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Araştırma Makalesi Research Article

FUNCTIONAL YARN PRODUCTION CONTAINING NATURAL MATERIALS FOR MEDICAL TEXTILES

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Keywords

Medical Textiles, Antibacterial Activity, Quince Seed, Thyme Oil, Functional Yarn, Ring Spun Yarn.

Abstract

In recent years, researchers have focused on the development of hygienic new products with less negative impact on the environment. For this reason, the use of natural/environmentally friendly materials is becoming more widespread and studies on these materials are increasing day by day. In this study, it was aimed to investigate the antibacterial activity of textile materials loaded with natural materials such as quince seed gel (QSG) and thyme oil, with a view to their use in medical textiles. This study focused on the application of QSG and thyme oil to spun yarns from staple fibers due to the its advantages such as possibility to be used in yarn/fabric form, porous structure, permeability, flexibility etc. In the study, QSG and thyme oil dispersions were prepared and applied to 100% acrylic fibres during ring spinning production via an alternative application method. Various properties of the produced yarns were analysed. SEM images indicated that fibre surface was covered with QSG and tyhme oil. Unlike QSG, the yarns loaded with thyme oil exhibited antibacterial activity property. The yarns produced were found to have tensile properties suitable for textile processing, although there was some reduction in strength and elongation at break. Based on the obtained results, it is believed that yarns containing natural materials may offer an alternative or complementary approach to treatment.

MEDİKAL TEKSTİLLER İÇİN DOĞAL MALZEME İÇERİKLİ FONKSİYONEL İPLİK ÜRETİMİ

Anahtar Kelimeler

Medikal Tekstiller, Antibakteriyel Aktivite, Ayva Çekirdeği, Kekik Yağ, Fonksiyonel İplik, Ring İplik.

Öz

Son yıllarda araştırmacılar, çevre üzerinde daha az olumsuz etkiye sahip hijyenik yeni ürünlerin geliştirilmesine odaklanmıştır. Bu nedenle doğal/çevre dostu malzemelerin kullanımı giderek yaygınlaşmakta ve bu malzemeler üzerine yapılan çalışmalar her geçen gün artmaktadır. Bu çalışmada, ayva çekirdeği jeli (QSG) ve kekik yağı gibi doğal malzemelerle yüklü tekstil malzemelerinin antibakteriyel aktivitesinin tıbbi tekstillerde kullanımı açısından incelenmesi amaçlanmıştır. Çalışmada, iplik/kumaş formunda kullanılabilmesi, gözenekli yapısı, geçirgenliği, esnekliği gibi avantajları nedeniyle QSG ve kekik yağının kesikli liflerden eğrilmiş ipliklere uygulanmasına odaklanmıştır. İplik üretimi için QSG ve kekik yağı dispersiyonları hazırlanmış ve ring iplik üretimi sırasında %100 akrilik elyaflara alternatif bir uygulama yöntemi ile uygulanmıştır. Üretilen ipliklerin çeşitli özellikleri analiz edilmiştir. SEM görüntüleri, elyaf yüzeyinin QSG ve kekik yağı ile kaplandığını göstermiştir. QSG'nin aksine, kekik yağı yüklü ipliklerin antibakteriyel aktivite özelliği sergilediği belirlenmiştir. Üretilen ipliklerin, mukavemet ve kopma uzamasında bir miktar azalma olmasına rağmen, tekstil işlemeye uygun gerilme özelliklerine sahip olduğu görülmüştür. Elde edilen sonuçlara dayanarak, doğal malzemeler içeren ipliklerin tedaviye alternatif veya tamamlayıcı bir yaklaşım sunabileceği düşünülmektedir.

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Highlights

- Investigation of quince seed gel (QSG) and thyme oil application to staple fibres and functional ring spun yarn production
- Evaluation of antibacterial activity of ring spun yarns containing quince seed gel (QSG) and thyme oil
- Evaluation of tensile properties of ring spun yarns containing quince seed gel (QSG) and thyme oil

Purpose and Scope

The aim of this study was to realize functional yarn production based on the application of natural materials such as quince seed gel (QSG) and thyme oil into the staple fibre bundle during ring spun yarn production and to investigate the antibacterial activity of produced ring spun yarns loaded with QSG and thyme oil, with a view to their use in medical textiles.

Design/methodology/approach

In the study, quince seed gel (QSG) and thyme oil dispersions were prepared. Prepared dispersions were applied into the staple fibre bundle by feeding in a controlled manner during spun yarn production and ring spun yarn production was realized. Yarn morphology and tensile properties of the produced yarns were analyzed. Antibacterial activity of the produced yarns was evaluated.

Findings

According to the scanning electron microscopy (SEM) images, it was observed that quince seed gel (QSG) and thyme oil covered the fibre surface. After the antibacterial activity tests, it was found that the yarns treated with thyme oil presented antibacterial activity (S. aureus), while the yarns loaded with quince seed gel did not show antibacterial activity due to the inability of the active substance to be sufficiently incorporated into the yarn structure. When the tensile properties of the yarns were examined, it was found that the surface structure of the fibres of the yarns and thus the fibre-fibre friction changed after the application of QSG and thyme oil, thus altering the strength and breaking elongation properties. However, the yarns were found to have sufficient tenacity and breaking elongation values for fabric production.

Practical implications

Although antibacterial activity could not be determined due to the insufficiency of the active ingredient in the quince seed gel (QSG) application, it is considered that more detailed trials should be carried out to make a more accurate assessment. However, various tests and analyses should be carried out to determine the potential of the natural materials loaded yarns as biomaterials, especially for wound healing.

