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Resistance of orange peel against microbial activity on various fabrics

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Abstract

Textile products are required to be safeguard them against bacteria and microorganisms infestation. Natural herbs and plant material may be used on the surface of fabrics rather than synthetic materials to protect them against biotic factors. In this regard a study was conducted to evaluate orange peel on several fabrics to create an antibacterial textile finish. AATCC 147 test method was used to measure the developed finish's efficacy against two different strains of bacteria, including *Escherichia coli* and *Staphylococcus aureus*. Treated and untreated fabrics were compared to determine significant ($P \leq 0.05$) difference. Treated materials showed zones of inhibition ranging from 32 - 45 mm, and for gram negative bacteria, it ranged between 30 to 41 mm. The zones of inhibition in the treated materials indicate areas where bacterial growth is actively controlled. Larger zones suggest a stronger antimicrobial effect. The active compounds in the orange peel extract may interfere with bacterial cell membranes, disrupt cellular processes, or inhibit essential enzymes.

Keywords: Antibacterial, Staphylococcus aureus, Escherichia coli

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Introduction

Textile plays an important role in the life of humans. It is being used for many purposes such as warmth, protection, modesty and decoration. It can be produced from either natural or synthetic sources. Various types of fibers and yarns have been produced to make the fabric through different processing techniques. The environmental impact of synthetic materials has raised significant concerns due to factors such as their non-biodegradability, contribution to pollution, and reliance on fossil fuels during production. As a result, there is an increasing drive to adopt more environmentally friendly substitutes, especially those made from natural resources or leftover agricultural materials. Synthetic materials, while offering various benefits like durability and versatility, tend to accumulate in the environment over time due to their slow decomposition rate. This persistence can lead to issues such as microplastic pollution, which affects ecosystems, wildlife, and even human health. Additionally, the creation of synthetic materials frequently uses petrochemicals, which increases greenhouse gas emissions and worsens already existing environmental issues (Aishwariya & Amsamani, 2018). To address these concerns, efforts are underway to transition towards natural materials that are biodegradable and have a lower environmental footprint. Natural fibres have a long history of use and are renowned for being eco-friendly. Examples include cotton, wool, and hemp. These materials have a low long-term environmental impact because they come from renewable resources and decompose naturally. Another promising approach involves the conversion of waste agricultural materials into sustainable alternatives. Agricultural residues, such as corn husks, rice straw, and banana stems, are often discarded after harvest. They can be used differently to make biodegradable materials that can replace synthetic items. This strategy lessens the need for virgin resources while also addressing issues with waste management. Innovative techniques and technologies have been created recently to harvest and turn natural resources into workable materials for a variety of purposes. For instance, bio-based polymers can be derived from plant starches or sugars, offering a sustainable alternative to petroleum-based plastics. Additionally, techniques like enzymatic treatment and fermentation can convert agricultural waste into valuable textiles and materials. Antimicrobial finishing treatment over the surface of fabrics helps to inhibit the growth of micro-organisms or can slow down their reproduction process. Basically this finish breaks the cell wall and hinders the process of protein synthesis necessary for the growth of microbes. It also prevents the enzyme production used as food for microbes (Afraz *et al.,* 2019).

When antimicrobial finishes were first introduced, they were mainly used in the pharmaceutical and medical industries to protect patients from harmful organisms. However, as consumer awareness and preferences have evolved, the textile industry has responded by incorporating antimicrobial and antibacterial properties not only in medical settings but also in everyday products like apparel and upholstery. The shift in consumer mindset and the growing emphasis on health and hygiene have played a significant role in driving this trend. People today are more conscious about their well-being and seek products that offer added protection against microbial threats. As a result, textile manufacturers have recognized the market demand for textiles that not only provide comfort and aesthetics but also contribute to maintaining a cleaner and healthier environment (Jantas & Gorna, 2006).

