(REFEREED RESEARCH)

PROBIOTIC PRINTED PET FABRICS FOR BIOCONTROL IN HOSPITAL TEXTILES

HASTANE TEKSTİLİNDE BİYOLOJİK KONTROL İÇİN PROBİYOTİK BASKILI PET KUMAŞLAR

Kim-Laura NİEHAUS, Aysin DURAL-EREM, Vincent NİERSTRASZ

Textile Materials Technology, Department of Textile Technology, Faculty of Textiles Engineering and Business, University of Borås, SE-50190 Borås, Sweden

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ABSTRACT

Over time, hospital-acquired infections have become one of the main threats to the safety of hospitalized patients. The proliferation of nosocomial pathogens is often reported in connection with hospital textiles. In the present study, probiotic agents were printed on a polyester fabric by means of screen-printing. Afterwards, the viability of the probiotics after application process was determined. The applicability of the obtained fabric was evaluated on the basis of contact angle measurements, abrasion resistance and washing tests which showed the effect on the viability of the probiotics after repeated laundering. SEM images revealed the quality of the printing process. Major findings include that it is possible to obtain probiotic printed fabrics and probiotics were able to survive after the printed on fabrics.

Keywords: Probiotics, Functional printing, Biocontrol, Viability tests, Hospital textiles

ÖZET

Zaman içerisinde, hastane kaynaklı enfeksiyonlar hastaneye yatırılan hastaların güvenliğine yönelik ana tehditlerden biri haline gelmiştir. Nozokomiyal patojenlerin çoğalması hastane tekstiliyle bağlantılı olduğu sıklıkla bildirilmektedir. Bu çalışmada, probiyotik ajanlar, bir polyester kumaş üzerine tarama baskı yöntemiyle basılmıştır. Ardından, uygulama sonrası probiyotiklerin canlılığı belirlenmiştir. Elde edilen kumaşların uygulanabilirliği, kontak açısı ölçümleri, aşınma direnci ve tekrarlanan yıkamalar sonrası probiyotiklerin canlılığı üzerindeki etkisini gösteren yıkama testleri temel alınarak değerlendirilmiştir. SEM görüntüleri baskı sürecinin kalitesini ortaya koymuştur. Temel bulgular, probiyotik baskılı kumaşların elde edilmesinin mümkün olduğunu ve probiyotiklerin kumaşlara basıldıktan sonra canlılıklarını koruyabildiklerini göstermiştir.

Anahtar Kelimeler: Probiyotikler, Fonksiyonel baskı, Biyolojik kontrol, canlılık testleri, Hastane tekstilleri

Corresponding Author: Aysin Dural Erem, aysin.erem@gmail.com

INTRODUCTION

Hospital-acquired infections (HAI) are a major cause of morbidity and mortality among the hospitalized patient (1). These infections are caused by the common nosocomial pathogens (2). Since textile materials such as uniforms, linens and patient apparels are common in healthcare facilities, the proliferation of nosocomial pathogens is often reported in connection with them. Contaminated textiles are an excellent substrate for bacterial growth under appropriate moisture and temperature conditions (3). When they are heavily contaminated, patients and the hospital staff are at a higher risk of getting infected and by this contribute to the distribution of HAI (1, 4). In order to prevent the growth of pathogens and to protect the user from undesirable infections, antimicrobials like silver, triclosan or QAC are introduced into different textile applications (5, 6). Ideal antimicrobial agents should be effective against microorganisms whilst being nontoxic and do not damage the skin flora and cause allergy, skin irritations (7). However, most of these agents work according to a leaching mechanism. This leaching, related to the amount, causes health and environmental problems (8). Sustainable alternatives, based on biological substrates such as enzymes and probiotics receive attention. The use of them as an antimicrobial agent minimizes the amount of hazardous chemicals. Probiotics may defined as live microorganisms generally bacteria or yeasts, which when

locally applied in sufficient numbers confer one or more specified demonstrated health benefits for the host (9). There is a large range of microorganisms with probiotic properties but the most common belong to lactic acid bacteria, *Bacillus* bacteria or yeast, most of them have an antimicrobial or antagonistic ability to inhibit pathogenic bacteria. The antagonistic capability of probiotics against other bacteria can be caused by the competitive exclusion and the production of

organic acids, such as lactic acid, which lead to a reduction in the pH level and thereby provide an unfavourable ground for pathogens (10, 11). In addition, they exhibit antimicrobial activity due to the production of antimicrobial substances (12). When the fabrics are treated with probiotics, they become a reservoir for probiotics and may provide antagonistic/antimicrobial activity against pathogens. The use of probiotic containing products in clinical settings is not unfamiliar in combat of HAI. Vandini and colleagues in 2014, revealed that microbial cleaning with different strains of *Bacillus* spores as part of cleaning products reduces the number of infection related pathogens (13). A subsequent study done by Caselli et al. (2016) investigated the impact of these microbial based cleaning products containing *Bacillus* strains on the reduction of antibiotic resistant bacteria strains. It became evident that the cleaners were not only effective in counteracting the growth of several pathogens; they further did not cause any drug-resistant pathogen population but rather lowered the already existing resistances (14). This research aims to develop strategy to incorporate probiotics in fabrics via traditional textile treatment such as screen printing to inhibit pathogens.