Social Implications

Increasing such studies and expanding their use will also be effective in meeting the demand for natural and biocompatible medical textile products.

Originality

When the studies in the literature were examined regarding the use of quince seed gel (QSG) and thyme oil, it was observed that the studies focused on electrospinning and microencapsulation methods of these materials. There is no similar study applying quince seed gel (QSG) and thyme oil to the yarns spun from staple fibres and investigating the yarn properties, particularly antibacterial properties, with regard to their use in the medical field. Therefore, this study is the first in terms of the production of acrylic ring yarn containing QSG and thyme oil and the examination of the antibacterial properties of the yarns.

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1. Introduction

Traditional and non-traditional plants are an integral part of 5000 years of medical history. The use of plants and their extracts in the medical field is generally focused on the treatment of wounds for wound healing purposes. Studies conducted for wound healing purposes date back to very ancient times and plants were first used for this purpose. Maver et al. (2015) stated that herbal medicines are more preferred in wound treatment, as they provide a suitable environment to support the natural wound healing mechanism. Today, herbal solutions continue to play an important role in primary healthcare in 80% of developed and developing countries. One of the reasons for this situation is that the use of pharmaceutical drugs causes undesirable side effects, even if they are minimal. The problems caused by pharmaceutical drugs have therefore led scientists to look for alternative methods. In recent years, intensive research has been conducted on wound healing using medicinal plants (Gergeroğlu, 2017).

Nowadays, plant extracts and some of their constituents are used in the medical field as well as in various products such as cosmetics, household cleaning products and air fresheners, hygiene products, agriculture and food. Plant extracts are also used in aromatherapy and other medical applications. Many plants and their extracts have been traditionally used since ancient times due to their great potential for the management and treatment of wounds. With the development of synthetic drugs, the use of plant extracts for medical therapeutic purposes has decreased compared to their use in cosmetics and food (El-Molla et al., 2015). However, as a result of consumers' concerns about the toxicity of synthetic drugs, the demand for safe and natural alternative drugs has increased. Studies on the evaluation of plant extracts have become active in recent years, especially in order to find possible alternative drugs with antibacterial and antioxidant properties of plant extracts.

In addition to the unique properties of herbal medicines, with the rapid growth of the world's population and environmental pollution, researchers in recent years have focused on developing new hygienic products with minimal negative impact on the environment. For this reason, the use of natural and environmentally friendly materials is becoming more widespread and studies on these materials are increasing day by day. In particular, biocompatibility, natural and environmentally friendly structure is desirable characteristics of materials to be used in the medical field.

In this study, it was aimed to investigate the antibacterial activity of textile materials containing natural materials such as quince seed gel (QSG) and thyme oil, with a view to their use in medical textiles.

Quince (Cydonia oblonga Miller) is the fruit of the Rosaceae family, which sheds its leaves in winter and has natural hard, acidic and suffocating properties. Quince is a tree species of the Rosaceae family, native to Anatolia, Turkestan and northwestern Iran (Ercan and Özkarakaş, 2005, Hemmati et al., 2012). In addition to its edible use as juice, jam and marmalade for nutritional purposes, it is also used in the industrial field due to its pectin and tannin content (Ercan and Özkarakaş, 2005). The gel obtained by soaking quince seeds in water is called quince seed gel (QSG). QSG has been used as a natural moisturiser in the food, cosmetic, pharmaceutical and textile sectors, and recently quince seed powder and extract have been used in cosmetic products. Quince seed has been the subject of research in recent years due to its easy availability, low cost, location in the waste part of the fruit, easy gel production, adhesive properties and high viscosity (Sharma et al., 2011; Jouki et al., 2013; Kafkas et al., 2018).

There are approximately 10 seeds in one fruit. The seeds are brown in colour, about 7 mm long and 5 mm wide (Jouki et al., 2013). These kernels contain hydrocolloids. When soaked in water, a mucilage or gel can be formed. A study reported that QSG contains 45.6% glucose; 27.1% uronic acid; 10.7% xylose; 7.4% fructose and 3.2% galactose (Hakala et al., 2014; Hosseinzadeh and Mohammadi, 2015).

Essential thyme oil obtained by distillation of oregano/thyme plant is used in many fields. There are many studies showing that thyme oil has analgesic, anti-inflammatory, anticarcinogenic, antibacterial, antifungal, wound healing and cell proliferation accelerator effects (Marino vd., 1999; Dorman ve Deans, 2000; Koparal ve Zeytinoğlu, 2003; Canbek et al., 2008; Önal, 2010;).

Natural/plant-based wound healing agents used worldwide in traditional medicine for skin wound treatment have been investigated in detail. Studies on the use of quince seed gel (QSG) and thyme oil as wound healing agents were examined. In their studies, Oran et al. (2022) investigated the design and production of a new biocompatible scaffold with fibroblast cell proliferation, based on the promising biological materials of bacterial cellulose (BC) and QSG. Özdil (2022) aimed to obtain a hybrid film containing nanomaterials in a green synthesis perspective using natural materials, and also aimed to investigate the usability of green synthesized hybrid materials as biosensor materials in the detection of heavy metal ions exposed from many places such as tap

