Antimicrobial property of functional viscose fibre by using mint extract

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ABSTRACT – REZUMAT

Antimicrobial property of functional viscose fibre by using mint extract

The use of cellulosic fibres treated with natural extracts can kill bacteria. Viscose is a regenerated cellulosic fibre with excellent biodegradability. The use of mint extract makes viscose a functional fibre, which gives beneficial results and can be used as an antimicrobial textile. The results clearly showed that the increasing ratio of the mint extract also increased the bacteriostatic ratio so that the antimicrobial property against E. Coli and S. Aureus for 100% viscose fabric is 97% and 94%, respectively. The bacteriostatic ratio against 50/50 cotton/functional viscose is proportionally lower, i.e., 85% and 81% against E. Coli and S. Aureus. The different number of washings affected the antimicrobial property of the fabrics in such a way that: the fabric with 100% functional viscose indicated a reduction of 14% for E. Coli, whereas the antimicrobial property decreased by 15% against S. Aureus after 5 to 20 washes as compared to the fabric with the blend 50/50. All the samples exhibited antimicrobial property more than 60% after 20 washes. The breaking strength of the functional viscose fibre decreased by about 12.9% in dry form and 14% in wet state compared with standard viscose fibre. However, the elongation of functional viscose fibre improved by 6.4% in dry form and 3.7% in the wet state, resulting in the low modulus of functional viscose fibre. The mosquito repellency rate ranges from 70–90% against 100% functional viscose fabrics, whereas 60–80% against the fabric is made up of a 50/50 blend for 5 to 20 washes. The overall results show acceptable behaviour against mosquito repellency. A simple approach was applied to develop antimicrobial textile products with cost-effectiveness and fruitful results.

Keywords: *viscose fibre, mint extract, anti-bacterial activity, anti-mosquito behaviour*

Proprietatea antimicrobiană a fibrei de viscoză funcţională prin utilizarea extractului de mentă

Utilizarea fibrelor celulozice tratate cu extracte naturale poate ucide bacteriile. Viscoza este o fibră celulozică regenerată cu o excelentă biodegradabilitate. Utilizarea extractului de mentă face din viscoză o fibră funcțională, care dă rezultate benefice și poate fi folosită ca material textil antimicrobian. Rezultatele au arătat în mod clar că proporția în creștere a extractului de mentă, a crescut și raportul bacteriostatic, astfel încât proprietatea antimicrobiană împotriva E. Coli și S. Aureus pentru materialul textil din viscoză 100% este de 97% și, respectiv, 94%. Raportul bacteriostatic față de materialul textil din 50/50 bumbac/viscoză funcțională este proporțional mai scăzut, adică 85% și 81% față de E. Coli și S. Aureus. Numărul diferit de spălări a afectat proprietatea antimicrobiană a materialelor textile în așa fel încât: materialul textil din 100% viscoză funcțională a indicat o reducere de 14% pentru E. Coli, în timp ce proprietatea antimicrobiană a scăzut cu 15% față de S. Aureus, după 5 până la 20 de spălări în comparație cu materialul textil din amestec 50/50. Toate probele au prezentat proprietăți antimicrobiene peste 60%, după 20 de spălări. Rezistența la rupere a fibrei funcționale de viscoză a scăzut cu aproximativ 12,9% în formă uscată și cu 14% în stare umedă, comparativ cu fibra de viscoză standard. Cu toate acestea, alungirea fibrei funcționale de viscoză s-a îmbunătățit cu 6,4% în formă uscată și cu 3,7% în stare umedă, rezultând un modul scăzut al fibrei funcționale de viscoză. Rata de respingere a țânțarilor variază de la 70–90% în cazul materialelor textile din viscoză funcțională 100%, în timp ce rata este de 60–80% în cazul materialelor textile din amestec 50/50, pentru 5 până la 20 de spălări. Rezultatele generale arată un comportament acceptabil împotriva respingerii țânțarilor. O abordare simplă a fost aplicată pentru a dezvolta produse textile antimicrobiene cu rentabilitate și rezultate corespunzătoare.

