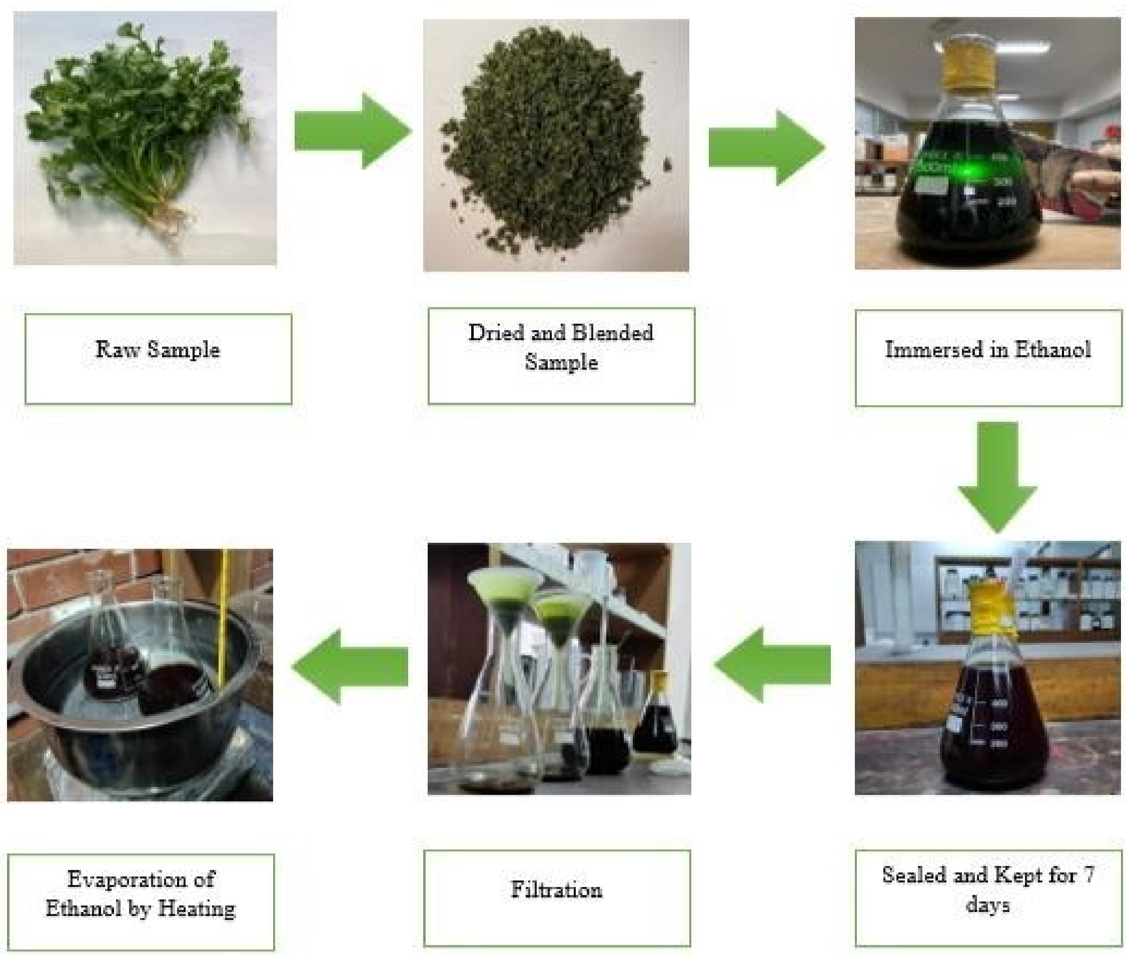
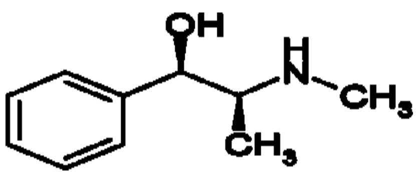
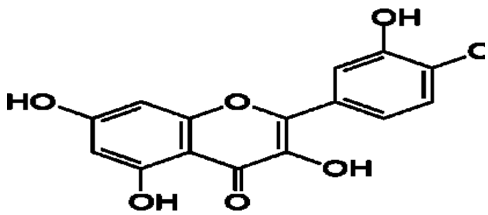
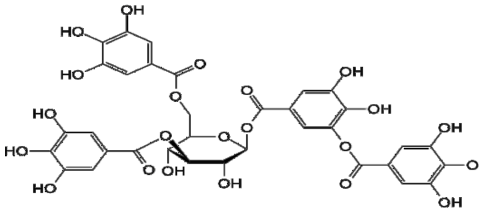
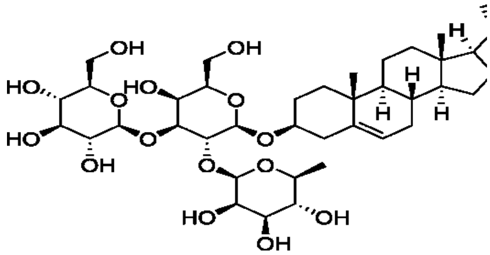
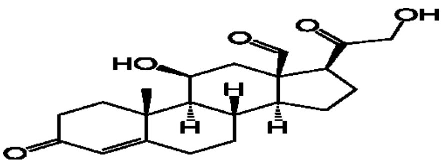
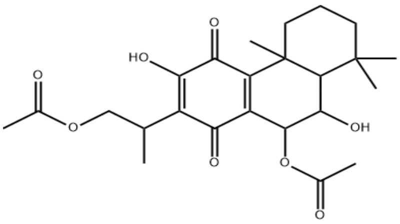
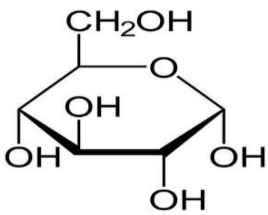
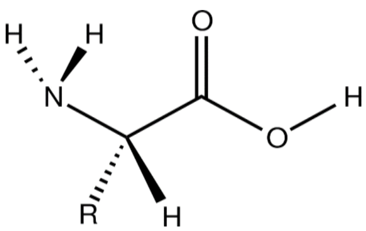
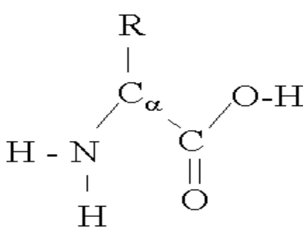