Incorporating antimicrobial and antibacterial properties into textiles involves the use of specialized treatments, coatings, or finishes that inhibit the growth and survival of microorganisms on the fabric's surface. These properties are particularly relevant for products that come into direct contact with the human body, such as clothing, bedding, and upholstery. Manufacturers hope to provide customers with increased safety in their daily lives by incorporating these features. Furthermore, the adoption of antimicrobial finishes in textiles goes beyond personal use to address broader concerns such as odor control and the potential to reduce the transmission of pathogens in shared spaces. The advancement of technology has enabled the development of innovative antimicrobial solutions that are safe, durable, and effective. Manufacturers frequently collaborate with scientists and researchers to develop strategies that satisfy consumer demands while also adhering to the industry norms and regulations (Holme, 2007).

Plant extracts can be encapsulated to achieve controlled release features (acacia-based capsule wall filled with herbal extracts) or utilized as finishing agents during textile processing. Despite extensive study into the antimicrobial properties of various plant extracts, there is still a need for antimicrobial active functionalization of textile materials employing plant extracts (Wolela, 2020). One business that is becoming more interested in using bioresource waste from fruits as a vital step toward sustainable growth is the textile industry. Researchers recently created a variety of high-end textile fabrics using fruit waste from the textile industry, including pineapple, apple, grape, and banana (Torre *et al*., 2019).

In Pakistan, the most popular fruits include apples, oranges, mangoes, bananas, guavas, and grapes. Citrus sinensis, an orange fruit, is one of the most significant fruits in the world because of its delicious flavour and beneficial nutrients. In order to consume an average dose of vitamin C each day, orange juice is typically consumed. Here, oranges are produced on a vast scale that not only meets local demand but also earns money through export to other nations. Oranges have a variety of health advantages, including supporting the heart and kidneys' and other organs' healthy operation. Additionally, it assists in maintaining healthy cholesterol levels in the body and controlling regular blood pressure (Deng, 2020).

The byproducts of citrus fruits, particularly their peels, are known to contain a significantly higher concentration of phenolic compounds and flavonoids compared to the fruit's pulp or edible portion. This phenomenon can be attributed to the unique composition and structure of these outer layers. It was studied that the peels of orange, lemon and grapefruit contain 15% high ratio of phenolics compared to the peeled portion of fruit. Phenolic compounds and flavonoids are classes of natural bioactive compounds found in various plants, and they are renowned for their antioxidant and antimicrobial properties. These compounds play a crucial role in the defense mechanisms of plants, aiding them in protecting against environmental stressors and potential pathogens. In citrus fruits, these phenolic compounds and flavonoids are primarily concentrated in the peels, which serve as a protective layer for the fruit. The fruit's outer covering serves as a barrier, protecting the inner flesh from potential dangers like UV radiation, pest infestations, and microbiological infections. The peel has a larger concentration of these bioactive substances to efficiently perform this protective work. When citrus fruits are eaten, the main focus is on the juicy and tasty edible part, which is frequently abundant in vitamins, carbohydrates, and water content. The peels, which are typically thrown away, contain a plethora of beneficial substances that can improve human health and wellbeing.

Researchers have found that these phenolic compounds and flavonoids present in citrus peels exhibit a range of health-promoting effects. They have antioxidant properties that help combat oxidative stress and reduce the risk of chronic diseases. Some of these substances have also shown antibacterial qualities, which can be especially helpful in a variety of contexts, including the textile sector. Citrus peel extracts have gained a lot of attention in recent years for a variety of uses, including in textiles and other materials. These compounds are useful for improving the characteristics of fabrics, boosting hygiene, and possibly even extending the lifespan of textile items due to their antibacterial and antioxidant qualities (Moraes *et al.,* 2012). Fruit peels make up a significant portion of the reported waste each year. Because of their fermentability, peel wastes are frequently thrown out as trash, which causes a significant waste of resources and significant economic and environmental issues (Moraes *et al.,* 2012 ; Sawalha *et al*., 2009).

Investigating the processing and use of an orange peel is essential in reducing the waste of natural resources and environmental degradation. This study aids in turning waste peels into environmentally friendly goods. The main objective of the current study was to induce antimicrobial properties in the fabric through extraction of oil from orange peel in order to reduce the microbial activity on clothes of the wearer.