water. In their studies, Darvishi et al. (2021) used zinc oxide (ZnO) nanoparticles synthesized with quince seed mucilage (as a new biopolymer)/chitosan+PEO in the preparation of nanobandages with antibacterial activity. In the study, nanofibers were obtained by electrospinning using a 20/80% quince seed mucilage/chitosan+PEO solution mixture. As a result, it was determined that the nanofiber bandage containing ZnO nanoparticles had a significant treatment effect on second-degree burn wounds, the burn healed faster, and no infection was observed in the wound. Jafari et al. (2021) prepared aqueous solutions containing different amounts of polyvinyl alcohol (PVA) and QSG. They examined the morphological properties of wound dressings produced by electrostatic spinning. In the study, it was also determined that the obtained structures showed significant biocompatibility against fibroblast cells, and fibroblast cells did not adhere properly to the sample after one day of culturing. In the studies of Allafchian et al. (2020), the polymer consisting of the combination of QSG and polycaprolactone (PCL) was used to obtain hybrid electrospun scaffolds. The study conducted by Şimşek (2020), the gel (mucilage) obtained from the seeds of quinces (Cydonia oblonga Miller) collected from Çanakkale was molded and lyophilized to obtain a three-dimensional porous form. After the analysis, it was stated that the obtained structures could have a possible use in regenerative medicine and tissue engineering applications. In the study conducted by Allafchian et al. (2018), it was determined that cell viability was higher in hybrid nanofiber scaffolds consisting of PCL and QSG compared to pure PCL scaffolds, and that the hybrid structure provided a suitable environment for the cells with its small-diameter pores, hydrophilic and non-toxic properties. Ghafourian et al. (2015) studied the effect of QSG on the proliferation of human fibroblast cells and stated that QSG may contain growth factors since it may stimulate fibroblast migration to the wound area. Atalay (2013) studied the effect of wheat germ oil and QSG on cutaneous wound healing in mice. It was determined that, unlike wheat oil, the wound closure rate in mice treated with QSG was no different from the control group. Janbaz et al. (2013) studied the effect of QSG on the digestive system and respiratory system muscles by applying quince gel to live tissue pieces of various animals. They stated that quince gel can be used in respiratory diseases such as asthma or digestive system disorders such as diarrhea and constipation. Hemmati et al. (2012) investigated the healing effects of QSG on T-2 toxin-induced skin lesions in rabbits. Hemmati and Mohammadian (2000) compared wound healing rates in rabbits that received no treatment, rabbits that received Eucerin cream containing 1% phenithion, and rabbits that received Eucerin cream containing 5%, 10%, and 15% QSG. The study found that rabbits treated with Eucerin with 10% QSG healed faster.

In literature, there are also studies the usage of QSG for non-medical applications. In their study, Moghaddas et al. (2020) investigated the use of QSG as a stabilizing agent based on the green synthesis method in the preparation of pure zinc oxide nanoparticles to be used for the degradation of photocatalytic methylene blue. Xie et al. (2018) studied the synthesis of a material containing Chinese quince seed mucilage and poly (N, N-diethylacyl amide-co-methacrylic acid) via free radical polymerization for pH-sensitive polymer and controlled drug release.

When the studies on thyme oil were examined, Zaharia et al. (2020) prepared emulsions by changing the concentrations of propolis (2–4% w/v) and thyme oil (2–4% v/v) and impregnated them on cotton fabrics. In the study, antibacterial activity was determined. Karagönlü et al. (2018) aimed to develop functional textile materials with antimicrobial properties and encapsulated thyme oil (Thymus vulgaris L.) by complex coacervation method using gelatin (GE) and gum arabic (GA) as wall material. No crosslinking agent was used to eliminate toxic effects during the encapsulation process. These capsules were applied to a nonwoven fabric and the effects of various processing parameters, including the amount of oil and wall material concentration, on encapsulation efficiency, particle size distribution and capsule loading were investigated. The antimicrobial activities of the capsule-applied fabrics were investigated and it was determined that both microcapsules and fabrics with different microcapsule concentrations showed antimicrobial activity against E. coli, S. aureus and C. albicans microorganisms. Scacchetti et al. (2017) investigated the production of cotton plain woven fabrics with thermoregulation and antimicrobial activity properties against S. aureus, E. coli, P. aeruginosa, T. rubrum and C. albicans by a simple finishing method. For this purpose, PCM microcapsules and monochlorotriazinyl-β-cyclodextrin were applied in the same bath and the obtained materials were impregnated with thyme oil as an active substance. At the end of the study, it was stated that comfortable cotton materials developed with antimicrobial properties could be used in various areas of health and biomedical applications in the future. Jouki et al. (2014) investigated the physical, thermal, antibacterial, antioxidant and barrier properties of films containing various proportions of thyme oil and QSG. Walentowska and Foksowicz-Flaczyk (2013) aimed to increase the resistance of lignocellulosic textiles to bacteria and mold by using a plant-derived biocide. In the study, the biocide thyme essential oil was used. The antimicrobial activity of thyme oil applied to linen-cotton blended and linen fabrics was evaluated by determining the bacterial growth, mold degree and their effects on fabric strength. It was determined that thyme essential oil applied to linen-cotton blended fabric as 8% concentration in methanol showed very high antibacterial and antifungal activity.

When evaluating the literature studies in general, it is observed that they focus on using natural materials such as thyme oil by encapsulation or electrostatic fibre attraction. The aim of this study was to realize functional yarn production based on the application of natural materials such as quince seed gel (QSG) and thyme oil into the staple fibre bundle during ring spun yarn production and to investigate the antibacterial activity of produced ring spun yarns loaded with QSG and thyme oil, with a view to their use in medical textiles. In terms of use in both yarn and fabric production, the yarn form was preferred. On the other hand, ring spun yarn production method was preferred for the yarn production because of its unique properties of spun yarns such as porous structure, permeability, flexibility and durability. For the application, an alternative application method was used. This method was used for the production of functional yarns with conductive and thermoregulation property in our previous studies. The method is based on integrating the materials for conductivity, thermoregulation, antibacterial activity etc. into the open fibre bundle before yarn twisting during the ring spinning process and hence trapping the material in the twisted yarn structure (Yılmaz et al., 2023; Kayabaşı et al., 2022; Yılmaz et al., 2022). In present study, QSG and thyme oil prepared at a certain concentration were applied to acrylic staple fibres and ring spun yarn production was carried out. In reviewing the literature, there is no similar study applying QSG and thyme oil to yarns spun from staple fibres and investigating the yarn properties, particularly antibacterial properties, with regard to their use in the medical field. Therefore, this study is the first to produce acrylic ring yarn containing QSG and thyme oil and to investigate the antimicrobial properties of the yarn.