Figure 2. The solvent extraction process of Coriander (*Coriandrum sativum*) herb

Table 3. Presence of phytochemical constituents in aqueous extract of Coriander (*Coriandrum sativum*) herb [14]

Phytochemicals	Structures	Inference
Alkaloids		Absence of alkaloids
Flavonoids		Absence of flavonoids

Phytochemicals	Structures	Inference
Tannins		Presence of tannins
Saponins		Absence of saponins
Steroids		Absence of steroids
Terpenoids		Presence of terpenoids
Carbohydrate		Presence of carbohydrates
Amino acids		Presence of amino acids
Proteins		Presence of proteins

Padding of Extracted Liquor on Cotton Fabric

Using a pad dyeing machine, coriander extract was applied to cotton cloth. The fabric was submerged in a roller while being padded. After that, it was squeezed to extract more solutions. This process was used to naturally saturate the material with the solution. For padding, the fabric was either folded or batched, and then it was applied to the padding machine over a set of rollers. The first sample was made by running the padding machine ten times while adding ten layers of coriander extract. The cloth surface had a noticeable stain accumulation from repetitive cushioning. To solve this issue, the amount of coriander extract was calculated ten times, and the second sample was then padded once with a solution of ten times as much concentrated coriander extract. The Stenter Machine was then used to dry the two samples.

Assessment of K/S Value

After bleaching the fabric, the colloidal silver nanoparticle solution made from herbal extracts discolours it. Along with the K/S value, the rate of stain release from coating foam on cotton fabric was examined. In this case, the K/S value determines how much colloidal fluid containing naturally occurring silver nanoparticles is deposited on the fibre surface. The average of five values was computed for each fabric after it had been folded once for a total thickness of two.

Scanning Electron Microscope (SEM)

The scanning electron microscope (SEM) of treated and untreated fabric was conducted to check the morphology of the fabrics.

Attenuated Total Reflection Test (ATR)

Attenuated Total Reflectance (ATR) was conducted to investigate the state of deterioration of treated fabric as well as to validate textile processing (dying/finishing).

Assessment of Antibacterial Activity (Disk Diffusion Method)

Maintenance of Bacterial Culture

Fresh sub-cultures of each bacterial strain were performed on tryptone soya agar media. To match the turbidity of the 0.5 McFarland Standard (1.09108 CFU/mL), one lapful colony was taken from each freshly cultured plate and used to inoculate 9 mL of tryptone soya broth. The mixture was then incubated in an incubator at 37 °C overnight. Reduced cell density per millilitre was achieved by thinning the suspension medium.