Materials and Methods

Oranges were obtained from local market. It was ensured that fresh fruits were collected. The peels were removed and immediately collected in a bowl. The dirt was dusted out from their surface and washed in distilled water and dried under the sun. The dried peels were placed in air-tight containers in oven for drying at 65 degrees centigrade for 24 hours, as this temperature was reported to be most suitable in protecting phenols and antioxidant characteristics (Deng, 2020). Then it was converted into powder form by grinding. This powder was dissolved in water with a liquor ratio of 70%. Sodium bicarbonate was used as a binder and fixing agent in the solution. It was applied through pad-dry method. Four different types of fabrics were obtained from Nishat Textile Mills Limited. These were manufactured by following plain interlacing pattern. The specification parameters of collected fabrics were checked and noted (Table 1). Fabrics were completely cleaned, desized and bleached.

Table 1. Construction specifications of collected samples

Sample Code	Fabric Type	Fabric Mass (gsm)	Yarn Density (warp x weft) (tex)	Threads per Inch
C-1	Cotton	150	11.12 x 12.36	145
C-2	Cotton	150	11.12 x 12.36	145
S-1	Silk	136	12.22 x 11.21	129
S-2	Silk	136	12.22 x 11.21	129
P-1	Polyester	142	11.87 x 10.64	135
P-2	Polyester	142	11.87 x 10.64	135
B-1	Blend (cotton 40%, viscose 60%)	125	12.54 x 11.78	127
B-2	Blend (cotton 40%, viscose 60%)	125	12.54 x 11.78	127

The antimicrobial effectiveness of the samples was assessed using the AATCC-147 (AATCC, 2016) standard test method. Following the test protocol guidelines, specimens were cut to the dimensions of 25x50 mm. For each specimen, a Petri dish containing 15mm of sterilized nutrient agar was prepared, which solidified into a gel-like form. Inoculum was prepared from a broth culture in distilled water, incubated for 24 hours. Staphylococcus aureus and Escherichia coli strains were then placed on separate Petri dishes. Using a spatula, the specimen was pressed onto the agar, creating five streaks. The plates were subsequently incubated for 24 hours at 37 °C. This methodology aimed to determine the antimicrobial efficacy of the tested specimens against the bacterial strains.

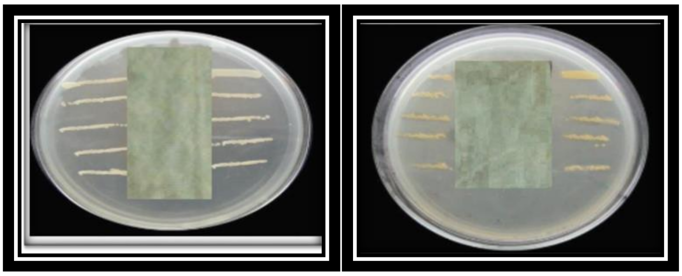
Results and Discussion

A comparison was made among samples for their treated and untreated condition. ANOVA was applied to analyze the observed value. P-value ≤ 0.05 was considered as significant. Table 2 clearly shows the low values for the untreated specimen for the measurement of inhibition of bacterial growth in each case. The bacteria on and near the surface of the tested fabrics can be killed with the aid of antimicrobial chemicals. The direction of the association between the zone's size and microbial activity is clear. Larger zones typically result in stronger antibacterial action, and vice versa (Gupta & Laha, 2007). It was observed that C-1 and C-2 showed excellent results in both bacterial types among all fabrics. Numerous plant-based extracts can be used as powerful weapons against microbial activity (Lee *et al.,* 2009). It was found that the addiction of sodium bicarbonate with orange and lemon peel produced anti odor and anti-bacterial properties in fabric used for medical industry. The finished fabric resisted the activity of all types of bacteria other than C. Albicans (Amanuel, 2018).