Cuvinte-cheie: *fibră de viscoză, extract de mentă, activitate antibacteriană, comportament anti-țânțari*

INTRODUCTION

Anti-bacterial textile products contribute to the health-care industrial sector. A diversity of textile products in the healthcare industry might be expected to give comfort and hygienic properties, such as bedding, surgical gowns, doctor coats, bedding, pillowcases, surgical masks, etc. However, the applications of anti-bacterial products are boundless rather than the healthcare industry, e.g., sports clothing and footwear. It was further extended to other applications like pet bedding, furniture, bath sheets, etc. After frequent washing, the significant aspect of anti-bacterial textiles products is to give long-lasting and continuous protection against detrimental bacteria (that might cause you ill and stains or odours) [1, 2].

For the time being, there is still a massive demand in the market to propose new techniques and advanced materials to exhibit antimicrobial properties to ensure satisfactory safety against microorganisms. Medical textiles are one of the most exciting areas in modern textiles to introduce products showing antimicrobial properties. Previously, the textile products were treated chemically; (phenols, iodine derivates, amines, formaldehyde derivatives, nitro compounds, inorganic salts, and antibiotics to restrain the bacteria attack. However, the chemical compounds are harmful due to their toxicity and poor degradability, which is not environmentally friendly and is against safety regulations. This is the reason why textile processing has been enforced to be concerned with the natural and non-toxic materials in the modern and technical processes, which are eco-friendly and not health hazards [3–7]. Natural fibres are attacked mainly by microorganisms rather than man-made ones due to the higher hygroscopic nature of natural fibres. Under certain conditions, the carbohydrates in cotton and proteins in keratinous fibres work as a source of nutrients. Furthermore, dust, soil, sweat, and textile finish can somehow contribute as a source of bacteria generation [8].

Compared with the other regenerated fibres, viscose fibre has a higher specific surface due to the high amorphous regions, thus having a higher specific surface. Using viscose fibres rather than the other regenerated fibres like modal and lyocell absorbed the highest amount of chitosan to act as an antimicrobial and antifungal activity [9–11]. Several studies showed that using antimicrobial fabrics or products increases the 60% of people to secure themselves from microorganisms. Thus, the demand has been increasing remarkably over recent years. The attention to hygienic products is increasing on the one hand, and the harmful effects of the chemicals on human health [12]. Microorganisms such as microbacteria, algae, and fungi, can grow and escalate on textile materials under appropriate conditions. The microorganisms produce the enzymes. Another concern is the production of undesirable odours when bacteria turn human sweat into compounds like carboxylic acid, aldehydes, and amines. Infestation of microbial textiles may also cause disease. Bacteria on underwear, such as *Staphylococcus*, can cause odours and purulence on the skin surface, and *Escherichia coli* can cause odours and ulcers [13–16]. The most recent studies focus on diverse ways to prevent bacterial infection by utilizing nanoparticles and assisting in manufacturing antimicrobial nanotherapeutics. Moreover, an innovative technique has been employed to overcome the bacterial resistance pattern to incorporate evolving nanomaterials (NMs) for anti-bacterial treatment. Nanomaterials may kill bacteria in various ways, making it difficult for bacteria to survive and build resistance to Nanomaterials. The surface chemistry, shape, core material, and size of Nanomaterials all influence the routes. Because of these factors, Nanomaterials-based products play an important role in improving treatment efficiency by interacting with bacteria biological systems and serving as an antibiotic replacement [17–18].

It's even better if the anti-bacterial materials are biodegradable, so cellulose research is important. Furthermore, as indicated by the findings of this research, the anti-bacterial potential of cellulose functionalized in wastewater treatment should not be overlooked, particularly in terms of water disinfection. We are resolved to view cellulose as a suitable support material used in many industries since its polyolic nature enables it to bind a series of molecules with chemical activities that may modify the hydrophilic/lipophilic balance and give enhanced qualities. One of the most promising advances in using cellulose derivatives in food preservation technology is the discovery of novel biomaterials with anti-bacterial capabilities [19].