Antimicrobial Susceptibility Testing

The modified method of disk agar diffusion was employed to test susceptibility. First, a cotton gauze stick was used to evenly splatter the standardized bacterial broth medium onto the surface of Mueller Hinton Agar (MHA) dishes. Before depositing the samples on agar plates, the medium surface was dried for 5–10 min, but no longer than 15 min, to allow absorption of further moisture. Before the agar plates were seeded, the swab was rotated to remove any extra suspension. The inoculated MHA plate was then covered with the sample and the positive control (Amoxycillin). For proper diffusion,the plates were left to stand at room temperature for at least 30 minutes. As a positive control, Amoxycillin antibiotic disks (5 g/mL) were employed for each microorganism. The plates were kept for 24 hours at 37 °C. The dishes were then examined for the zone of inhibition after being placed on a black surface. This was accomplished using a test tube containing 9 mL of tryptone soya broth, a disk borer, cotton swab sticks, Mueller Hinton agar plates, an inoculating loop, and a disk with a positive control antibiotic (Ciprofloxacin, Cup borer, 0.5 McFarland standard) (Figure 3) [14]. Here, 5 repetitions were conducted.

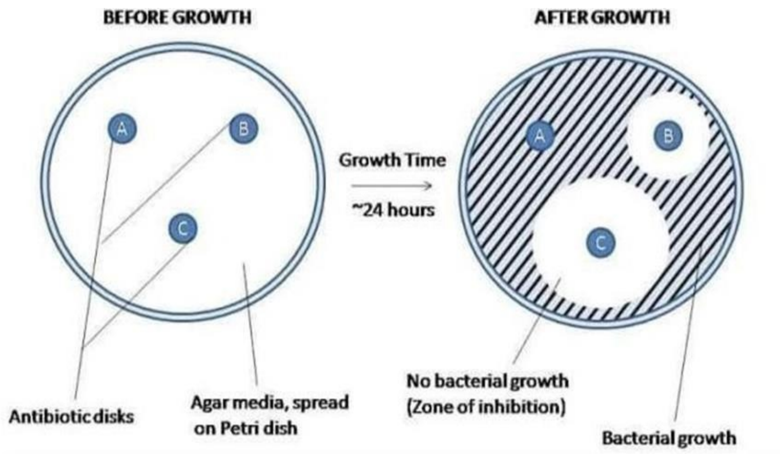


Figure 3. Disk diffusion method

Wound Healing Observation

With the assistance and consent of a veterinarian (Dr Md. Robiul Hasan, Chief surgeon, Pet care clinic, Dhaka, Bangladesh), 6-month-old rabbits were chosen, and an artificial wound measuring 5 mm in length and 1 mm in depth was made on it. The rabbit was then treated with a sample bandage to measurethe healing properties. Initially, the rabbit's foot was severed with a surgical blade that was 5 mm long and 1 mm deep. Then a bandage was placed on in a cross-bind configuration and cushioned with herbal extract. The temperature of the rabbit's body was then determined. Every six hours, a measurement of body temperature was taken.

RESULTS AND DISCUSSION

Analysis of K/S Value

The K/S values of the first sample's 10 layers and the second sample's ten times more concentrated layer are shown in Figure 4 respectively. The chart above can be used to calculate the K/S values for the first sample's 10 layers and the secondsample's ten times concentrated layer. Since the first sample was saturated with Coriander extract solutions after the ninthlayer, the K/S values in the ninth and tenth layers of the first sample were larger than those in the other layers. In this instance, more coriander extract is deposited on the fibre surface as the K/S number increases. The repeated pad-dry-cure process left a significant amount of discolouration on the first sample's textile surface. To get around this problem, the coriander extract was amplified by ten and used to make a second sample with just one layer that was 10 times more concentrated. Indicating that more coriander extract was deposited on the fibre surface of the second sample, the K/S valueof the 10 times concentrated layer of the second sample was comparable to that of the tenth layer of the first sample. Additionally, there was barely any stain in the second sample, and the first sample required more time, work, and resources than the ten-fold concentrated solution (Figure 4).