2. Material and Method

2.1. Material

Quinces were supplied from Isparta (Turkey). In the study, commercial thyme oil (0.86 g/ml) was obtained and used in the spinning process.

2.2. Method

2.2.1. Preparation of Quince Seed Gel (QSG)

Quinces were cut with a knife and their seeds were removed. The seeds were weighed on a precision scale. 2.6 g of seeds and 50 ml of water were put into the prepared bottle shaker. It was mixed at 150 rpm for 24 hours at room temperature (Figures 1a, b and c). The dispersion consisting of the mixture of quince seeds and pure water removed from the shaker and then filtered. It was observed that gelation occurred after the mixing process and white consistency dispersion was obtained. In the study, a second sample was prepared as 5.3 g of quince seeds and 50 ml of pure water to increase the usage rate of quince seeds. It was determined that gelation was more intense as expected when the number of seeds increased in the same amount of water. However, yarn spinning could not be performed at the mentioned concentration. Therefore, quince seed gel (QSG) dispersion containing 50 ml and 2.6 g of seeds was used in the yarn spinning process in the study.

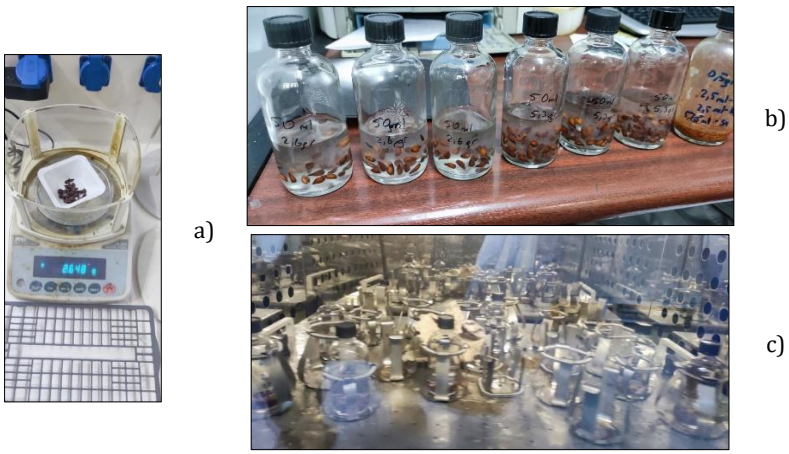

Figure 1. a, b) Preparation of quince seed gel (QSG), c) mixing in a shaker

2.2.2. Yarn Production

This study aimed to produce ring spun yarns loaded with natural materials such as quince seed gel (QSG) and thyme oil. Since spun yarns have properties such as porous structure, permeability, flexibility and strength, it was aimed to realize the application of QSG and thyme oil to the yarns spun from staple fibres. The study

employed the alternative application method developed in previous studies for the application of QSG and thyme oil into staple fibres to produce a functional yarn. An alternative application method was defined in our previous studies in detailed (Yılmaz et al., 2023; Kayabaşı et al., 2022; Yılmaz et al., 2022; Özen et al., 2022). The method provides the application of the dispersions containing various materials depending on desired functionality such as carbon powder, graphene, microcapsules to staple textile fibres in the main drafting zone of the ring spinning machine (Yılmaz et al., 2023; Kayabaşı et al., 2022; Yılmaz et al., 2022; Özen et al., 2022). The method relies on the application of the prepared dispersion opened fiber bundle during drafting process before the spun yarn production. The conventional ring spinning system was chosen for the application and spun yarn production because of its unique properties, such as being a widely used spinning method in yarn production and having no limitations in terms of fibre type and yarn count, yarn strength and other yarn properties. The prepared QSG and thyme oil dispersions were fed to the open fibre bundle during the drafting process of the ring spinning in a controlled manner (80 ml/h) using a specially designed feeding apparatus. The yarn samples obtained were wound on the cops as in ring spinning (Demirtaş, 2023).

2.3. Test and Analysis

In the study, the morphology of the yarn samples was analysed by Scanning Electron Microscopy (SEM), antibacterial activity property was investigated by AATCC-147 antibacterial activity test method and AATCC-100 test method. In order to determine the antibacterial activity property, knitted fabric samples were prepared from the ring spun yarns on a sock knitting machine.

AATCC-147 test method is a qualitative method that can be applied more easily and quickly than other test methods used for the determination of antimicrobial activity of textile materials. In this test method, S. aureus bacterial culture was used. According to the method, S. aureus bacterial culture which was incubated overnight in liquid medium was prepared the next day at 0.5 McFarland turbidity (108 cfu/ml) and 100 µl of 106 cfu/ml bacterial culture was spread on Müller-Hinton agar medium with the help of drigalski spatula. The media were allowed to dry at room temperature for a while and the fabric samples, which were previously sterilised at 121 °C at 1.5 atm pressure for 15 minutes, were placed on the media under sterile conditions with the help of pliers. The media on which the quince seed gel (QSG) and thyme oil applied samples were placed were incubated at 37 °C for 18-24 hours. At the end of incubation, the zone diameter formed around the samples on the medium was observed.