MATERIALS AND METHODS

The functional viscose fibres have been obtained from Qingdao Baicao new materials co. Limited. Mint fibre is produced by mixing nano-grade menthone powders (derived from natural peppermint) into cellulose and then wet spinning the cellulose into mint fibres. Before the extrusion point, bactericidal agents are applied to the spinning solution. There is 8% mint menthone and 92% cellulose in this product. So, the mint fibre is cellulose-based.

Mechanical properties of simple viscose fibre and functional viscose fibre

The mechanical properties of functional viscose fibre compared to the standard viscose fibre have been given in table 1.

Table 1

MECHANICAL PROPERTIES OF SIMPLE VISCOSE FIBRE AND FUNCTIONAL VISCOSE FIBRE

Fibre type	Breaking tenacity (cN/tex)		Elongation at break (%)	
	Dry form	Wet form	Dry form	Wet form
Common	2.48	1.71	17.75	25.86
Functional	2.16	1.47	18.89	26.81

Yarn and fabric specifications

The yarns have been spun with different blend ratios, i.e., 100% cotton, 50/50 cotton/functional viscose, and 100% functional viscose, with a count of 24.6 tex (24Ne). These yarns are further knitted into 1×1 rib fabrics on a circular knitting machine.

Microorganisms and culture medium

Two microorganisms were used in the antimicrobial test: *Staphylococcus aureus* (gram-positive bacterium) and *Escherichia coli* (gram-negative bacterium). *Escherichia coli* was selected due to its prominence in daily life, while *Staphylococcus* was used because it causes significant cross-infection in hospitals. Nutrient Agar was used to sustain the strains (*Escherichia coli* and *Staphylococcus aureus*). The incubation was performed at 37°C and stored at 4°C. The Luria Broth (LB) medium has been introduced to culture the *Escherichia coli* and *Staphylococcus aureus*. Which comprises of the ingredients; yeast extract 0.5%, peptone 1%, NaCl 1%, agar 2% & pH 7.4, The above mediums were sterilized at 121°C for 30 min.

Approach for evaluating the antimicrobial property of viscose fibres

This experiment measures the antimicrobial property by adding mint extract with the viscose fibre preparation for antimicrobial activity under the Shake flask method (GB/T 20944.3-2008). 0.75 g swatches of 100% cotton fabric (control sample) were mixed with 70 ml of phosphate buffer solution (PBS) in a 250 ml Erlen Meyer flask, respectively, then sterilized at 121°C for 30 min. For each fibre treatment, two replicates were used.

Escherichia coli and *Staphylococcus aureus* were incubated in Luria Broth (LB) liquid medium for 10 hours before each antimicrobial analysis. The density of cultures was diluted with sterile PBS to 1×105 CFU/ml to 5×105 CFU/ml by the Turbidimetric process at the end of the incubation. The turbidity was estimated at 500 nm using a SHIMADZU UV 1900i Spectrophotometer (China). Next, 5 ml of the distilled bacterial suspension and PBS with the fibre swatches were combined and rattled for 5 minutes to disperse them. After the dilution factor, 0.5 ml of the mixture was placed in Petri dishes and incubated for 24 hours at 37°C (*Escherichia coli* and *Staphylococcus aureus*). The remainder of the cross was shaken for 6 hours before being plated and incubated. Equation 1 expresses the results as a per cent reduction of bacteria (R), where A and B represent the colony numbers before and after shaking the culture for 6 hours.

$$R = \frac{A - B}{A} \times 100\ (\%) \qquad (1)$$

The colonies are counted with the inter-science (France), with the model Scan 500 as shown in figure 1.

Fig. 1. Colony counting machine by InterScience (Scan 500)

Mosquito repellent activity

Functional viscose fibre and ordinary viscose fibre are put in cavities A and C, respectively, as shown in figure 2. The gauze has been fixed on both sides of the box to keep it airy and keep mosquitos alive. In cavity B, 20 mosquitos were mounted. The partitions between A and B, as well as B and C, were then eliminated. We need to record the number of mosquitos in cavities A and C [4, 5].