Table 2. Statistical analysis of zone of inhibition of treated and untreated samples

Sample code	**Bacteria species**	**Zone of inhibition (mm)**		**Mean square**	**F**	**p-value**
		Treated specimen	Untreated specimen			
C-1	Staphylococcus aureus	45	4	71.23	22.31	0.001
C-2	Escherchia coli	41	3	54.98	12.43	0.001
S-1	Staphylococcus aureus	32	0	73.23	14.76	0.002
S-2	Escherchia coli	30	1	45.22	19.81	0.001
P-1	Staphylococcus aureus	39	3	34.65	22.65	0.000
P-2	Escherchia coli	37	2	63.76	12.50	0.001
B-1	Staphylococcus aureus	35	4	53.67	16.75	0.001
B-2	Escherchia coli	31	3	43.98	13.53	0.001

Silk fabric also presented good values 32mm and 30mm respectively for S-1 and S-2. In another study, the blend of an orange peel with papaya peel was examined to determine their combined impact on fabric properties. The findings highlighted that this combination led to the development of antimicrobial potentials within the fabric, hence enhancing its resistance to harmful microorganisms. This innovative approach has the potential to smuggest improved hygiene and health-related benefits to various textile applications (Rani et al., 2020). Materials treated with orange oil extract generally displayed higher percentage reduction rates, when compared to those treated with rosemary oil extract thereby promoting orange extract as a better antimicrobial finishing agent (Iordache *et al.*, 2016). Sample P-1 shows 39 mm growth of inhibition of bacteria for Staphylococcus aureus, a gram positive bacteria. There are various types of organisms such as bacteria, virus, algae, fungi, protista, certain plants and animals (Amengialue *et al.*, 2016 ; Renaud *et al.*, 2006). Peptidoglycan and teichoic acid are components of gram-positive bacteria. Peptidoglycan, which makes up 90% of cell walls, is composed of amino acids and sugar. Staphylococcus aureus which comes in the shape of a pair, short chain, or cluster with a graphic appearance, is one example of a gram-positive bacterium. It grows in a temperature range of 35 to 40°C and ranges in size from 0.5 to 1.0m. Specimen P-2 shows 37 mm growth for negative gram bacteria. As they have more cell walls than gram positive bacteria, they are more difficult to eradicate. Escherichia coli is a kind of gram-negative bacterium. It lives in the human intestine and has a bacillus-like morphology (Naebe *et al.*, 2022). B-1 showed better rate of inhibition as 35mm and 31mm compared with 4mm and 3mm for untreated samples respectively for both types of bacteria (Fig 1). Antibacterial qualities were produced by laminating cotton fabric with several natural plant materials, including neem, pomegranate, and turmeric (Mahesh *et al.*, 2011).



(a) (b)

Figure 1. Microbial activity of *E. Coli (a) and* S. aureus (b) *on specimen*

Chemical surface modifications can affect the inhibition of bacteria in the fabrics. Physical surface coatings and laminations are best to use to avoid the bacterial growth in most of the fabrics. According to the blend ratio and the type of antimicrobial treatment used, the inhibition zone size changed, demonstrating the impact of both fabric composition and treatment on the antimicrobial efficacy (Wang et al., 2020). Some of the fibres have the ability to wick moisture away from their surface, thus inhibiting the survival and growth of bacteria. This moisture wicking behaviour may result in the development of antibacterial zone. This moisture-wicking behavior not only helps in maintaining dryness but also creates an environment less conducive for the survival and proliferation of bacteria. As moisture is essential for the growth of many bacteria, depriving them of this moisture inhibits their ability to thrive. Consequently, these moisture-wicking fibers can lead to the creation of zones on the fabric surface that are less hospitable for bacterial growth, thus contributing to the development of antibacterial properties in textiles. This characteristic is especially valuable in applications where hygiene and microbial resistance are essential, such as medical textiles and sportswear (Gocek & Duru, 2021). The results showed higher resistance against the bacterial growth with all types of fabrics due to the finishing treatment applied over their surface. The oil extracted from an orange peel is highly effective against microbes. Flavones and other powerful antibacterial agents including numerous polymethoxylated have been found in orange extract. It is primarily caused by the presence of alkaloids, which have potential against bacteria (Tariq *et al.*, 2017).