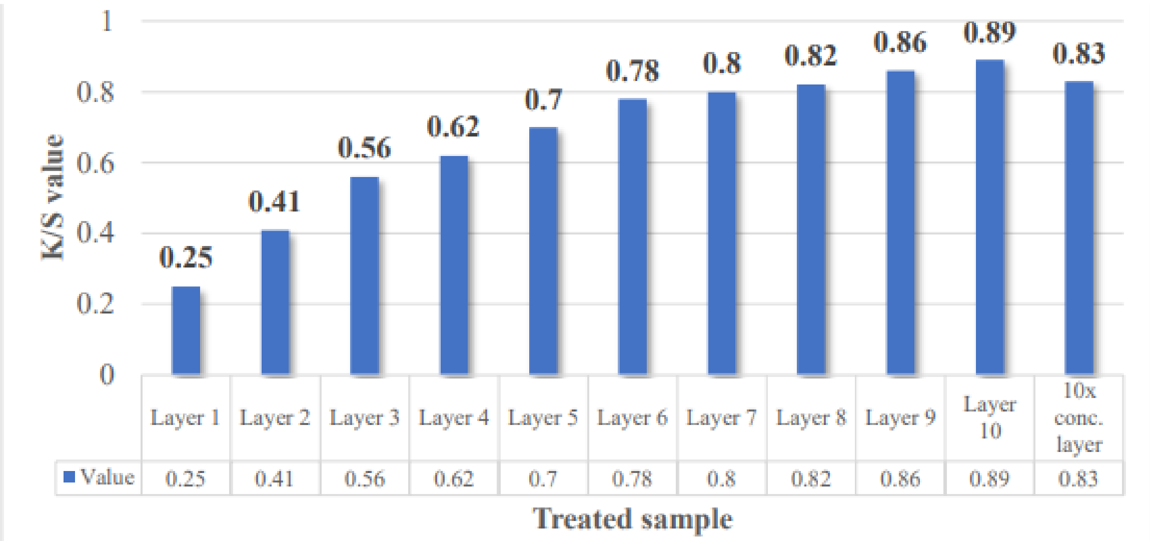


Figure 4. Analysis of K/S value

Scanning Electron Microscope Image Analysis

As seen in Figure 5, the coriander extract-treated cotton sample has an even distribution across its surface. According to the scanning electron microscope image of the second sample's ten times concentrated layer, a significant amount of coriander extract was deposited on the fibre surface. The fibre surface in Figure 5 is covered in glittering granules that resemble coriander extract seeping into the cotton sample. The sample padded with coriander extract solution generated a mirror wall on the fibre surface that reflected the UV rays rather than allowing them to pass through the fabric since their wavelength ranged from 200 to 400 nm.

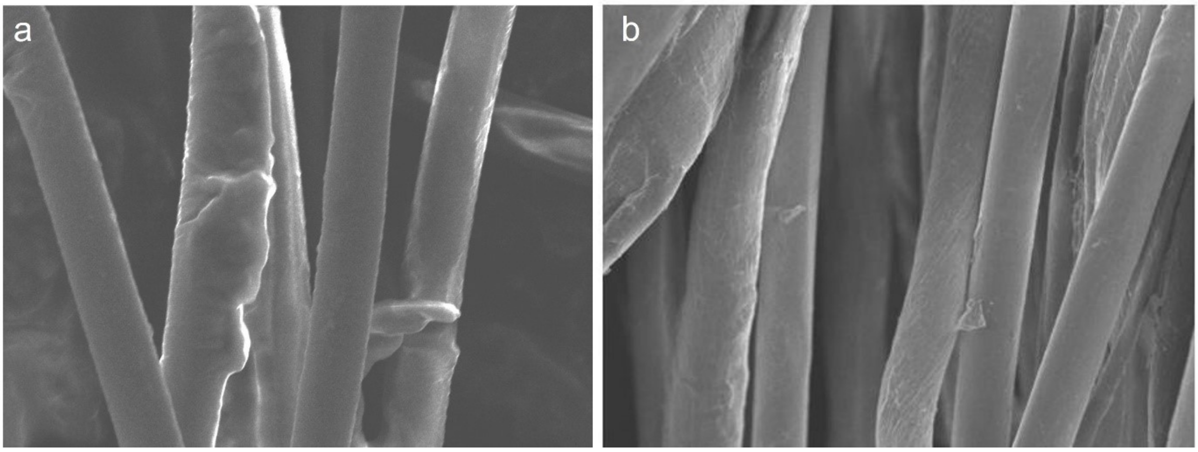


Figure 5. Cotton sample a) untreated, b) treated with Coriander extract under scanning electron microscope

