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Md. Golam Kibria, Kawser Parveen Chowdhury, Ariful Haque Ashik, Md. Esrafil Hossain Riyad

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Wound Healing Functionality of Mangosteen Extracts on Viscose Fabric

Md. Golam KIBRIA[1*], Kawser Parveen CHOWDHURY[2], Ariful Haque ASHIK[1], Md. Esrafil Hossain RIYAD[1]

[1]Department of Textile Machinery Design and Maintenance, Bangladesh University of Textiles, Tejgaon, Dhaka 1208, Bangladesh

[2]Department of Wet Process Engineering, Bangladesh University of Textiles, Tejgaon, Dhaka 1208, Bangladesh

*kibria@tmdm.butex.edu.bd

Article

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ABSTRACT

The aim of this study was to introduce novel dressing with different extracts of mangosteen for quick blood clotting and wound healing. Insufficient use of natural biomaterials for blood clotting and wound healing in the medical textile sector has been observed. In order to improve the situation, viscose woven fabrics treated with mangosteen leaf, peel and pericarp extract were examined. Fresh mangosteens were collected from local market and different pastes were prepared by using an electric blender. The pretreated viscose woven fabrics were dyed with these pastes using glycerin as mordant. After the sample preparation, an antibacterial test, odor test, blood clotting test, strength test, color fastness tests were done. The treated samples exhibited good antibacterial activity against gram negative bacteria and mild antibacterial activity against gram positive bacteria, especially the fabrics treated with mangosteen leaf and pericarp. Besides, the treated samples did not create annoying odors as like the untreated one. To justify healing properties, implementations of the samples were done on a rabbit. Leaf and pericarp treated fabrics exhibited good blood clotting in comparison with untreated fabric. All the treated samples exhibited average to good color fastness to wash and rubbing properties with sufficient tensile strength. Morphological changes of the treated and untreated fibers were examined by SEM and FTIR analysis and the results clearly showed the differences in the untreated and treated samples. The experiments were carried out in an environment friendly way which indicates the production and processing of these dressing materials can have an enormous contribution to sustainable operations and products for the development of medical textiles sector.

KEYWORDS

mangosteen, viscose fabric, antibacterial, anti-odor, blood clotting, wound healing

INTRODUCTION

Mangosteen is a tropical fruit that has been used in Southeast Asia for decades as traditional medicine as well as nutritional supplements [1]. Moreover, recent research has found that mangosteen extract has anti-microbial and anti-bacterial properties [2]. This extract could be used on viscose fabric for anti-microbial and anti-bacterial finishing. Furthermore, mangosteen extract has documented healing properties [3]. The objective of this research is to imitate all these effects on viscose woven fabric and investigate its wound healing functionality.

Palakawong et al. stated that the fruit of the mangosteen tree (*Garcinia mangostana Linn*) has gained increasing acceptance as a distinctively flavored commodity that is also a rich source of nutrients and

health-promoting phytochemicals, including phenylated and oxygenated xanthones, flavonoids, flavanols, tannins, anthocyanins, ascorbic acid, carotenoids, and other bioactive compounds [4]. Biological studies on the constituents of the fruit hulls have demonstrated antibacterial, antifungal, antitumor-promotion, and other biological activities. In Thai folk medicine, the fruit hulls of *G. mangostana* are used for healing skin infections and wounds and for the relief of diarrhea [5].

Sarin Tadtong et al. determined the antibacterial activities against the pathogenic bacteria in the oral cavity of the mangosteen pericarp extract [6]. R. Suhartati et al. examined the antibacterial activity of mangosteen leaves ethanol extract *(Garcinia mangostana Linn)* on the growth of *Ps. aeruginosa* bacteria. *Pseudomonas aeruginosa* causes various infections such as skin infections. Mangosteen leaves contain active compounds that are useful in inhibiting bacterial growth [7]. Sitti RH et al. showed that the nano mangosteen peel extract has antibacterial activity stronger impact to three tested bacterial: *S. aureus, B. cereus,* and *S. flexinery* [8]. José Pedraza-Chaverri et al. studied the antibacterial and antifungal properties of α-mangostin and four of its derivatives. They found that bacteria *S. aureus, P. aeruginosa, Salmonella typhimurium* and *Bacillus subtilis* were highly susceptible to xanthones, whereas *Proteus sp., Klebsiella sp.* and *Escherichia coli* were only moderately susceptible [9]. Million Ayele et al. focused on extracting natural dyes from mango leaves and mango peel and found sustainable ways of cotton dyeing. Natural coloring agents were extracted using an aqueous extraction technique and the cotton fabric was dyed using the extracts followed by mordanting using different mordant types [10]. Patel et al. colored viscose rayon fabrics with some commercial natural dyes such as harde, turmeric and madder by using metallic salts as mordant. They took an attempt to increase the exhaustion rate as well as reduce the wastage percentage of colorants during natural dyeing [11]. The addition of glycerine to dye solution aids in the keeping properties and at the same time increases the clearness of the microscopical picture [12]. Anastasia WheniIndrianingsih et al. studied the antibacterial activity of cotton fabrics dyed with *G. mangostana* peel and different mordants against gram negative bacteria *(Escherichia Coli)* and gram positive bacteria *(Staphylococcus aureus).* They conducted SEM, FTIR and color chromametric analysis to characterize the dyed samples. They suggested the potentiality of using *G. mangostana* peel waste as an antibacterial agent to be used in natural dyeing of fabrics that can be applied in the medical textiles sector [13].