The occurrence of antibacterial zones in untreated fabrics can be attributed to the fact that these fabrics were not produced using fibers that naturally possess antibacterial properties. In contrast, certain natural fibers possess inherent antibacterial characteristics due to the presence of specific compounds like lanolin and sericin. These compounds have innate antibacterial qualities and contribute to countering bacterial activity. When these natural fibers are used in fabric production, the antibacterial zones emerge as a result of these compounds, which can inhibit the growth of bacteria and contribute to the overall hygiene and microbial resistance of the fabric. This natural antibacterial attribute is particularly advantageous in applications where maintaining a clean and sterile environment is essential (Nesa et al., 2020). Moreover, some of the synthetic fibers contain metals which may hold antimicrobial ability. fibers are engineered with antimicrobial agents, often in the form of metals. These antimicrobial agents, such as silver nanoparticles or copper ions, are integrated into the fibers during the manufacturing process. The synthetic fibres are naturally antibacterial due to the presence of these metals. When these antimicrobial synthetic fibers are used in the production of textiles, they contribute to the creation of fabrics that possess the ability to inhibit the growth of bacteria, fungi, and other microorganisms. The metal-based antimicrobial agents work by releasing ions that interact with the microorganisms, disrupting their cell membranes and metabolic processes. This prevents the microbes from multiplying, hence minimizing their presence and potential danger. The risk of infection transmission and cross-contamination can be reduced with the use of these textiles (Maximino *et al.*, 2021). The intersections in the fibre structure physically help to entrap the bacteria by hindering their movement and growth. The formation of antimicrobial zones can be smoothed out by trapping behaviour that restricts the colonization of bacteria. The presence of air spaces, surface morphology, and placement of yarns on the substrate can greatly affect the antibacterial properties of finished article. In the field of textiles, the structure of fibres has a major impact on how bacteria, in particular, interact with them. Fibres' complex internal structures, which are revealed by their intersections and surface characteristics, can have a big impact on how effective they are against bacteria. The intersections within the microstructure of fibres can operate as physical barriers for bacteria, according to research into their microstructure. The mobility and expansion of bacteria on the fiber's surface is impeded by these intersections, which serve as barriers. One key mechanism for the antibacterial properties of some fabrics is the restriction of bacterial movement. These zones are regions where the growth of bacteria is restricted or prevented due to the inherent antibacterial properties of the textile. The smoothing out of these zones can be attributed to a trapping behavior exhibited by the textile's structure. The physical entrapment of bacteria within the fabric's matrix hinders their ability to colonize and multiply, effectively inhibiting their growth. The antibacterial efficacy of textiles is also significantly influenced by various factors related to their structure. Air spaces within the fabric, surface morphology (texture), and the arrangement of yarns on the substrate can all impact the extent of antibacterial properties exhibited by the finished article. For instance, materials having a high degree of porosity may enable improved air circulation, which would therefore promote the dispersion of antibacterial agents and increase their efficiency. Similar to this, the fabric's surface characteristics might make it difficult for bacteria to stick to and develop (Alosmanov *et al.*, 2022).

Conclusion

The study's findings established that fabrics treated with orange peel extracts exhibited notable antibacterial attributes. This utilization of orange peel as an ingredient in antimicrobial finishes demonstrated its potential as a valuable resource in the creation of such finishes for a wide range of clothing items. The research highlighted the efficacy of orange peel-derived treatments in enhancing the fabric's resistance to microbial activities, indicating their potential utility in garments. To build on these findings, future can explore the antimicrobial potential of other citrus fruit extracts in combating bacteria when applied to textiles. Investigating a broader spectrum of natural extracts could contribute to the development of eco-friendly antimicrobial strategies for textiles, fostering both sustainability and improved hygiene in clothing.

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