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AN AGENT FOR ANTIMICROBIAL TREATMENT OF TEXTILE MATERIALS IN SHOEMAKING INDUSTRY

Pavlína Vltavská
Rahula Janiš
Jan Růžička
Petr Hlaváček

Faculty of Technology, Tomas Bata University in Zlín
Nám. T.G.M. 275, 762 72 Zlín
The Czech Republic

ABSTRACT
The effectivity of a new antimicrobial treatment for textile materials based on the use of monoacylglycerol of caprylic acid to various species of saprophytic mould Aspergillus niger ATCC 16404, pathogenic mould Trichophyton mentagrophytes ATCC 9533, pathogenic yeast Candida albicans ATCC 10231, gram-negative bacteria Escherichia coli ATCC 11229, Klebsiella pneumonie ATCC 4352 and gram-positive bacteria Staphylococcus aureus ATCC 6853 was tested. Testing was carried out according to Agarsdiffusionstest DIN EN ISO 20645 by 2-layer method. The results show that caprylic acid, 8-carbon saturated fatty acid, causes highly effective killing of all tested strains of bacteria and pathogenic microorganisms with an only exception of saprophytic mould, which is partially resistant.

Keywords: Foot Mycosis, Monoacylglycerol, Antimicrobial treatment

1. INTRODUCTION
Monoacylglycerols (MAGs) are the most important partial esters of fatty acids and glycerol. They belong to the group of lipids. A series of studies describe their emulsifying, anti-static, lubricating and microbicidal properties [1]. In recent years there has been increasing interest in the field of study of monoacylglycerols of fatty acids regarding both preparation and their potential applications. The obvious reason for an extensive use of MAGs in various fields of human activities consists of number of their unique characteristics. Due to their amphiphilic nature, they have emulsifying properties and inhibitory activities against a wide range of microorganisms [2-4]. Moreover, they are biocompatible and biodegradable; it means MAGs are body and environment friendly. Their high antimicrobial activity predestinates them for the use as antimycotic preparations [5].
Microbial contamination of lining and insole materials could be limited by antimicrobial treatment to a significant degree. In recent years the number of modern and effective preparations without side effects was offered. However, a lot of them do not meet the requirements. Therefore, the treatment of textile materials as a prevention of foot mycotic diseases is the main object of our research. This work deals with the treatment of lining and insole materials like polyamide (PA), polyester (PES), boiled cotton and 100% cotton by 15% MAG of caprylic acid solution in ethanol and testing thus modified materials against microorganisms which most frequently occur on the feet and in the shoes.

2. MATERIALS
Monoacylglycerol was prepared by the reaction of fatty acid (caprylic acid) with glycidol in the presence of Cr(III) complexes as catalysts [6]. The MAG was produced in conversion

98.5 %. Subsequently, on the basis of Agarsdiffusionstest DIN EN ISO 20645 (Figure 1.), optimal concentration of MAG solution in ethanol (15%) was chosen. From PA, PES, 100% cotton and boiled cotton, samples of round shape 3.5 cm in diameter were cut. Further, individual materials were modified by their immersion into ethanolic MAG solution for 6 hours, then they were dried in a drier at 40° C for one hour. Further, the modified samples were tested against various species of dermatophytes (*Trichophyton mentagrophytes* ATCC 9533), saprophytes (*Aspergillus niger ATCC 16404*), pathogenic yeast (*Candida albicans ATCC 10231*), gram-negative bacteria (*Escherichia coli* ATCC 11229, *Klebsiella pneumonie* ATCC 4352) and gram-positive bacteria (*Staphylococcus aureus* ATCC 6853).