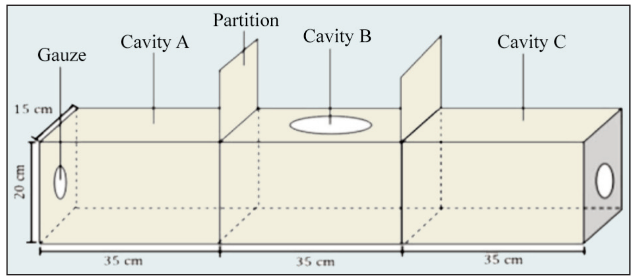

Fig. 2. Mosquito repellent testing setup

Then, the rate of mosquito repellency can be estimated using equation 2.

$$Q = \frac{N_C - N_A}{N_C - N_A} \times 100\% \qquad (2)$$

where Q represents the anti-mosquito rate. While N_A represents the number of mosquitoes in cavity ‘A’ and N_C represents the number of mosquitoes in cavity ‘C’.

RESULTS AND DISCUSSIONS

Yarn mechanical property

The breaking strength of the functional viscose fibre has been decreased by about 12.9% in dry form and 14% in wet state, compared with standard viscose fibre. At the same time, the elongation of functional viscose fibre has been increased by 6.4% in dry form and 3.7% in the wet state, which helps the functional viscose fibre behave with a low modulus. That implies after applying plant extract to the viscose spinning solution, the binding composition of functional viscose fibres changes and the crystallinity decreases significantly. In addition, the presence of an enormous number of functional agent molecules between cellulose macromolecules prevents them from hydrogen bonding with several cellulose molecules, reducing fracture strength. However, when the cellulose molecules slip further, the elongation is increased.

Antimicrobial property

100% cotton has been used as a response material. Whereas, the number of colonies of 100% cotton is too high that the machine cannot count such no. of colonies. The number of colonies of bacteria has been counted for each sample. The number of colonies of *E. Coli* for 50/50% (cotton & mint added viscose fibre) with different concentrations has been shown in figure 3, *a–f*. While figure 3, *g–l* denotes the number

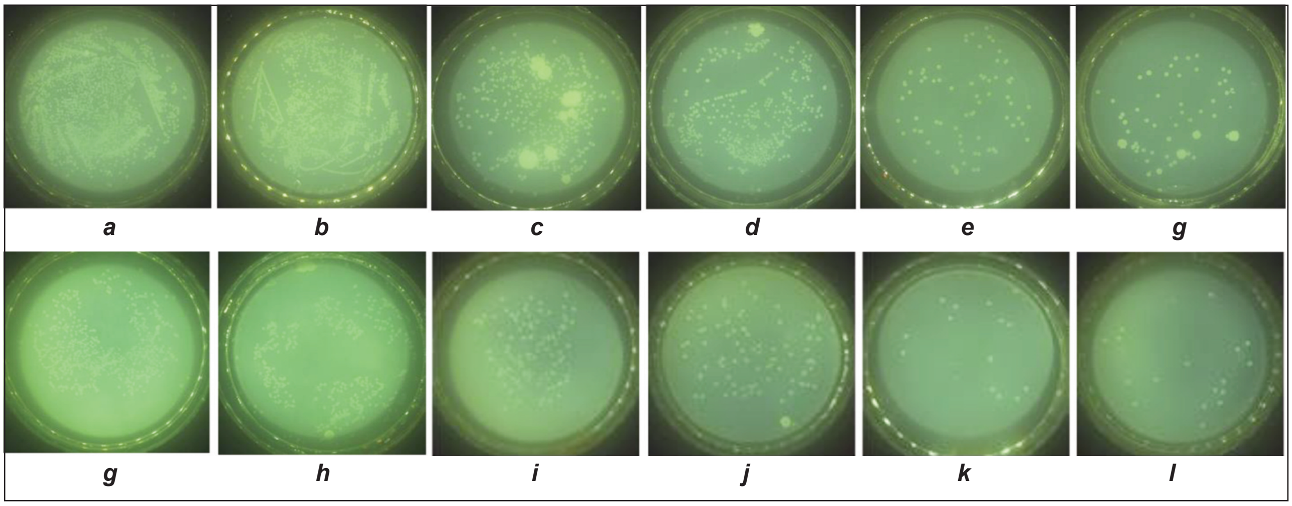

Fig. 3. *E.Coli* colonies: *a* – 50/50-3×10^5; *b* – 50/50-3×10^5; *c* – 50/50-4×10^5; *d* – 50/50-4×10^5; *e* – 50/50-5×10^5; *f* – 50/50-5×10^5; *g* – 100-3×10^5; *h* – 100-3×10^5; *i* – 100-4×10^5; *j* – 100-4×10^5; *k* – 100-5×10^5; *l* – 100-5×10^5