Attenuated Total Reflection Test (ATR) Analysis

Figure 6 shows the infrared spectrum of fabric treated with coriander extraction, with the vertical axis denoting per cent transmittance and the horizontal axis denoting wave number. The functional group region, which covers the wavelengths from 4000 cm^{-1} to 2000 cm^{-1}, and the fingerprint region, which covers the wavelengths from 4000 cm^{-1} to 600 cm^{-1}, are the typical ranges for an IR spectrum (2000 cm^{-1} to 600 cm^{-1}).

At 3340 cm^{-1}, overlapping O-H/N-H stretching bands corresponding to amino acids were found, whereas at 2927 cm^{-1} and 719 cm^{-1}, respectively, C-H stretching and bending vibrations corresponding to tannins were found. At 1402 cm^{-1}, N- H deformation vibrations that resemble proteins were found. Peaks at 1726 cm^{-1} were likewise connected to the terpenoidand phenol-corresponding C=O and C=C carbon backbone lengths, respectively. Peaks at 1249 cm^{-1} suggested stretchingand bending vibrations of C-O bonds in carboxyl groups, indicating carbohydrate, whereas peaks at 1099 cm^{-1} and 1020 cm^{-1} indicated asymmetric and symmetric C-O-C vibrations, respectively. Thus, it was established that amino acids, tannins, proteins, carbohydrates, terpenoids, and phenol phytochemicals exist. Consequently, the ATR study supported the existence of phytochemicals in coriander extract in the sample [15].

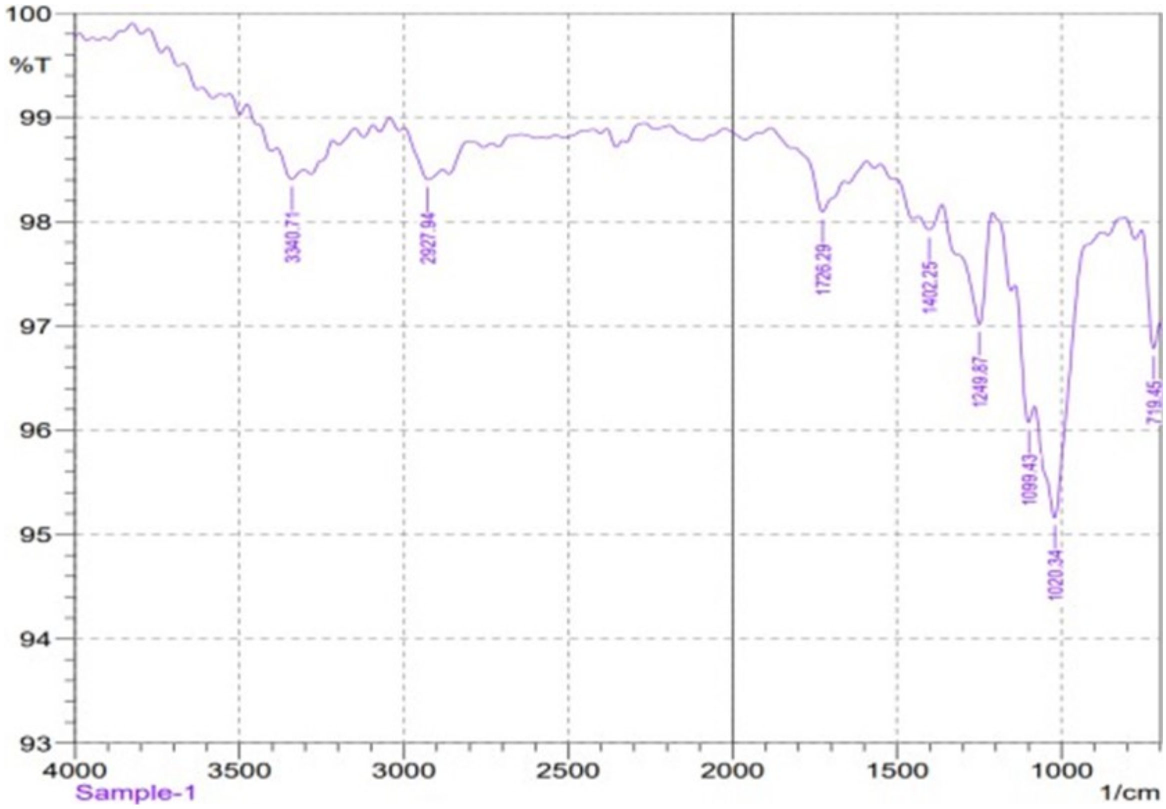


Figure 6. The infrared spectrum of Coriander extraction treated fabric

Assessment of Anti-Microbial Activity (Disk Diffusion Method)