Gondokesumo et al. tried to evaluate the molecular mechanisms and identify different active compounds from mangosteen peel extract which are useful in healing skin burns. They adopted the data mining technique and identified about 120 compounds in mangosteen peel with 60 types of xanthones. Among these Smeaxanthone A, Garcinone E, γ-mangosteen, and gartanin were four high potency compounds. Through computational study, they concluded that the four compounds have potential targets prediction related to interleukin 6, epidermal growth factor, and transforming growth factor beta 1, which regulates epithelial cell proliferation and thus playing a vital role in skin burns

healing process [14]. Ibrahim et al. highlighted the clinical studies on wound healing promotions by the selected natural products and the mechanisms involved. Numerous studies on the potential of natural products with anti-inflammatory, antioxidant, antibacterial and pro-collagen synthesis properties as wound healing agents have been performed. Their medicinal properties can be contributed by the content of bioactive phytochemical constituents such as alkaloids, essential oils, flavonoids, tannins, saponins, and phenolic compounds in the natural products [15].

To highlight the development of the mangosteen as a widely used nutraceutical, Dmitriy Obolskiy et al. stated that products derived from *G. Mangostana* are now increasingly being distributed throughout the world and mangosteen is being used traditionally for the treatment of skin infections and wounds due to its anti-inflammatory properties. This fruit is also used for the therapy of various conditions such as dysentery, different urinary disorders, cystitis and gonorrhoea [16]. Sombolayuk et al. suggested that mangosteen pericarp extract (MPE) may accelerate wound healing. This study aimed to evaluate the effect of the MPE cream in various concentrations in acute wound healing of albino mice, both histologically and macroscopically [17]. A recent study has determined the effect of different concentrations of ethanol extract gel formation of mangosteen pericarp on wound healing in burns [18]. Ratnoff stated that blood clotting is the end-result of an orderly sequence of enzymatic reactions which lead to the conversion of a soluble plasma protein, fibrinogen into an insoluble, fibrous substance, fibrin. These enzymatic reactions are of peculiar interest, for at each step an inert clotting factor is changed to an active form which catalyzes the next step in the sequence. Ultimately, thrombin is generated, and this enzyme transforms fibrinogen into fibrin [19].

In general, antioxidant therapy that is used for the treatment of skin burns, reinforces cellular antioxidant defense mechanisms, minimizes free oxygen radicals, and improves the wound healing process. Different free radical scavenging agents normally involve in the de-activation, minimization, and ROS removal, as well as accelerating the wound-healing process. As a result, traditional applications of different compounds having free radical scavenging properties can protect tissues from oxidative damage and also significantly develop wound healing process. Traditional antibacterial agents are also commonly being used to promote wound healing in patients. Over the decades, various herbal medicines have been widely used for natural medication of skin burn injuries. Mangosteen has been used as a traditional medicine in southeastern Asia for diarrhea, dysentery, inflammation, and ulcers, as well as for wound healing. Mangosteen rind extract and purified constituents have been implemented to a variety of biological tests relating to infectious diseases, cancer chemoprevention and chemotherapy, diabetes, and neurological conditions. Mangosteen extract and its constituent xanthones have been proved to have antioxidant, anti-inflammatory, and antibacterial activities [20].

Janarthanan and Kumar investigated the utilization of different phenolic compounds found in red seaweeds for making textile face masks for anti-aging application. They treated cotton fabric with

seaweed extracts using a pad-dry-cure method. They found that the air permeability, water permeability and wickability of the treated samples were slightly affected compared to untreated sample. They suggested the use of red seaweed treated cotton fabrics in wound dressing, surgical gowns, face masks, gauze material, bandages, and compression garments [21]. Prokash et al. used leave extracts of Aloe Vera, piper betel and neem leaf on bamboo fibre based materials for wound dressing applications. They treated bamboo fabrics with different natural extracts and assessed the antibacterial activity of the treated samples and performed in vivo studies of wound healing on albino rats. They suggested these treated samples to be used for medical textile applications [22].