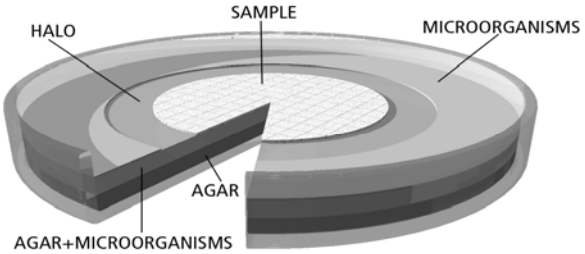

Figure 1. Agarsdiffusionstest (2-layer method)

3. METHODS

3.1. Used techniques

Testing was carried out by Agarsdiffusionstest DIN EN ISO 20645 by 2-layer method (Figure 1). This was mantained so that ten milliliters of mixture of Sabouraud agar (Nutrieat Broth) and 100µl spore suspension was poured on the Petri dish with solid agar. After solidifying of this first layer the sample of the tested material was placed on agar surface. A standard density of spore suspension was 10^7 - 10^8 CFU per ml. Each material was tested twice side-by-side, both from front and back side.

3.2 Cultivation of microorganisms

For each experiment, the yeast, dermatophytes and saprophytes were incubated at 30°C on Sabouraud agar, whereas the bacteria were kept at 37°C on Nutrieat Broth.

3.3 Evaluation of testing

The first growth evaluation of fungi and bacteria was performed after 24 hours, the others after 2, 7, 14 and 30 days of cultivation. The effectivity of antimicrobial action of thus modified lining and insole materials was expressed by the presence or absence of Halo and the growth of particular microorganisms below and on the surface of the sample.

4. RESULTS

On the basis of the results of Agarsdiffusiontest, 15% MAG solution in ethanol was chosen for the modification of textiles samples. This concentration embodied the highest antimicrobial efficiency against the whole range of testing microorganisms and for the whole period of testing. Table 1. provides the results of the presence or absence of Halo. As can be seen, most of test culture (*Candida albicans, Trichophyton mentagrophytes*) and all tested bacteria (data not shown) Halo contain, which means an antimicrobial activity of MAG solution.

Table 1. The results of presence or absence of Halo

cultiv.		30 days	tested material			
		material	PA	PES	100% cott.	boiled cott.
			pres. of H.	pres. of H.	pres. of H.	pres. of H.
testing culture	Asper. n.	front-X	N	N	N	N
		front-X	N	N	N	N
		back-Y	N	N	N	N
		back-Y	N	N	N	N
	Trichop. m	front-X	A	A	A	A
		front-X	A	A	A	A
		back-Y	N	A	A	A
		back-Y	N	A	A	A
	Can. albi.	front-X	A	A	A	A
		front-X	A	A	A	A
		back-Y	A	A	A	A
		back-Y	A	A	A	A

N = absebce of Halo
A = presence of Halo

The inhibition or growth of chosen microorganisms (*Trichophyton mentagrophytes*, *Aspergillus niger* and *Candida albicans*) after 30 days of testing are shown in Table 2.

Table 2. The results of yeast and moulds growth on treated lining and insole materials by 15% MAG $C_{8:0}$ solution after 30-day cultivation

cultivat.		30 days	tested material							
		material	PA		PES		100% COTTON		BOILED COTTON	
			[%]	(%)	[%]	(%)	[%]	(%)	[%]	(%)
testing culture	Asper. n.	front-X	15%	60%	20%	40%	15%	50%	10%	30%
		front-X	20%	60%	25%	35%	15%	50%	10%	30%
		back-Y	15%	75%	10%	40%	15%	50%	10%	20%
		back-Y	10%	75%	10%	40%	15%	60%	10%	20%
	Trichop. m	front-X	0%	5%	0%	0%	0%	0%	0%	0%
		front-X	0%	5%	0%	0%	0%	0%	0%	0%
		back-Y	2%	5%	0%	0%	0%	0%	0%	0%
		back-Y	5%	5%	0%	0%	0%	0%	0%	0%
	Can. albi.	front-X	0%	0%	0%	0%	0%	0%	0%	0%
		front-X	0%	0%	0%	0%	0%	0%	0%	0%
		back-Y	0%	0%	0%	0%	0%	0%	0%	0%
		back-Y	0%	0%	0%	0%	0%	0%	0%	0%