Table 4 compares the antibacterial efficacy of samples padded with *Coriandrum sativum* and Amoxicillin chemical (standard) against Gram-negative bacteria (*Escherichia coli*) and Gram-positive bacteria (*Staphylococcus aureus*). Zones of inhibition (ZOI) measured 12 mm in samples padded with *Coriandrum sativum* (woven gauze) and 19 mm in samples padded with amoxicillin against Gram-negative bacteria (*Escherichia coli*) (Figure 7). ZOI of 14 mm was present in samples padded with *Coriandrum sativum* (woven gauze) for Gram-positive bacteria (*Staphylococcus aureus*) (Figure. 8). Samples that had been padded with amoxicillin had a ZOI of 39 mm against Gram-positive bacteria (*Staphylococcus aureus).*

Table 4. Antibacterial activity against Gram-positive and Gram-negative bacteria on samples padded with *Coriandrum sativum* and Amoxicillin chemical

Sample	Sample size(mm^2)	Bacterial strain	Mean Diameter of ZOI (mm) ZOI = Zone of Inhibition	Median	Mode	Standard Deviation	Standard Error
Cotton sample padded with *Coriandrum sativum* extract	6 x 6	Gram-negative bacteria (*Escherichia coli*)	12	12	12	1.8	0.77
		Gram-positive bacteria (*Staphylococcus aureus*)	14	13	13	2.10	0.82
Cotton sample padded with Amoxicillin chemical	6 x 6	Gram-negative bacteria (*Escherichia coli*)	19	19	19	1.20	0.60
		Gram-positive bacteria (*Staphylococcus aureus*)	39	40	40	1.11	0.71

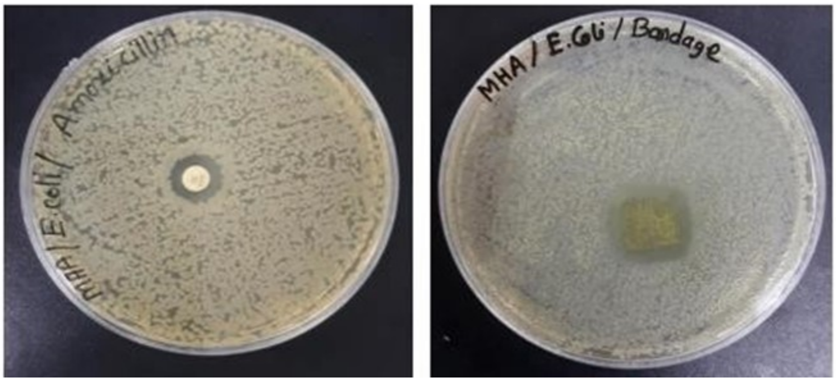


Figure. 7 Antibacterial activity against Gram-negative bacteria (*Escherichia coli*) on samples padded with Amoxicillinchemical and *Coriandrum sativum* extract

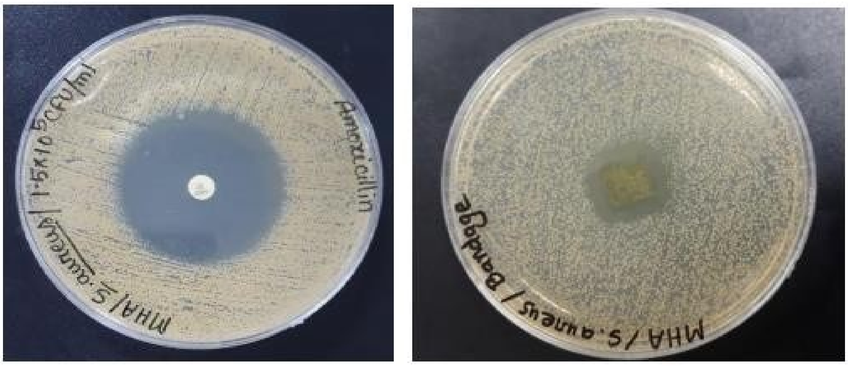


Figure. 8 Antibacterial activity against Gram-positive bacteria (*Staphylococcus aureus*) on samples padded with Amoxicillinchemical and *Coriandrum sativum* extract