Sampath et al. developed wound dressing materials by coating different natural extract of *Calotropis gigantean*, *Eucalyptus globulus* and buds of *Syzygium aromaticum* solution on bamboo gauze fabrics. They found that the increase in natural extract concentration increased the wound healing rate. All the treated samples exhibited good antibacterial properties [23].

EXPERIMENTAL

Materials

100% Viscose Woven Fabric

Fabric Specification (ASTM Standard)

Fabric density: 31 threads/cm in warp direction and 27 threads/cm in weft direction

Yarn fineness: 19.7 tex for both warp and weft yarn

Fabric width: 137 cm

Fabric mass per unit area: 126 gm^{-2}

Weave type: $^{1}/_{1}$ plain weave

Pretreatment Chemicals

Desizing Agents: Enzyme (RUCOLASE), Lubricating Agent (Albafluid C), Wetting Agent (RUCOWET), Acetic Acid (CH_3COOH); Scouring and Bleaching Agents: Soda Ash (Na_2CO_3), Hydrogen Peroxide (H_2O_2), Wetting Agent (RUCOWET), Lubricating Agent (Albafluid C), Sequestering Agent (Prestogen FCB), Stabilizer (RUCO-STAB)

Dyeing Ingredients: Mangosteen Leaf, Peel and Pericarp Paste; Glycerin as Mordant.

Sedation and Antiseptic Agent: G-Ketamine (0.5 ml/25 mg) and Povimax 10%

Methods

Sample Preparation

Pretreatment Process

At first viscose woven fabric was dry singed in a gas singing machine. Then desizing, scouring and bleaching were done with standard recipes in a soft flow machine. Finally the pretreated fabric was dried in a Stenter machine.

Dyeing Process

Preparation of Pastes: Fresh mangosteen leaves were washed two times with 500 ml distilled water in a steel container. Then the washed leaves were blended in an electric blender. Finally the blended leaf paste was filtrated through cotton bleached fabric and preserved in a glass jar at room temperature. Mangosteen peel and pericarp paste were also prepared following the same procedure.

Fabric Preparation: Six pieces of 25 cm x 25 cm bleached samples were washed at first in a steel container with 500 ml water at 100 °C for 10 minutes. Then the washed samples were squeezed and dried in hot air.

Dyeing Flowchart: 100 g of Leaf Paste (in a Steel Bath) ⟶ 500 ml Distilled Water ⟶ Stirrer (40 °C, 5 min) ⟶ Add 5 cm^3 of Glycerin ⟶ Stirrer (50 °C, 3 min) ⟶ Add Fabric Samples ⟶ Dyeing (80 °C, 30 min) ⟶ Cooling to Room Temperature ⟶ Squeeze ⟶ Sun Dry ⟶ Sealed in a Airtight Bag

The same procedures were followed for dyeing samples with mangosteen peel and pericarp.

Figure 1. Dyeing of 100% viscose woven fabric with mangosteen leaf

Sterilization Process

Sterilization refers to any process that removes, kills or deactivates microorganisms such as fungi, bacteria, spores, unicellular eukaryotic. Sterilization of the samples was done in an autoclave machine by dry saturated steam at 120 °C for 30 minutes with a steam pressure of 103 kPa.

Sample Testing and Characterization

Healing Properties Test

Method: Open surgery (An "open" surgery means the cutting of skin and tissues so that the surgeon has a full view of the structures or organs involved.)

Treated and untreated bandages were applied to the created wounds of a rabbit. Then wound conditions were observed and body temperatures were measured at regular intervals. Rabbit is chosen for this experiment as they are very docile, non-aggressive, easy to handle and widely bred.