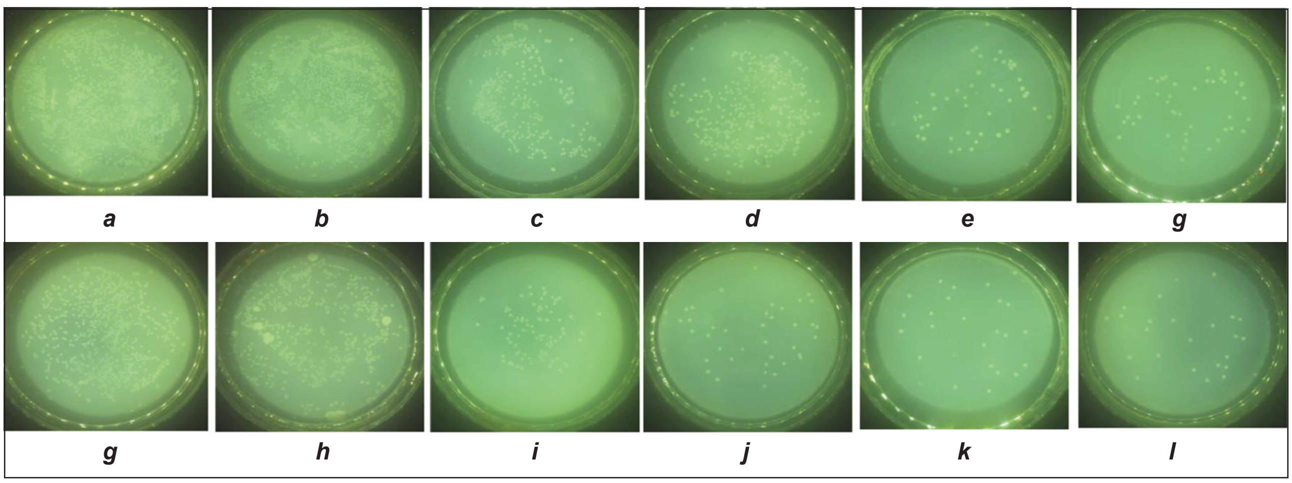

Fig. 4. *S. Aureus* colonies: *a* – 50/50-3×10^5; *b* – 50/50-3×10^5; *c* – 50/50-4×10^5; *d* – 50/50-4×10^5; *e* – 50/50-5×10^5; *f* – 50/50-5×10^5; *g* – 100-3×10^5; *h* – 100-3×10^5; *i* – 100-4×10^5; *j* – 100-4×10^5; *k* – 100-5×10^5; *l* – 100-5×10^5

of colonies of *E.Coli* against 100% viscose mint. Moreover, the number of colonies of *S.Aureus* for 50/50% (cotton & mint added viscose fibre) with different concentrations has been shown in figure 4, *a–f*. Whereas figure 4, *g–l* indicates the number of colonies of *S.Aureus* against 100% viscose mint. which signifies that the addition of mint extract results in fewer bacteria colonies for 50/50% (cotton & mint added viscose fibre) for the different concentrations. The number of bacteria colonies has been reduced for higher concentrations. The number of colonies for 100% viscose mint is deficient, indicating that the mint extract helps restrain bacteria. The antimicrobial property against the *E.Coli* and *S. Aureus* for 100% mint fabric is 97% and 94%, respectively. Whereas the bacteriostatic ratio against 50/50 cotton, viscose blend is proportionally lower, i.e., 85% and 81% against *E.Coli* and *S. Aureus* as shown in figure 5. It designates that the mint extract can help restrain bacteria.