According to Table 4's findings, samples padded with *Coriandrum sativum* aqueous extracts displayed outstanding antibacterial potential by having specific values of the zone of inhibition against both Gram-negative bacteria (*Escherichia coli*)and Gram-positive bacteria (*Staphylococcus aureus*). It occurred because their aqueous extracts contained amino acids, tannins, proteins, carbohydrates, terpenoids phytochemicals (Table 3).

Water-soluble polyphenols known as tannins have an astringent effect and form complexes with enzymes. When combined with tannins, several microbial enzymes in pure forms exhibit zones of inhibition [16]. Terpenoids are antibacterial substances that are effective against a variety of microorganisms and are capable of forming intricate structures with bacterial cell walls [17]. Cationic amino acid-based surfactants are excellent candidates to be used as antimicrobial compounds. These surfactants act via perturbation of bacterial membranes [18]. Carbohydrates are omnipresent andd serve as the foundation for cells' structural framework, a source of energy for metabolism, and an essential part of some intercellular recognition activities. Therefore, it should come as no surprise that many currently available antibioticsare based on carbohydrates, that is, they contain a glycan portion in their structure, or they are non-carbohydrate moleculesthat target an enzyme or receptor linked to carbohydrate synthesis, metabolism, or recognition [19]. In addition to helping neutrophils kill microorganisms inside their phagosomes, antimicrobial proteins and peptides (AMPs) are also released intoextracellular fluids by epithelial cells that line mucosal surfaces and the skin [20].

Wound Healing Observation

To see how wounds, heal, rabbits were utilized. The cutting site that had been bandaged with the sample padded with the herbal extract was maintained under surveillance. After each 6 hours of bandaging, the rabbit's body temperature was checked. It was within acceptable range (38.5 ± 0.5 ^{o}C), indicating that there had been no infection at the site of the cut. When the bandages were removed after seven days, the area was entirely healed.