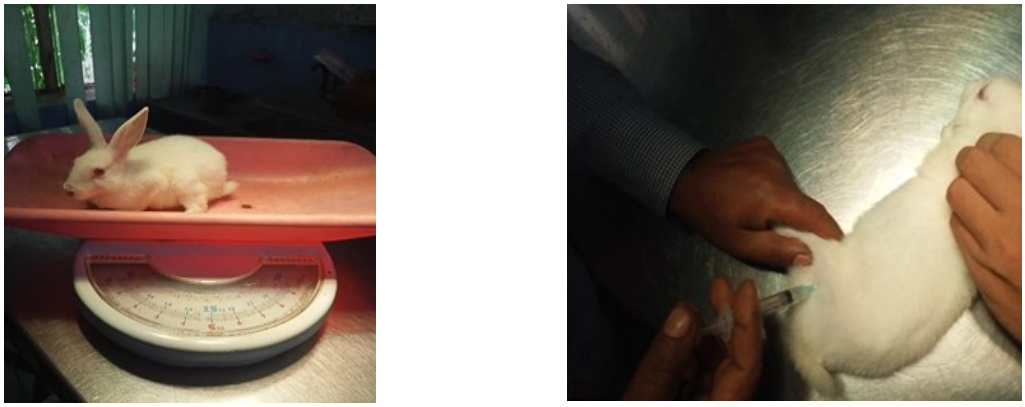

Figure 2. Weighting and sedation of the rabbit

Figure 3. Creating wounds on the rabbit and applying treated bandages

Blood Clotting Test

This test was carried out following Duke's method to determine bleeding time using the untreated and treated bandages. At the first Ketamine medicine was injected in the leg of the rabbit for sedation according to its weight. Then, body of the rabbit was cleaned and Povimax 10% medicine was used for antiseptic purpose. A wound was created by using a surgical blade with the help of a veterinary surgeon. At the time of starting bleeding, this wound was wrapped by untreated sample and observed blood clotting after 30 s interval until the bleeding stopped. By following the same process, leaf, peel and pericarp treated samples were used respectively to determine coagulation time.

Antibacterial Activity Test

The antibacterial activity of the samples was assessed by the agar diffusion test following SN 195 920 method for qualitative analysis of bacterial growth. At first the test agar plate was swabbed with a defined concentration of the test organism, later paper disks were placed on the lawn of bacteria containing a distinct antibiotic concentration. The samples were kept in the centre of nutrient agar plates that had been inoculated with the test bacteria. The assessment of this test was based on the level of growth both around and under the sample. All the samples were incubated at 37 °C for 18-24 hours.

Odour Test

The test was performed following SNV 195651 to determine the nasal nuisance through textile materials. The test specimen (40 g) was taken and was placed on top of 300 ml sodium carbonate solution. Then it was kept in desiccator. The desiccator was put into an oven set to a temperature of 37 ± 2 °C for 15 hours. Minimum six people were required independently to judge the odor intensity.

Other Tests

Tensile Strength Test (ISO 13934-2), Color Fastness to Wash Test (ISO 105 C06), and Color Fastness to Rubbing Test (ISO-105-X12) were carried out for all the samples.

Materials Characterization

Samples were characterized by SEM and FTIR analysis. The morphology of the surface structure of the untreated and treated samples was analyzed using Hitachi Scanning Electron Microscope SU 3500, Japan in 1500 and 3000 magnifications. To improve the imaging of the samples gold coating was done prior investigation. For FTIR analysis of samples Agilent Cary 630 FTIR Spectrometer was used where number of sample scans was 32 with a resolution of eight and the range of wavenumber was 650-4000 cm^{-1}.

RESULTS AND DISCUSSION

Antibacterial Activity Assessment

The untreated sample exhibited no antibacterial activity against both gram positive bacteria *(Staphylococcus aureus)* and gram negative bacteria *(Escherichia Coli)*. The samples treated with mangosteen leaf and pericarp exhibited good antibacterial activity against gram negative bacteria and mild antibacterial activity against gram positive bacteria (Table 1). The peel treated sample showed less antibacterial activity among the treated samples.

Table 1. Antibacterial activity assessment of untreated and treated samples

Sample (20 mm)	Sample Colour	Antibacterial Activity *(Escherichia Coli)*	Antibacterial Activity *(Staphylococcus aureus)*
Untreated Sample	White	-	-
Leaf Treated Sample	Light Green	+++	++
Peel Treated Sample	Light Cream	++	+
Pericarp Treated Sample	Light pink	+++	++

All the treated samples exhibited better performance against gram negative bacteria, this can be attributed to the differences in the structure between the gram negative and gram positive bacteria [24]. Phytochemicals responsible for showing antibacterial activity in mangosteen leaves are mainly four active compounds such as flavonoids, tannins, alkaloids and saponins, whereas manogosteen pericarp contains the majority of the xanthone compounds (almost 50) specially α-mangostin and γ-mangostin which are responsible for better antibacterial properties. On the other hand, mangosteen peel also showed good antibacterial activity due to the presence of flavonoids, anthocyanins and some xanthone derivatives [6,7,13].

Figure 4. Antibacterial activity evaluation of different samples

Anti-odor Activity Assessment

Table 2 shows that all the treated fabrics have good anti-odor properties as these fabrics have good antibacterial properties, where as the untreated fabric generates annoying odor due to having no antibacterial property.