MATERIAL AND METHOD

Material

The printing paste was composed of Tubifast AS 5087 FF binder, Tubivis DL 600 thickener, and Tubiassist Fix 157W cross-linker was provided by CHT R. Beitlich GmbH. The ready-made pigment paste Violett 5 BC was purchased from Zenit AB. The probiotic finishing agent Tana®Biotic DC was kindly provided by Tanatex Chemicals. The exact formula of Tana®Biotic DC is unknown as its a commercial product. The textile substrate was a polyester woven fabric supplied from FOV Fabric AB. Fabric specifications were summarized as weight 146g/m, weft 40 threads/cm, warp 55 threads/cm, carbon yarn density 1/23picks and 1/25ends with 2/2 twill weave.

Method

The thickener was dissolved in water using a plain stirrer. Then the other components were added in thickener solution and stirred for 30min at 400rpm. The ingredients of the different pastes are shown in Table1.

The printing paste was homogenized and applied to the PET fabric using a printing screen with 43-threads/cm mesh. The total number of passes was six. After application, the fabric was dried at 80°C for 15min then cured at 150°C for 5min.

The wettability of the fabrics was evaluated using Theta Optical Tensiometer (Scientific/ Biolin Holding AB). The test was conducted by a water droplet size of 1 or 3μL and the angles of the drops were measured after 0.5sec. Samples were tested for abrasion in a Cromocol, Martindale 2000 abrasion tester according to EN ISO 12947-2AC:2006 standard. Evaluation of the damage and breakage of fibres and searching for pilling will be made at 1000, 2000, 5000, 10000, and 15000 rubs with a visual analyse. The morphology of the fabric surfaces was determined using the environmental scanning electron microscope (ESEM) Quanta 250 FEG (FEI, USA) with 10 kV acceleration voltages.

Table1. Ingredient of the printing pastes

	P1	P2	P3
Binder (g)	6	6	6
Thickener (g)	1.7	1.6	1.5
Cross-linker (g)	-	1	1
Pigment (g)	2	2	2
Probiotic agent(mL)	25	25	2.5
Water (g)	65.3	64.4	87
pH of the paste	6-7	6-7	6-7
Viscosity (Pa.s)	993	919	2270

Viability test for probiotics

The viability of spores attached to the fabrics was evaluated in agar plate test method, which is used to monitor and culture of microorganisms. Prior to the test, the samples (5x5cm) were heated at 75°C for 1h to ensure that they are free from any bacterial contamination. Then the samples put in tryptic soy agar (TSA) plate and 4.5mL of 1% Triphenyl tetrazolium chloride (TTC) solution to fully cover the samples. The agar plates were incubated at 30°C for 48h. After incubation, the growth of bacteria was evaluated. In order to determine the durability of probiotics on fabrics, the fastness to washing test was performed using Wascator FOM 71 MP (Electrolux) according to ISO 6330:2012. The viability of the probiotics was evaluated after 3 and 5 repeated washes.

RESULTS & DISCUSSION

Screen-printing was used an application method as the probiotic spores were entrapped within the paste and easily applied on the polyester fabric. Firstly, the viability of probiotics on a fabric after application was evaluated with agar plate method and results are summarized in Table 2, where the red points represent colonies of beneficial bacteria. As the colonization of the probiotics was so dense, the exact counts could not obtained and estimated counts were given in the results.

According to these results, all samples exhibited a certain amount of growth more than 10000 CFU/surface. Recent studies mainly focused on the encapsulation or incorporation of probiotics into the textile fibre during electro spinning or melt spinning processes and obtained high viability results after the applications (15-17). Therefore, process conditions of screen printing are a promising approach for the application of probiotics on the fabric. Since the dimensions of probiotics cells are approximately 1-2 μm in length and 0.5-1μm in breadth (18), they can be easily embedded in the viscous paste and applied. For the further evaluation of the viability of probiotics, the fastness to washing of the printed parts of the fabrics and

the viability of the probiotics after 5 and 3 washes were evaluated (Table 4). Fastness tests showed the viability of the probiotics may decrease related to the washing cycles. While it is possible to observe some growth on all samples after three washes, the most of the samples couldn't exhibit enough growth of probiotics after five washes.