Whereas, 50/50 = cotton/functional viscose fibre blend, 100 = 100% functional viscose fibre, 3×10^5, 4×10^5, 4×10^5 = different culture density.

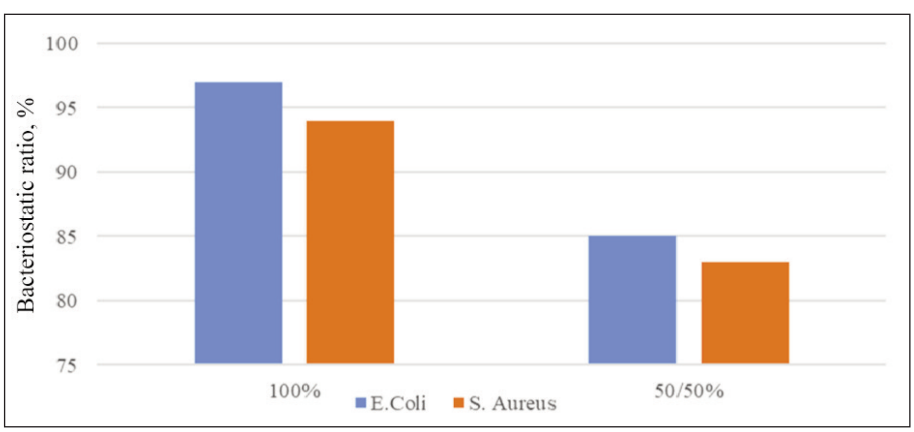

Fig. 5. Bacteriostatic ratio against *E.Coli* and *S. Aureus*

Whereas, 50/50 = cotton/functional viscose fibre blend, 100 = 100% functional viscose fibre, 3×10^5, 4×10^5, 4×10^5 = different culture density.

SEM of cotton and functional viscose fibres

The SEM of cotton and viscose with mint extract as well as simple viscose fibre have been shown in figure 6, *a* shows the structure of the cotton fibre, while figure 6, *b* which the adhesion of mint extract on the yarn's surface, whereas figure 6, *c* shows the structure of simple viscose yarn.

Effect of washing on antimicrobial property of the fabric

The results of bacteria reduction after the different number of washing are shown in figure 7. The fabric with 100% mint indicated a 14% reduction of bacteria by 14% for *E. Coli*. While the antimicrobial property decreased by 15% against *S. Aureus* after 5–20 washes compared to the fabric with the blend 50/50. Moreover, the bacteriostatic ratio decreased by 3–4% as compared with *E. Coli* and *S. Aureus* against fabric with a content of 100% functional viscose fibre as far as a 4–8% reduction ratio has been observed for *E. Coli* and *S. Aureus* against fabric with the content of 50/50 cotton/functional viscose fibre. Which still exhibits the property to resist bacteria. In contrast, *E.Coli* indicates the maximum resistance to bacteria.

Mosquito repellency test

The mosquito repellent test has been performed against the 100% functional viscose fabric and 50/50 cotton/ functional viscose fabric. The results given in figure 8 indicate that the mosquito repellency rate ranges from 70–90% for 5 to 20 washes against 100% functional viscose fabrics. The mosquito repellency rate lies between 60–80% for 5 to 20 washes against the fabric made up of a 50/50 blend. The overall results show acceptable behaviour against mosquito repellency.

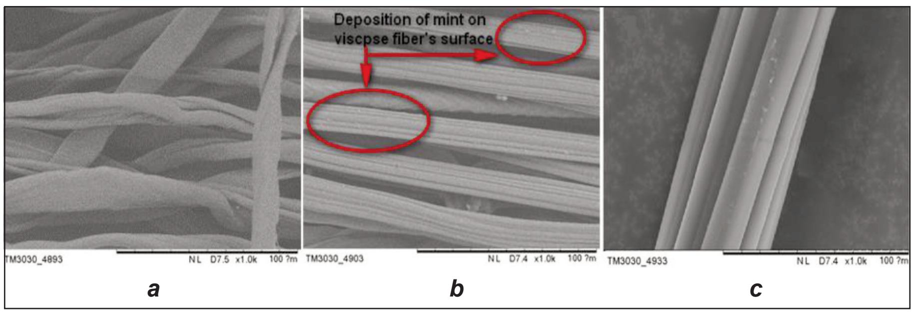

Fig. 6. Images of: *a* – the structure of the cotton fibre; *b* – the adhesion of mint extract on the yarn's surface; *c* – the structure of simple viscose yarn