Table 2. Anti-odor activity assessment of untreated and treated samples

Sample	Sample Colour	Result
Untreated Sample	White	Annoying Odor
Leaf Treated Sample	Light Green	Weak Odor
Peel Treated Sample	Light Cream	Tolerable Odor
Pericarp Treated Sample	Light pink	Weak Odor

Samples treated with mangosteen leaves, peel and pericarp contain different phytochemicals such as prenylated and oxygenated xanthones and their derivatives, flavonoids, anthocyanins, alkaloids, tannins and saponins [6,7,13] which resist bacteria and other microorganism growth and as a result, no annoying odor generates in the treated samples.

Blood Clotting Time Assessment

The untreated sample had a blood coagulation time of 210 s; whereas the fabric treated with mangosteen peel took less time (150 s) to coagulate blood. Both the fabrics treated with mangosteen leaf and pericarp showed better result as the coagulation time for these samples was 120 s which was least among all the samples. This result also suggests that the treated samples exhibited wound healing properties.

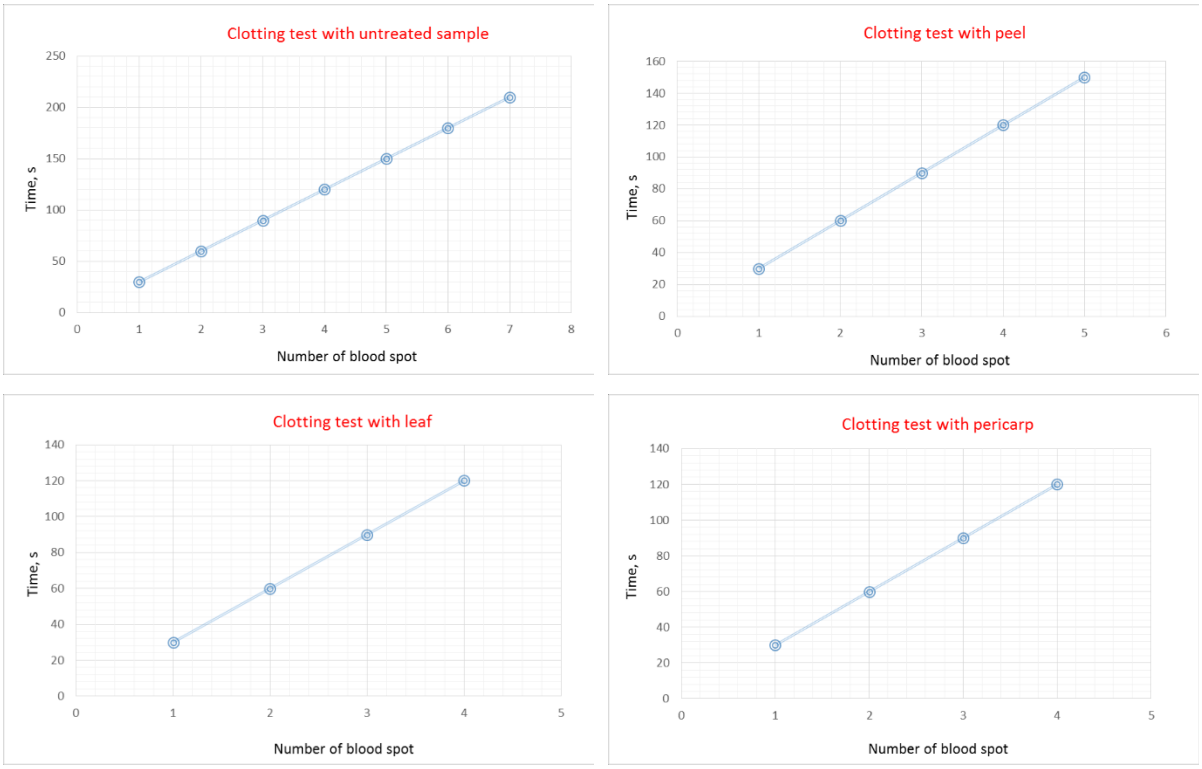

Figure 5. Graphical representation of coagulation time assessment of different samples

Observation of Wound Conditions

After two days the bandages were opened and observed the condition of wounds (Figure 6). All the treated bandages worked effectively for healing the wounds created in different places of the rabbit. The bandages treated with mangosteen pericarp showed good result in this case.

