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ANTIBACTERIAL TREATMENT OF KNITTED FABRICS MADE OF FIBER BLENDS USING TUMBLER-TYPE EQUIPMENT

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Abstract: *Microbes can be carried by and even multiply on textiles, which can act as reservoirs containing infectious agents such as bacteria, viruses, and fungi and could be vectors of infection in hospitals or communities. Scientific studies demonstrated two scenarios concerning the interrelationships between microorganisms and textiles: textiles can transmit microorganisms and thus infections, and textiles containing antimicrobial agents prevent the transmission of infections. This study aimed to evaluate the behavior in finishing specific knitted textile structures of different fiber compositions, designed, and produced for obtaining antibacterial knitted garments for people with special needs, using a conventional finishing agent and application method to be ready for application on tumbler-type industrial equipment. Different assortments of fibers, yarn compositions, and knitted fabric geometry were used to produce knitted textile materials. For acquiring an antibacterial effect, a bacteriostatic product based on silver chloride and titanium dioxide was used for the finishing of knitted fabrics, which was applied by exhaustion method, on a tumbler-type laboratory apparatus. Antibacterial activity was assessed by agar diffusion plate test on E. Coli and S. Aureus test strains. Higher inhibition zone values are obtained in the case of knits made of conventional fibrous blends (cotton/acrylic fibers), compared to the variants containing Bamboo, Lenpur, and Coolmax fibers.*

Keywords: *antibacterial textiles, knitted fabrics, finishing, functional knitted garments, tumbler-type equipment*

1. INTRODUCTION

Many infections spread through clothing and textiles. In certain conditions of temperature, humidity, and lighting, some microorganisms develop and proliferate on the surface of porous materials, including textiles. Microbes can be carried by and even multiply on textiles, which can act as reservoirs containing infectious agents such as bacteria, viruses, and fungi and could be vectors of infection in hospitals or communities [1]. Bacteria and other microorganisms adhere to all types of surfaces by a sequence of four processes: transport (diffusive, convective, active movement), initial adhesion, attachment, and colonization of surfaces. If the surfaces can be designed to minimize or alleviate the adhesion of microbes, then the materials will be more effective in many situations and environments [2]. Scientific studies demonstrated two scenarios concerning the interrelationships between microorganisms and textiles: textiles can transmit microorganisms and thus infections, and textiles containing antimicrobial agents prevent the transmission of infections [1]. The incorporation of antimicrobial agents on textile products, able to stop the spread of microbes, is of utmost importance, thus antimicrobial fabrics have become an important issue in the textile industry. Antimicrobial textiles can be termed based on their specificity against microbes, i.e., antibacterial, antifungal, or/and antiviral. Depending upon the treatment and antimicrobial compound used, e.g organic and inorganic antimicrobial agents, plant and fruit extracts, animal-derived compounds, dyes, and mordants [3], [4], [5], the antimicrobial fabric may be leaching type or non-leaching type, while based on its mechanism it can be biocide (kill the microorganisms) or biostatic (inhibits their growth). For clothing, biostatic fabric is preferred as they preserve the natural bacterial flora of the skin and have no adverse effect on human skin, while the biocidal fabric is preferred for medical and environmental applications [6]. This study is part of a research project aimed at obtaining functional knitted textile products by finishing on tumbler-type industrial apparatus.

2. MATERIALS AND METHODS

2.1 Textile materials

Knitted textile materials used in this study were designed and produced by SC DATSA TEXTIL SRL within Competitiveness Operational Program 2014-2020, by using different assortments of fibers, yarn compositions, and knitted fabric geometry, as detailed in Table 1. Yarns containing Bamboo, Lenpur, and Coolmax fibers were added in some knitted variants to improve the comfort and the antibacterial effect of the final products.

Table 1: Knitted fabrics subjected to antimicrobial treatment

Sample code	Fiber composition of yarns	Fabric geometry	Mass (g/m^2)
1A	50/50% cotton/acryl, Nm 30/2; 100% Bamboo, Nm 34/1	Ajour	292.8
1As	50/50% cotton/acryl, Nm 30/2	Ajour	203.8
3A	50/50% cotton/acryl, Nm 30/2; 100% Lenpur, Nm 34/1	Plain Jersey	334.5
3As	50/50% cotton/acryl, Nm 30/2	Plain Jersey	227
1O	50/50% cotton/acryl, Nm 30/2; 100% Lenpur, Nm 34/1	Rib	521.7
1Os	50/50% bbc/acryl, Nm 30/2	Rib	358.6
1C	50/50% bbc/acryl, Nm 30/2; 100% Coolmax, Nm 50/1	Honeycomb	337.5
2C	50/50% bbc/acryl, Nm 30/2; 100% Bambus, Nm 34/1	Honeycomb	407.3
1Cs	50/50% bbc/acryl, Nm 30/2	Honeycomb	402.1

2.2 Antibacterial agent

For acquiring an antibacterial effect on knitted fabrics, Sanitized® T 27-22 Silver (Sanitized AG, Switzerland) based on silver chloride and titanium dioxide was used as an antibacterial agent due to its safe bacteriostatic effect against many gram-positive and gram-negative bacteria, including MRSA, yeasts, and micro-fungi. According to the producer it effectively reduces the formation of bacteria and odor, acting on the bacterial cell membrane, which inhibits cell function and blocks the respiration and vital food intake of bacteria.