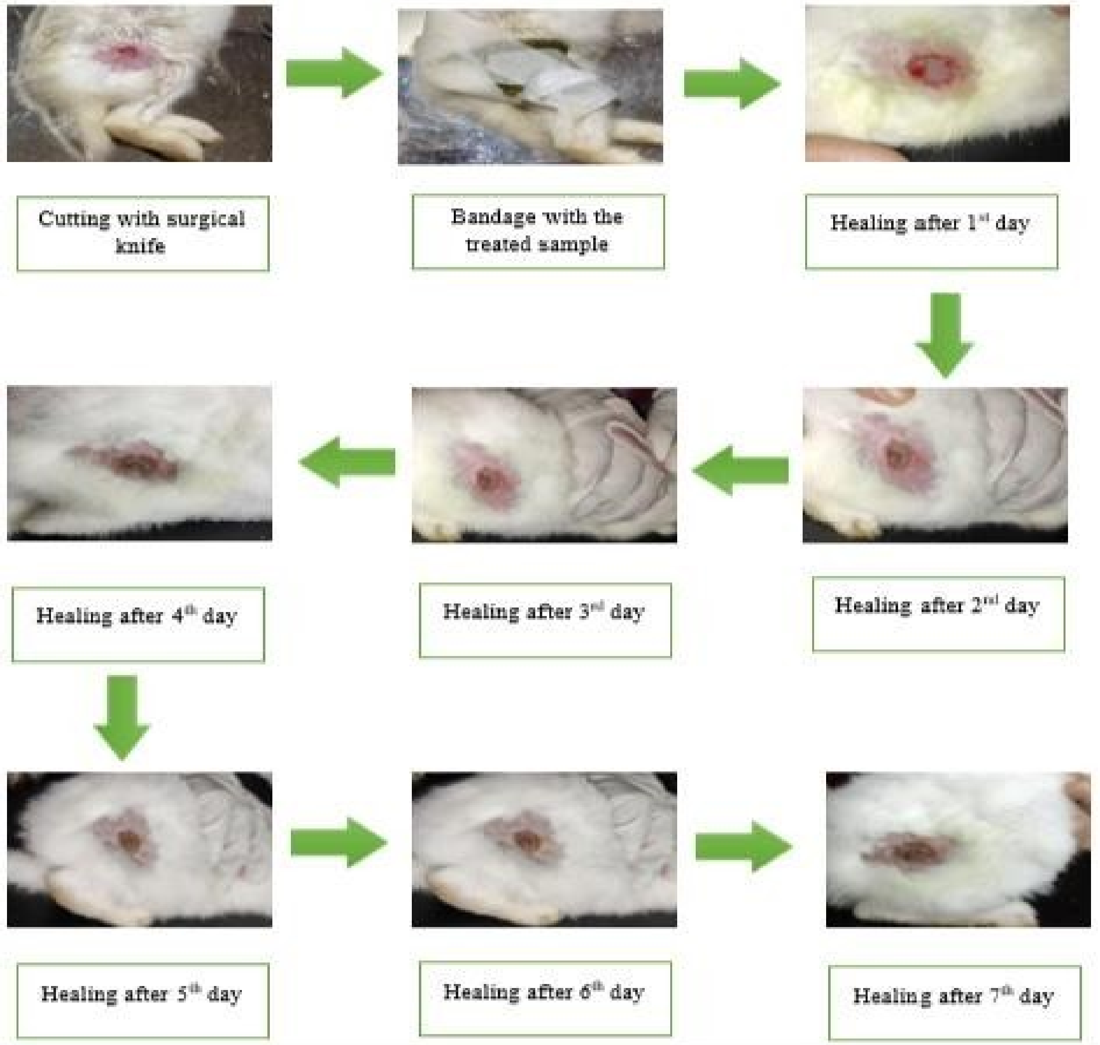


Figure 9. Implementation of herbal bandage on the wound place of rabbit and observation of the healing process

The bandage did not hurt the rabbits as there has not been any sign of scratch or bite on the wound which confirms that natural plant extract has no side toxic effect on the wound [1]. In this study, the application of the treated bandage made the hemostasis faster indicating a healthy healing [21].

The healing of a wound depends on the level of inflammation. Here our treated fabric showed good antiinflamation properties. Initial inflammation is necessary for healing, but an excess level of inflammation can stop tissue repair [22].

The inflammation in the wound starts after the wound initiation time to three or four days. This inflammation has been mitigated by this anti-inflammatory coriander herb bandage. The bandage helped the faster platelets cluster and better fibrin clot on the wound site. The study showed thicker and uniform scabs on the skin which is also supported by a previous study where they used *Morinda citrifolia L. Leaf ethanol extract* for wound healing application [23].

This study showed early healing of rabbit wounds with normal tissue growth, and wound closure, which indicated a healthy and quick healing. So, this coriander extract-treated cotton fabric bandage has shown good anti-inflammatory wound healing activity in vivo conditions.

CONCLUSION

The coriander leaf extract is widely available and possesses antimicrobial qualities. The coriander leaf extract in cotton fabric as a bandage showed great possibility for wound healing application. For mild wounds, the coriander leaf extract bandage can be used as the first line of defence against infection. A higher concentration of the extract works better for the inhibition of bacterial growth, and application to cotton fabric was not affected. Cotton fabrics treated with natural herbs have strong antibacterial properties for both gram-positive and gram-negative bacteria. To ascertain the herb's effectiveness, tests into minimum inhibitory concentrations were also done against test pathogens. It was found that the treated fabric is more hygienic and fungus-free.

Author Contributions

Conceptualization – Ghosh J; methodology – Ghosh J and Rupanty NS; formal analysis – Ghosh J and Rupanty NS; investigation – Ghosh J and Rupanty NS; resources – Ghosh J and Das SC ; writing-original draft preparation – Ghosh J and Das SC; writing-review and editing – Rupanty NS and Das SC; visualization – Ghosh J, Rupanty NS and Das SC; supervision – Ghosh J. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

Funding

This research received no external funding.

Hazards

Research involving chemicals, procedures or equipment have no unusual hazards.

Human research subjects

The research was conducted in accordance with relevant guidelines and regulations for experiments involving humans or affirmation that informed consent was obtained from all human research subjects.

Animal research subjects

Research was conducted following national or international laws or relevant guidelines and regulations. Identification of the institution approving the experiment: Dr Md. Robiul Hasan, Chief surgeon, Pet care clinic, Dhaka, Bangladesh.

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