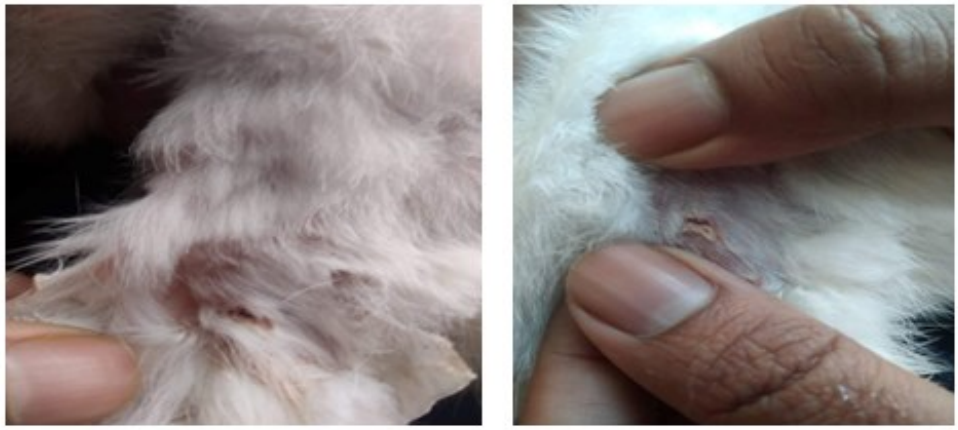

Figure 6. Opening the bandages after two days

The treated bandages can be used to assist faster healing of wounds, especially the bandage treated with mangosteen pericarp as it has documented antioxidant, antibacterial and anti-inflammatory properties.

Observation of Body Temperature

The normal body temperature of a rabbit is 39-40 °C. Body temperatures of the rabbit were measured with a clinical thermometer before and after creating the wounds at six hours interval. The body temperatures were in normal range (38.9-40.5 °C) after creating the wounds in different places of the rabbit.

Tensile Strength Test

From Table 3 it is clear that the tensile strength for all the treated samples in warp way were increased, where as the treated samples experienced a decrease of tensile strength in a weft way except the sample treated with mangosteen leaf.

Table 3. Tensile strength test result for different samples

Sample	Warp direction (N)	Weft direction (N)
Untreated Sample	202	205
Peel Treated Sample	217	199
Leaf Treated Sample	227	212
Pericarp Treated Sample	220	182

On an average, the tensile strength of all the treated samples was increased due to the chemical incorporation of different phytochemicals of mangosteen extracts on viscose fabrics which reduced the moisture regain of fabrics and thus improved the wet strength [25]. Typical wound dressing has a

tensile strength of 5 to 150 N depending on fibre types, fabric structures and active compounds [26,27]. Therefore, all the treated samples have enough tensile strength to be used as wound dressings.

Color Fastness to Wash Test

The below table represents that all the treated samples exhibited average to good color fastness to washing properties. In case of color change, the rating in grey scale is average (3-4) and for color staining this is good (4-5). This result suggests that the treated samples have sufficient wash fastness properties as these samples were prepared following natural dyeing method.

Table 4. Color fastness to wash test result for different samples

	Peel Treated Sample	Leaf Treated Sample	Pericarp Treated Sample
Color Change	3-4	3-4	3
Color Staining (Cotton)	4-5	4-5	4-5
Color Staining (Nylon)	4-5	4-5	4
Color staining (Wool)	4-5	4-5	4-5

Color Fastness to Rubbing Test

The Table 5 represents that all the treated samples exhibited average to good color fastness to rubbing properties. In case of dry rubbing, the rating in grey scale is good (4-5) and for wet rubbing this is average (3-4). All the dyed samples have sufficient rubbing fastness properties that ensure proper dyeing of the samples.

Table 5. Color fastness to rubbing test result for different samples

	Peel Treated Sample	Leaf Treated Sample	Pericarp Treated Sample
Dry Rubbing	4-5	4-5	4-5
Wet Rubbing	3-4	3-4	3

Scanning Electron Microscopic Analysis

From Figure 7, it is clearly noticeable that there are significant differences between the scanning electron microscopic views of untreated and treated samples. This result suggests the extra chemical incorporation in the samples treated with mangosteen peel, leaf and pericarp.