The AATCC-147 method is a qualitative method to determine the rate of antibacterial activity on textile surfaces, and the AATCC-100 test method was used to quantitatively determine the efficiency of the yarns. In this standard, samples were cut into squares of the desired size with an approximate area of 1-4 cm^2 and samples of the same size were sterilised. An untreated negative control was also used with the test sample. The sample fabrics were soaked with 1 ml of a solution containing bacteria at a density of 106 cfu/ml, transferred to screw-cap bottles and incubated at 37 °C for 18-24 hours. At the end of the incubation period, the fabric samples removed from the bottles were transferred to the liquid medium (Mueller-Hinton liquid medium) and thoroughly mixed by vortexing, allowing the colonised bacteria on the surface of the fabric sample to migrate into the medium. To enumerate the living organisms in this medium, serial dilutions (1/1, 1/10, 1/100, 1/1000) were prepared and inoculated on Mueller-Hinton agar medium. All petri dishes were incubated at 37 °C for 24 h. At the end of incubation, the amount of growth in each dilution was calculated by multiplying the number of growing colonies by the dilution ratio. The antimicrobial activity of the samples treated with QSG and thyme oil was determined quantitatively according to the AATCC-100 test standard, using the formula below.

$$R\ (\%) = 100\ (B-A)/B$$

In this equation;
R = Proportional decrease,
B = Number of organisms in the solution that came into contact with the sample at the beginning,
A = Number of organisms in the neutralization solution that came into contact with the sample.

The magnitude of the R values obtained with this method is scaled as antimicrobial activity;
if $R \geq 99.99$, it is “excellent”,
if $99 < R < 99.99$, it is “good”,
if $0 < R < 99$, it is “acceptable”.

The tenacity and elongation properties of the yarns were tested on MesdanLab Strength Tester test devices. In the tenacity and elongation properties, the test length was 500 mm and the test speed was 5000 mm/min. At least, 10 tests were performed for each sample (ASTM D2256).

3. Experimental Results

3.1. Scanning Electron Microscope (SEM) Images

SEM images of ring spun yarns loaded with and without quince seed gel (QSG) and thyme oil are given in Figures 2-4. When the images were examined, it was seen that the fibers followed a helical path and they were twisted within the yarn structure due to the real twist given by the ring-traveler of ring spinning system during the yarn production. In terms of yarn structure, it was observed that there was no significant difference between unloaded reference and QSG and thyme oil loaded ring spun yarns. No significant changes in yarn character was observed after the application with an alternative application method, consistent with our previous studies aimed at producing yarns with conductive and thermoregulatory functional properties (Özen et al., 2022; Yılmaz et al., 2022). In unloaded reference ring spun yarns, a striped structure, which is a unique feature of acrylic fibers, was observed. However, in the loaded yarns, it was determined that QSG and thyme oil covered the surface of the fibers. The fibres appeared to be coated like a film with QSG and thyme oil. Almost all fibres have a similar film-like appearance.