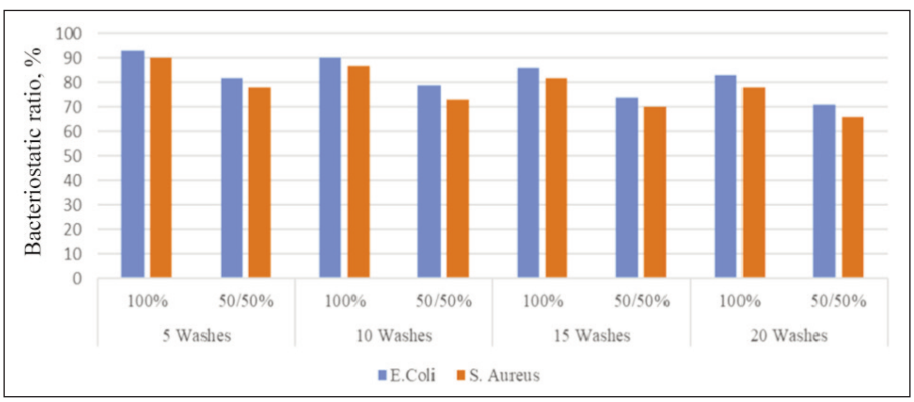

Fig. 7. Effect of the number of washing on Bacteriostatic ratio against *E. Coli* and *S. Aureus*

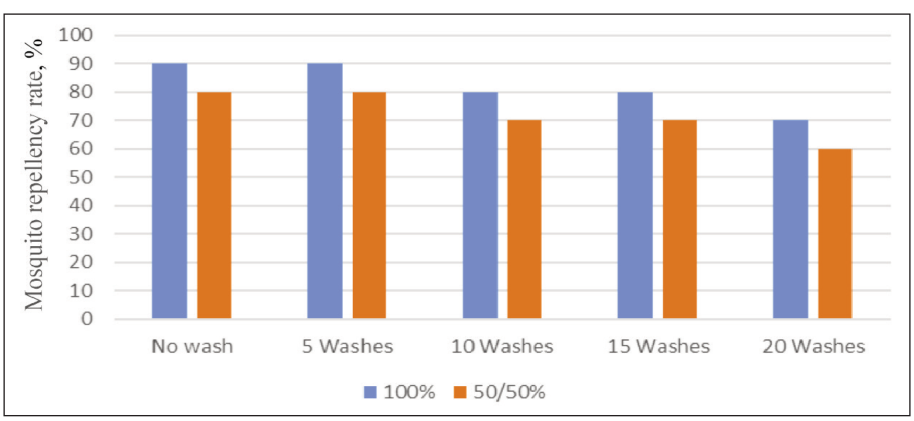

Fig. 8. Mosquito repellency rate against 100% functional viscose and 50/50 cotton/functional viscose fabric

CONCLUSIONS

From the above results, the conclusions can be drawn as follows:

1. The regenerated cellulose fibres can be used as a functional textile by adding natural additives. Which, in general, has no toxic effect, and no health hazard. The mint extract provides an antimicrobial product that can be applied to hospital beddings, masks, patient dresses, shoe pads, and skin problems like itches on allergies. Mint can provide comfort as well as aesthetic properties.
2. The addition of mint within cellulosic fibres can play a vital role in the fabrication, acting as a mosquito repellent.

Future work must be carried out for different microorganisms and also in a sense to evaluate the comfort and anti-allergic properties. Further, the mint extract should be added to other cellulosic fibres such as cotton, Tencel, and modal to assess their antimicrobial, comfort, and aesthetic properties. Furthermore, mint extract might play a significant role in reducing inflammation. Moreover, the different natural extracts must be explored to reduce the usage of chemical finishes that cause a damaging impact on the skin and do not possess eco-friendly behaviour.

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