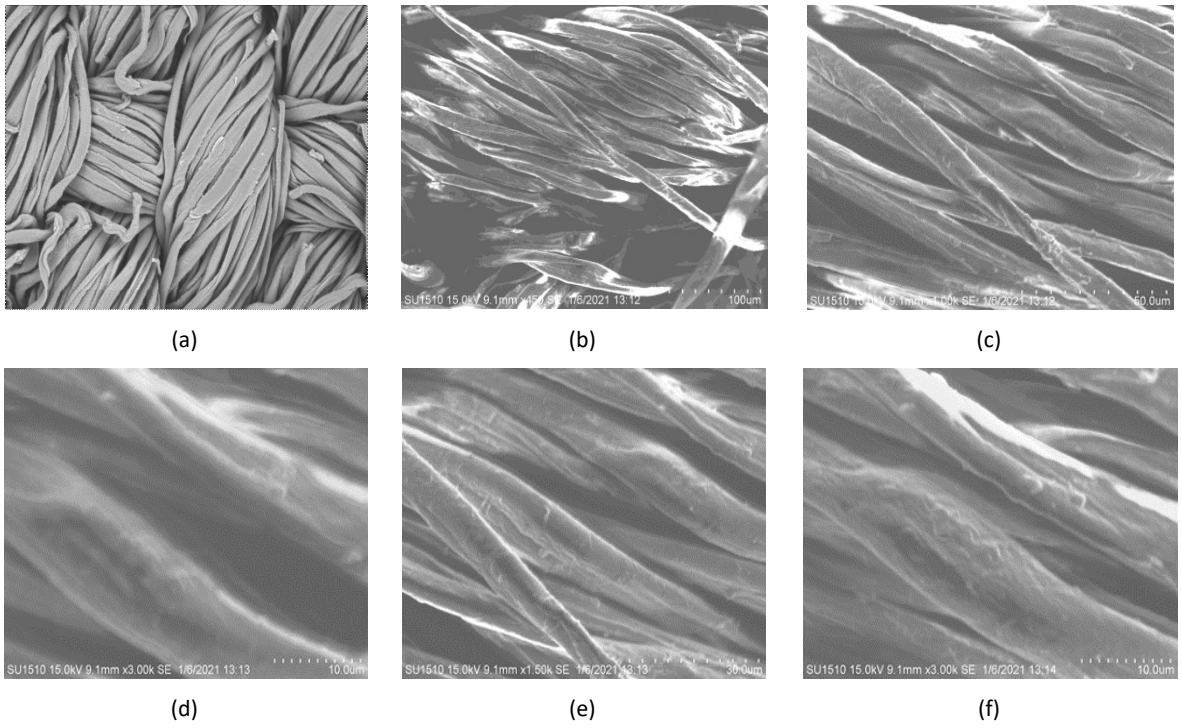

Figure 7. SEM image of: (a) bleached viscose woven fabric (untreated); (b) mangosteen peel treated fabric; (c,d) mangosteen leaf treated fabric; (e,f) mangosteen pericarp treated fabric

Figure 7(a) and 7(b) resemble the image of bleached viscose woven fabric and fabric treated with mangosteen peel respectively. Figure 7(c,d) represents mangosteen leaf extract on viscose woven fabric whereas Figure 7(e,f) depicts the mangosteen pericarp treated samples.

FTIR Analysis of Samples

On spectrums of Figure 8, it can be noticed several peaks, which characterize the different chemical functional groups of mangosteen leaf and pericarp extracts on viscose woven fabrics.