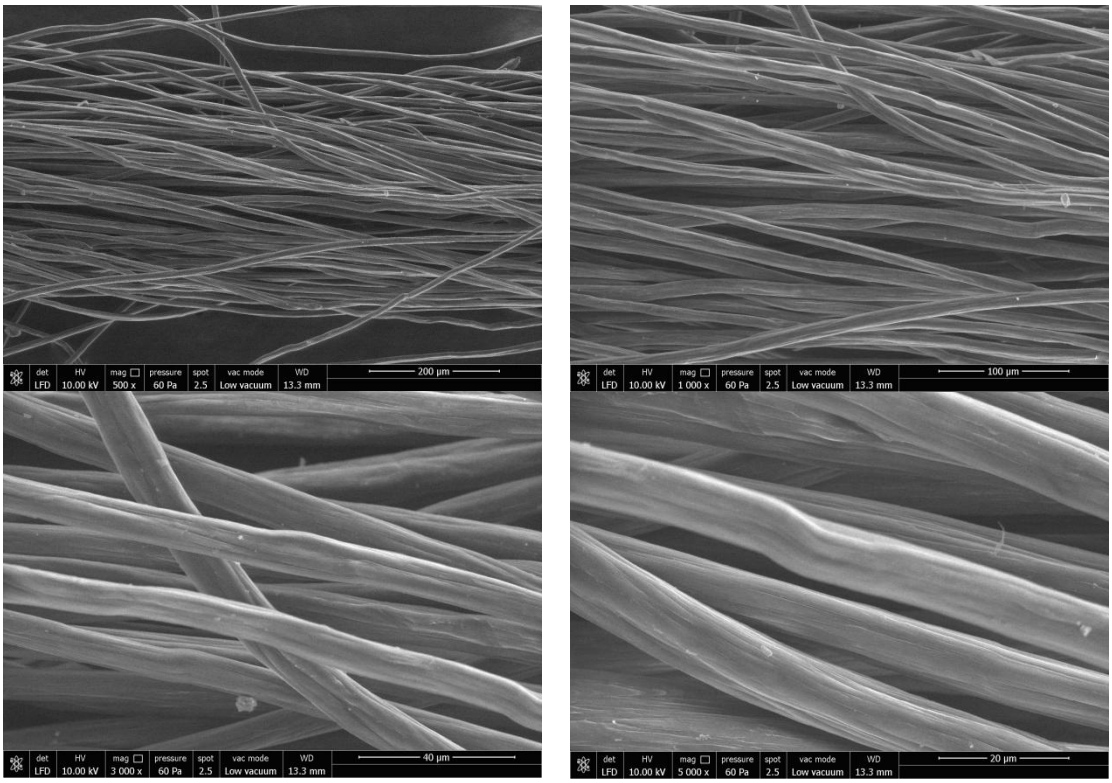

Figure 2. SEM images of reference unloaded acrylic ring yarns

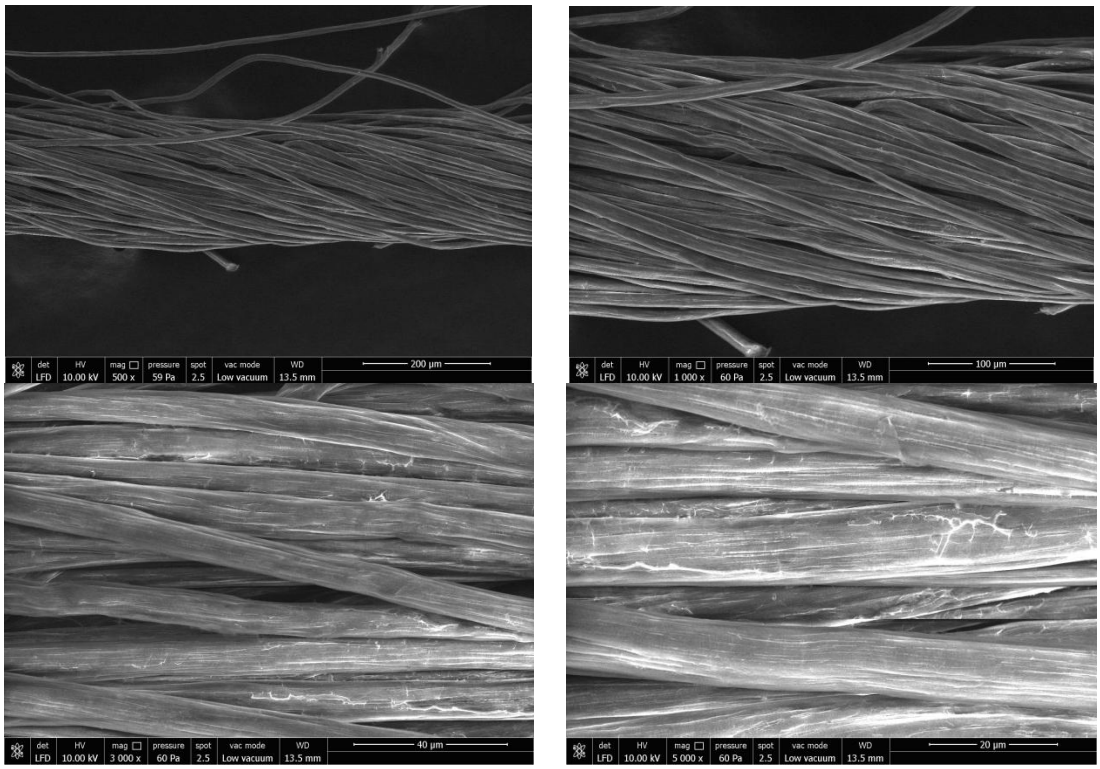

Figure 3. SEM images of acrylic ring yarns loaded with quince seed gel

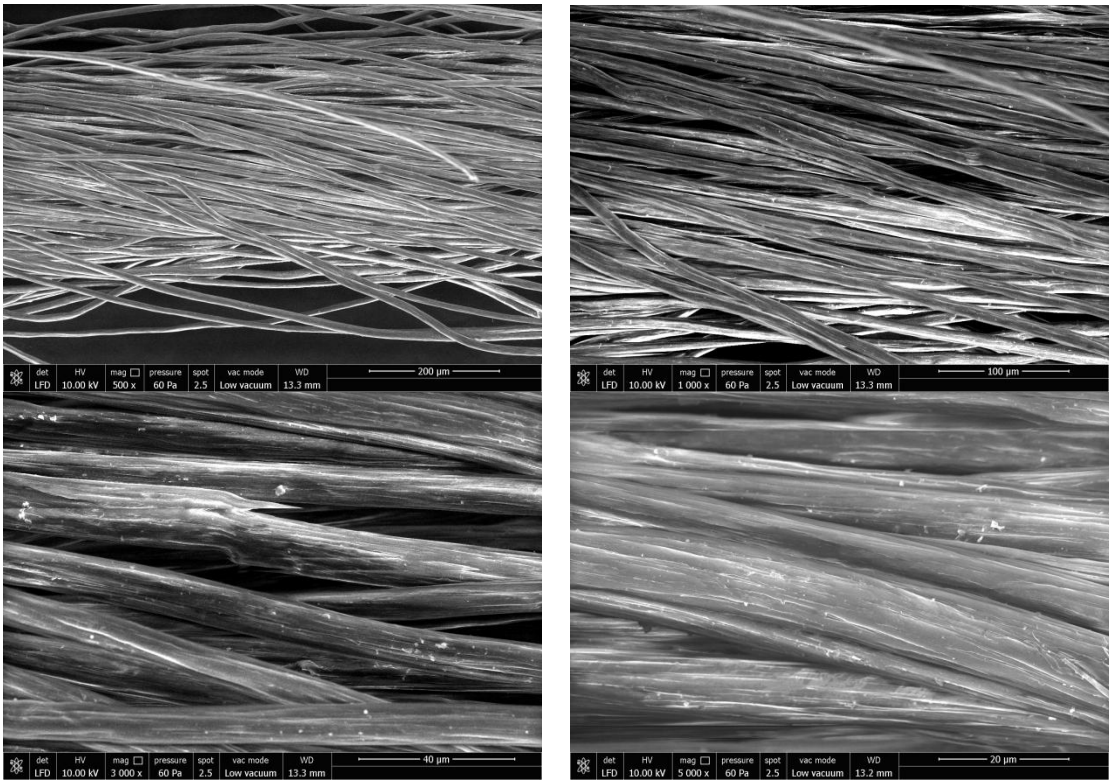

Figure 4. SEM images of acrylic ring yarns loaded with thyme oil

3.2. Antibacterial Activity

The antibacterial activation properties of the fabrics knitted from ring spun yarns loaded with quince seed gel (QSG) and thyme oil were investigated by AATCC-147 antibacterial activity test method and the AATCC-100 test method. No antibacterial activity was detected in the knitted fabrics produced from QSG loaded ring spun yarns. On the other hand, the inhibition results shown in Figure 5 were determined qualitatively at the end of the incubation in solid media on which the fabrics treated with thyme oil were placed and on which a liquid bacterial culture was spread. The experiments were continued using the AATCC-100 method for the quanlitative

determination of antibacterial activity.

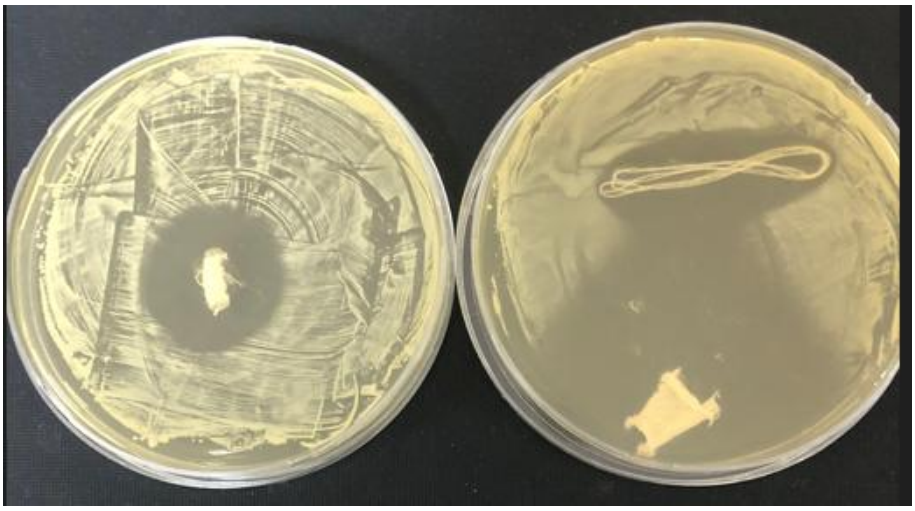