2.3 Finishing procedures

Antibacterial finishing was applied by exhaustion method, on tumbler-type laboratory apparatus “Redkrome” (Ugolini-Italy) equipped with an 8L container. Hydro-extraction and drying were made on a tumbler drying machine. The sequence of technological operations and operation parameters was as follows: scouring with 1 g/L nonionic wetting agent and detergent, based on fatty alcohol polyglycol ether (Kemapon PC/LF, Kem Color S.p.a, Italy), temperature 40°C, duration 20 minutes, followed by subsequent warm and cold rinsings, hydro-extraction at 800-1000 rpm, antibacterial finishing with 0.8% Sanitized T 27-22 Silver, liquor ratio 1:10, temperature 60°C, pH=6, duration 45 minutes, hydro-extraction at 800-1000 rpm, and drying at low-temperature range.

2.4 Antibacterial activity assessment

The antibacterial activity of the treated samples was qualitatively assessed by the Agar diffusion method according to the SR EN ISO 20645:2005 standard method -Determination of antibacterial activity-agar diffusion plate test, by using bacterial cultures in liquid medium replicated at 24 hours of ATCC 6538 *S. aureus* (Gram-positive) and ATCC 11229 *E. coli* (Gram-negative) strains test. The textile specimens (18 ± 2 mm in diameter) were placed on the surface of the nutrient medium and then incubated at 37 ± 1°C for 24 h. Inhibition zones were calculated using the following formula:

$$H = (D - d) / 2 \qquad \textbf{(1)}$$

where: H is the inhibition zone [mm]; D – is the total diameter of the specimen and inhibition zone [mm]; d – is the diameter of specimen [mm].

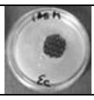
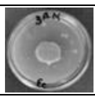
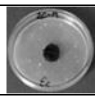
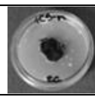
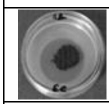
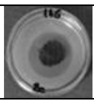
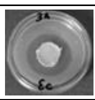
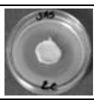
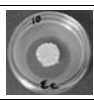
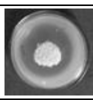
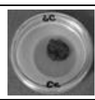
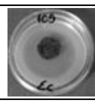
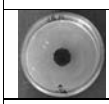
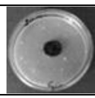
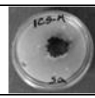
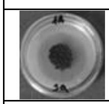
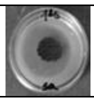
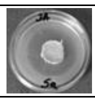
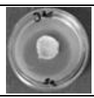
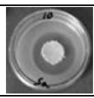
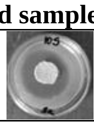
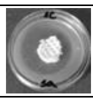
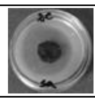
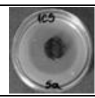
For bacterial growth, the contact zone under the samples was determined with a microscope at 20× magnification. Following the standard method, the inhibition zone was measured in mm and the degree of bacterial growth was estimated in the nutrient medium under the specimen.

3. RESULTS AND DISCUSSION

Antibacterial activity

Images of Petri plates after 24 h incubation and the inhibition zone (mm) of the knitted fabric variants subjected to antimicrobial treatment are shown in Table 2.

Table 2. Images of Petri plates and inhibition zone (mm) showing antibacterial effect after 24 h against **a.** E. coli; **b.** S. aureus

Sample code	1A	1As	3A	3As	1O	1Os	1C	2C	1Cs
E. Coli test strain/ inhibition zone (mm)	**Reference samples-untreated**								
									
	-	-	-	-	-	-	-	-	-
	Antibacterial treated samples								
									
	9 mm	10 mm	8.5 mm	10 mm	8.5 mm	7.5 mm	8 mm	13.5 mm	12.5 mm
S. Aureus test strain/ inhibition zone (mm)	**Reference samples-untreated**								
									
	-	-	-	-	-	-	-	-	-
	Antibacterial treated samples								
									
	11 mm	12 mm	9.5 mm	11 mm	10 mm	9.5 mm	12.5mm	15 mm	14 mm

Analyzing the data obtained after antimicrobial testing, the following can be concluded:
- the untreated knitted fabric considered reference does not have an antibacterial effect, the test strains had a significant development, the inhibition zone around the textile samples being absent.
- all knitted fabric variants treated with Sanitized® T 27-22 Silver have antibacterial activity with important inhibition zones between 7,5 mm and 13,5 mm in the case of the *E. Coli* test strain and between 9,5 mm and 15 mm in the case of *the S. Aureus* test strain.
- slightly higher values of the inhibition zone are observed, with a minimum of 1 mm and a maximum of 4.5 mm, in the case of textile materials made of conventional fibrous blends (cotton/acrylic fibers code 1As, 3As, 1Cs), compared to the variants containing fibers with special properties, respectively Bamboo (code 1A), Lenpur (code 3A) and Coolmax fibers (code 1C).

4. CONCLUSIONS

The antibacterial finishing treatment applied by exhaustion method on a tumbler type equipment gives a certain antibacterial effect on knits made of fibrous blends of 50/50% cotton/acrylic fibers with or without blends with other yarns containing fibers with special properties (Bamboo, Lenpur, Coolmax). However, by comparing the two types of knitted supports (with or without fibers with special properties) slightly higher values of the inhibition zone are observed in the case of knitted fabrics made of conventional fibrous blends only.

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