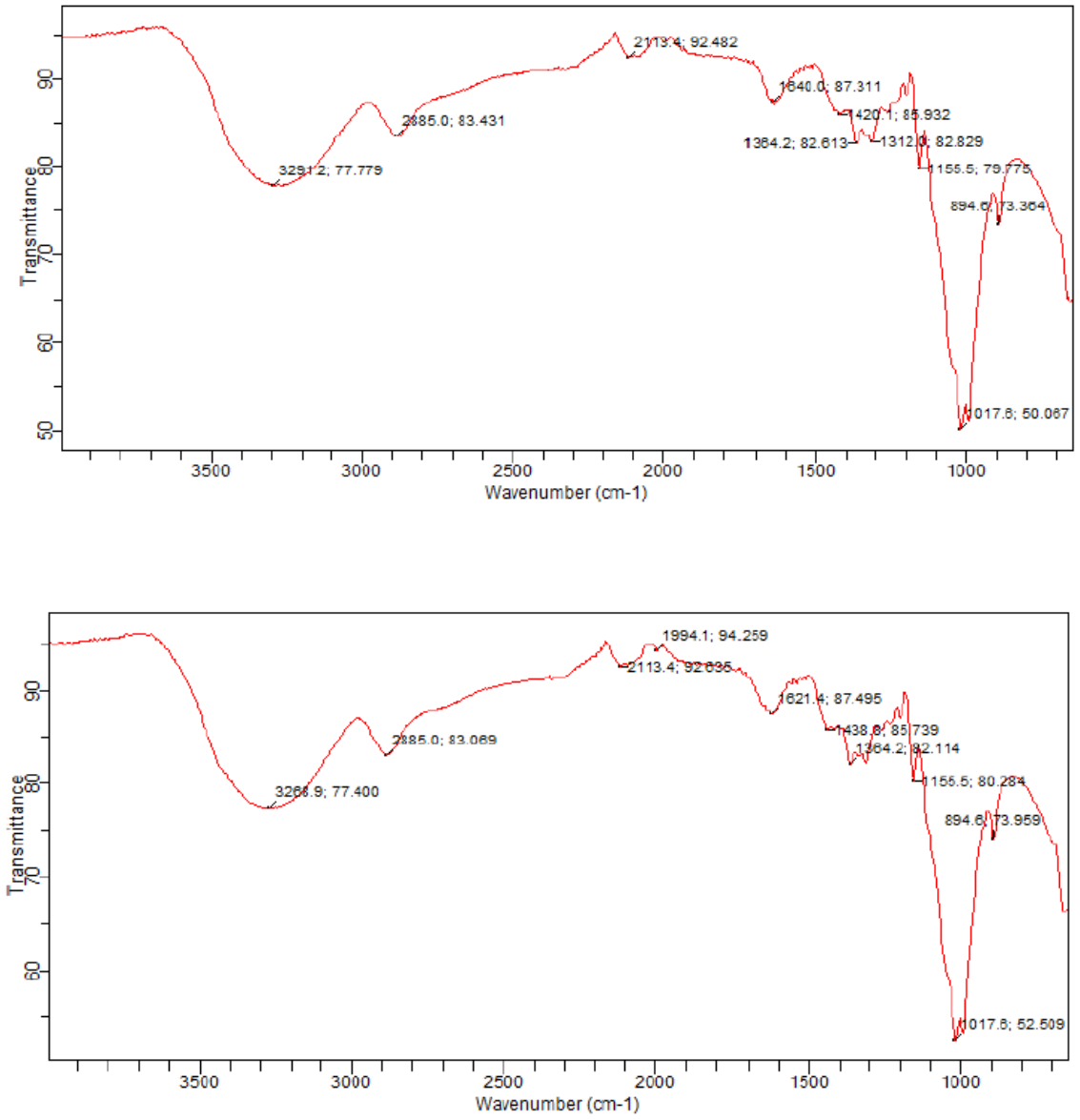

Figure 8. FTIR spectrum of mangosteen leaf and pericarp extract on viscose woven fabric

Transmittance band due to hydrogen bonded O-H stretching (3600-3000 cm^{-1}) could be found in both spectrums. The bands in the 1040-1050 cm^{-1} and 1280-1290 cm^{-1} region are assigned to the stretching and deformation of aromatic C-O groups and the stretching of aryl-alkyl ether linkage C-O-C groups, respectively. In these regions, the peaks in the both spectrums were sharper showing that the C-O and C-O-C bonds in mangosteen leaf and pericarp were more reacted. The same result also occurred at 1450-1460 cm^{-1} and 1620-1640 cm^{-1}. The intensity of the transmittance in these regions is mostly stable, indicating that methylene groups and aromatic ketone groups in xanthones of mangosteen pericarp and leaf. These functional groups suggest the availability of different phytochemicals such as

xanthones, flavonoids, anthocyanins etc. responsible for showing antimicrobial and antioxidant properties in the treated samples.

CONCLUSION

This study shows that mangosteen extracts can accelerate wound healing and thus can be used in acute wound for faster healing. All the treated bandages worked effectively for healing the wounds created in different places of the rabbit, especially the bandage treated with mangosteen pericarp.

The untreated sample has a blood coagulation time of 210 s; whereas both the fabrics treated with mangosteen leaf and pericarp show better result as the coagulation time for these samples is 120 s which is least among all the samples. Mangosteen extracts dyed viscose woven fabrics showed good antibacterial activity against *S. aureus* and *E. coli*. The application of natural dyes from mangosteen leaves, peel and pericarp, combined with glycerine, could develop antibacterial viscose woven fabrics without any adverse effect on human health or the environment.

All the treated samples have sufficient tensile strength and color fastness properties to be used as a wound dressing. The viscose woven fabric was used due to its high absorbency, breathability, comfort and softness compared to other cellulosic fibres.

Further research can be carried on bamboo or wool fibres as these fibres have inherent antibacterial properties to get better performance. The different extracts of mangosteen were used to minimize the dependency of the synthetic antibacterial agents used in wound dressings.

The results presented in this research can be helpful to the researchers in medical textiles especially in wound dressing. However, further research on the suitability and sustainability of the commercial application of mangosteen extracts treated bandages need to be conducted.

Author Contributions

Conceptualization – Kibria MG; methodology – Chowdhury KP and Kibria MG; formal analysis – Kibria MG and Ashik AH; writing - review and editing – Kibria MG and Riyad MEH; Supervision – Chowdhury KP. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Animal research subjects

Open surgery of the rabbit for blood clotting and wound healing tests was done by a experienced veterinary surgeon with proper guidelines and in accordance with national laws and regulation. Location of Testing Laboratory: Central Veterinary Hospital, 48 Kazi Alauddin Road, Dhaka 1000, Bangladesh; Supervisor: Dr. Md. Amir Hossain, Veterinary Surgeon.

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