Figure 5. Inhibition zones formed around the thyme oil loaded ring spun yarn and knitted fabric obtained from these yarns

According to the results of AATCC-100 Test Method, at the end of 24 hours incubation with S. aureus, R (%) (proportional reduction) value of knitted fabric samples treated with thyme oil was determined between 99 < R < 99.99 and 'good' activity result was obtained (Figure 6). Therefore, antibacterial activity was determined in thyme oil applied samples. This result is consistent with the findings in the literature (Zaharia et al., 2020; Karagönlü et al., 2018; Scacchetti et al., 2017; Walentowska and Foksowicz-Flaczyk, 2013). In the study, Zaharia et al. (2020) stated that essential thyme oil is one of the most powerful antiseptic essential oils due to the essential phenolic components in its structure. In quince seed gel (QSG), a reason might be that the active ingredients required for antibacterial activity were not sufficient in the dispersion.

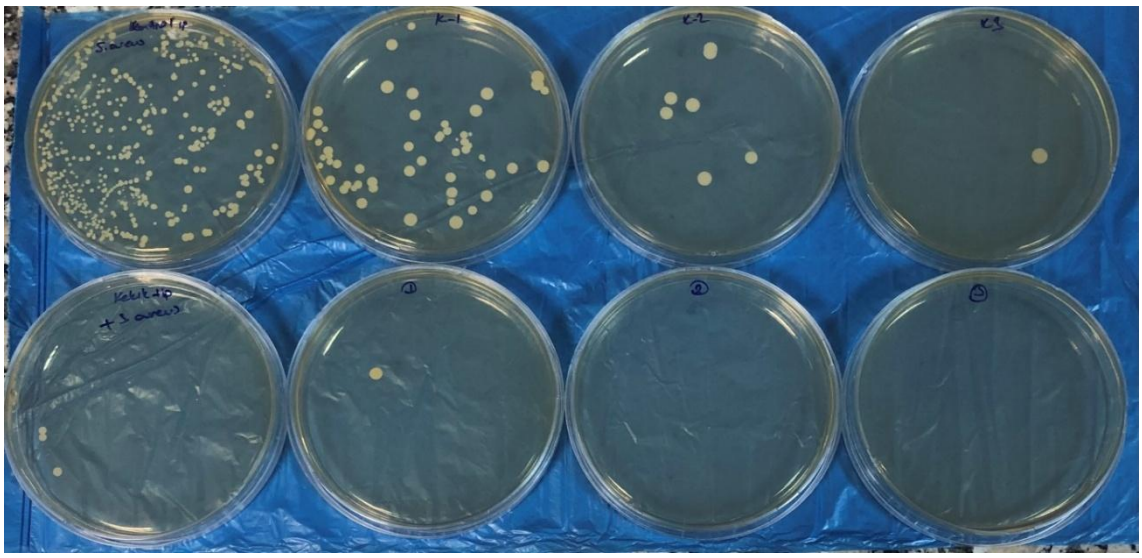

Figure 6. Colonies observed by smearing at different dilutions after 24 hours of incubation