Table 2. The viability results

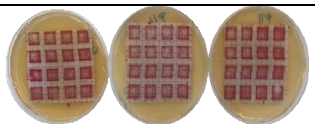
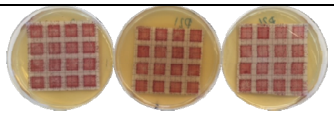
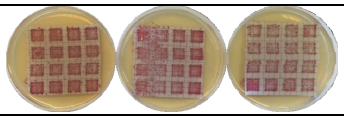
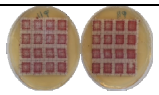
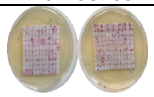
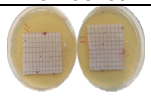
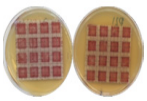
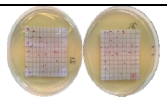
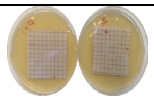
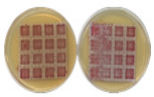
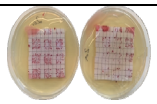
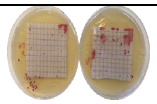
	Agar view	Bacteria amount (CFU)
P1		> 10000 Heavy growth
P2		> 10000 Heavy growth
P3		> 10000 Heavy growth

Table 4. Viability of probiotics on washed samples

	Unwashed	After 3 washes	After 5 washes
P1			
P2			
P3			

In order to investigate the applicability of the fabric, the wettability was explored. To determine the wettability of the fabrics, the water contact angle (Θ) was measured. The effect of the printing parts on the contact angle results of untreated polyester fabric exhibited a high wettability and average contact angle of 42.7° as it is produced with microfibers. Regarding the contact angle results of the printed parts of the treated fabrics, they revealed high angles indicating a low wettability (Table 5).

Table 5. Contact angle results

Sample	Contact Angle θ (°)
Fabric	42.7 ± 4.3
P1	121.8 ± 3.5
P2	118.3 ± 4.4
P3	137.2 ± 2.0

Uddin and Lomas (2010) had the similar results with screen–printed cotton fabrics, their wettability of the fabrics decreased after printing process (19). SEM images of the printed fabrics are shown in Figure 2.

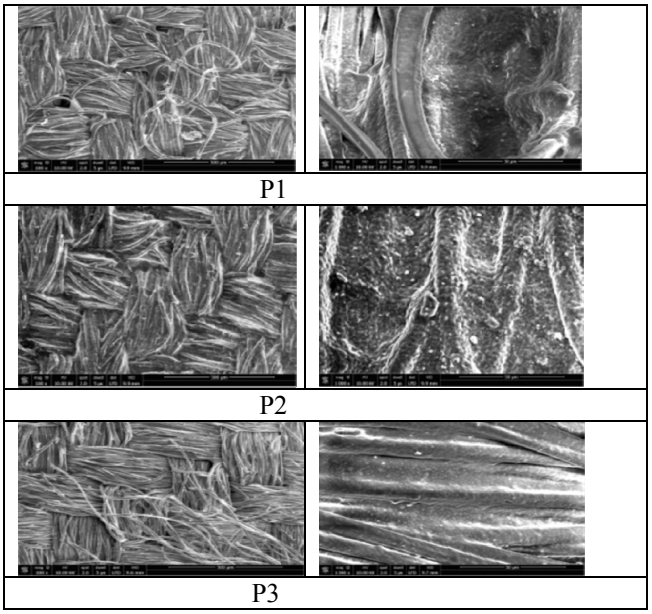


Figure 2. SEM images of the samples

They only give an impression of the quality of the print as none of the printed samples clearly showed a spore like structure. The analysis by SEM revealed that the treated samples showed a homogenous application of the paste. Abrasion resistant of the samples were tested to determine their durability and obtained results showed that the reference fabrics gave the worst results and specimen breakdown occurred after 15000 rubs with broken fibers in warp and weft direction. The printed fabrics didn't reveal broken fibers in both directions after 15000 rubs and only the print intensity decreased.

Table 6. Abrasion resistant of the samples

Rubs	Fabric	P1	P2	P3
2000	5	5	4	5
4000	4	5	4	4
6000	4	5	5	4
8000	4	4	4	4
10000	2	4	4	4
12000	2	3	3	4
14000	2	2	3	3
15000	1	2	2	3

CONCLUSION

Usage of probiotic printed fabrics in the hospital textiles may become efficient tool for preventing HAI which are strictly related to spreading of nosocomial pathogens. In the present study, the aim was to develop strategy to incorporate beneficial spores in fabrics by using screen printing to prevent or reduce the colonization of pathogens on hospital textiles and transmission trough these textiles. The results were shown that all samples exhibited certain amount of viability and about 10^4CFU were counted on each sample. These results showed that the viability of probiotics printed on a textile was achieved by printing a paste containing probiotic agents on a polyester substrate. With the incorporation of beneficial bacteria/spores in the woven fabrics, these fabrics become a reservoir for beneficial

bacteria and may provide an antagonistic/ antimicrobial activity against the contamination of pathogens. Usage of these fabrics in bed linens or uniforms may reduce the infections causing by nosocomial pathogens. Based on data obtained from this study, a further study is underway which will focus on competition tests to determine the inhibition mechanism of printed fabrics with beneficial bacteria/spores more detailed against common pathogens.

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