[%] - growth (no growth) of pertinent microorganisms below sample
(%) - growth (no growth) of pertinent microorganisms on sample

As can be seen, 15% MAG solution proved very good antimicrobial efficiency against all testing bacteria (*Escherichia coli* ATCC 11229, *Klebsiella pneumonie* ATCC 4352, *Staphylococcus aureus* ATCC 6853) for the whole period of testing and for all tested materials where no growth appeared (data not shown). High microbicidal effectivity was observed for *Candida albicans* ATCC 10231 too (Figure 2.). The samples treated by 15% MAG solution were also efficient against *Trichophyton mentagrophytes* ATCC 9533 (Figure 3.), except for sample of PA, where partial growth after 14 days of testing appeared. In case of *Aspergillus niger* ATCC 16404 (Figure 4.) the partial growth occurred from the 7th day of testing and continued during the next days. The results indicate that our antimycotic treatment completely inhibits the expansion of pathogenic microorganisms, even though its effect on the growth of saprophytic mould has not been proved.

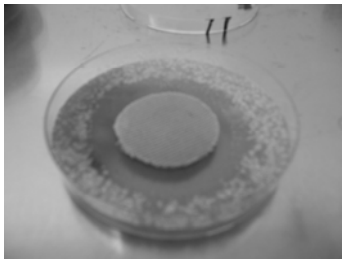

Figure 2. Modified sample of PES tested against Candida albicans

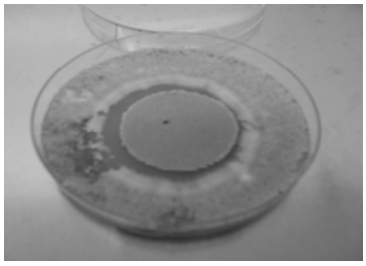

Figure 3. Modified sample of PES tested against Trichophyton mentagrophytes

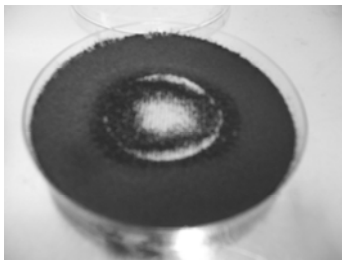

Figure 4. Modified sample of PES tested against Aspergillus niger

5. CONCLUSIONS

The results presented here support the potentional utilization of tested MAG for the modification of lining and insole materials. Nearly all linings and insole material modified by 15% MAG solution in ethanol have proved very good antimicrobial efficiency. In case of *Candida albicans, Escherichia coli*, *Klebsiella pneumonie* and *Staphylococcus aureus*, their growth was thoroughly suppressed for the whole period of testing and for all tested materials. Against *Trichophyton mentagrophytes* all samples treated by MAG were resistant nearly for the whole period of testing and for all tested materials except for PA. *Aspergillus niger* showed to be a culture partially resistant. All in all, the most prominent result of the work is the fact that textiles treated by MAG of caprylic acid limit the growth of pathogenic microorganisms commonly found on the foot.

6. ACKNOWLEDGEMENT

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7. REFERENCES

[1] Nichols D.: Plastics, Additives and Compounding. 2002, 4, p. 14
[2] Pokorný J. et al.: Lipid technology, SNTL, Praha, 1986
[3] Petschow B. W., Batema R. P., Ford L.L.: Antimicrob. Agents Chemother. 1996, 40, p. 302
[4] Bergsson G., Arnifinnsson J., Karlsson S. M.: Antimicrob. Agents Chemother. 1998,42, p. 2290
[5] Růžička J. et. al.: Antimicrobial effects of 1-monoacylglycerols prepared by catalytic reaction of glycidol with fatty acids. Eur Food Technol. 217 (2003), p. 329 – 331
[6] Janiš R., Krejčí J., Klásek A.: Preparation of 1-monoacylglycerols from Glycidol and Fatty Acids Catalyzed by the Chromium(III)-Fatty acid System. Eur. J. Lipid Sci. Technol. 102 (2000), p. 351