3.3. Tensile Properties of The Yarns

The changes in yarn tensile properties of acrylic ring spun yarns loaded with natural materials such as quince seed gel (QSG) and thyme oil were investigated and compared with unloaded reference ring spun yarns. The results obtained are given in Table 1. When the yarn tenacity results were evaluated, it was determined that the unloaded ring spun yarns had the highest values and the yarns loaded with QSG had the lowest ones. The decrease in the tenacity values was 14.8% for the yarns loaded with QSG and 7.6% for the yarns with thyme oil. Therefore, a tendency to decrease in yarn tenacity values was observed in the yarns loaded with both natural materials, and the lowest decrease was found in the yarns with thyme oil. As known, the breaking behaviour of spun yarns can be explained by the sliding mechanism of the fibres and the strength of the fibres themselves. Therefore, the changes in the tenacity values of the loaded ring spun yarns could be explained by the fact that the natural materials might change the surface structure of the fibres and thus the fibre-fibre friction after the application. In particular, in the SEM images of the QSG loaded yarns, it was observed that the fibres had a

smoother structure compared to the thyme oil applied yarns. Therefore, it is thought that the fibre-fibre friction between the fibres of the QSG applied yarns was adversely affected, the fibres could not adhere to each other and therefore the yarn tenacity values decreased more. It was observed that the fibres had a rough structure in the yarns with thyme oil and a lower decrease in the tenacity values occurred due to this structure. The tensile behavior of spun yarns is a primarily function of fiber properties and yarn structure (Soltani and Johari, 2012). The yarn tensile properties are also affected by the frictional fiber properties (Sinoimeri, 2009). Friction is important in cases such as needle punching process, carding and spinning of yarns, wool felting, abrasion, and wear of cloth (Soltani and Johari, 2012). The phenomenon of friction results from the interaction between two contacting surfaces. The frictional behaviour of the two surfaces will be influenced by factors that affect this interaction system either individually or collectively (Alirezazadeh et al., 2018). In our previous study, the application of nanocapsules to the cotton ring spun yarn structure increased the yarn tenacity values. This finding was explained by the increment of fiber-to-fiber friction resulting from the presence of nanoparticles on the fiber surface (Alay Aksoy et al., 2024). However, in this study it is assumed that the QSG and thyme oil application had a negative effect on the friction between the fibres and therefore reduces the strength of the yarn.

Table 1. Yarn tenacity and breaking elongation results of yarn samples

Yarn Type	Tenacity (RKM)	Breaking Elongation (%)
Reference	13.922	9.468
Quince seed gel	11.856	7.692
Thyme oil	12.865	9.048

The trend in the breaking elongation results of the ring spun yarns was similar to the yarn tenacity results. The lowest breaking elongation was determined in the yarns with quince seed gel (QSG) while the highest one was determined in the yarns loaded with thyme oil. Compared to the unloaded reference yarns, the breaking elongation values decreased by 18.8% in the yarns loaded with QSG and 4.4% in the yarns with thyme oil. Particularly, it was observed that the yarns loaded QSG had a hard hold after application. It was thought that this case negatively affected the breaking elongation of the yarns. Although the tenacity and breaking elongation values of the yarns decreased to a certain extent after application, fabric production by knitting method was successfully carried out from the yarns. Therefore, the tensile properties of the yarns are comparable with the reference yarns and sufficient for fabric production (>10 cN/tex).

4. Result and Discussion

Present study aimed to investigate the possibility the application of natural materials such as quince seed gel and thyme oil to the fibre bundle during spun yarn production and to analyse the antibacterial activity functional property for an alternative or complementary approach to wound treatment. In the study, quince seeds were kept in the water for a certain period of time and quince seed gel (QSG) was obtained. Commercially available thyme oil was used. The prepared QSG and thyme oil dispersions were fed to the open fibre bundle during the ring spinning process in a controlled manner (80 ml/h) by means of a specially designed feeding apparatus. After rin spun yarn production, morphology, tenacity, breaking elongation and antibacterial activity of the yarns were analysed. According to Scanning Electron Microscopy (SEM) images, it was observed that QSG and thyme oil covered the fibre surface. Antibacterial activity tests indicated that the yarns treated with thyme oil showed antibacterial activity (S. aureus), while the yarns treated with QSG did not show antibacterial activity due to the inability of the active substance to be sufficiently incorporated into the yarn structure. As to tensile properties of the yarns, it was determined that surface structure of the fibres in the yarn structure and thus the fibre-fibre friction changed after the application of QSG and thyme oil, thus changing the tenacity and elongation at break properties. It was observed that the yarn tenacity and breaking elongation values decreased. The reduction in yarn tenacity was about 14.8% for the yarns loaded with QSG and 7.6% for the yarns with thyme oil. On the other hand, yarn breaking elongation decreased 18.8% for the yarns loaded with QSG and 4.4% for the yarns with thyme oil. However, it was determined that the yarns had sufficient yarn tenacity and breaking elongation values for fabric production such as weaving and knitting and were comparable to yarns without any natural materials.

In line with the findings obtained, different natural materials such as QSG and thyme oil were successfully applied to acrylic fibres by alternative application method and ring yarn production was carried out. Based on the obtained results, it is believed that yarns containing natural materials may offer an alternative or complementary approach to treatment. Although the antibacterial activity could not be determined due to the insufficiency of the active ingredient of the quince seed, it is thought that more detailed trials should be carried

out in order to make a more precise evaluation. However, different tests and analyses should be performed to determine the potential of yarns containing natural materials as biomaterials, especially for wound healing.

Conflict of Interest

No conflict of interest was declared by the authors.

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