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### Development of Probiotic Printings for Polyester Fabrics

### Polyester Kumaşlar için Probiyotik Baskıların Geliştirilmesi

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**Araştırma Makalesi / Research Article**

**DEVELOPMENT OF PROBIOTIC PRINTINGS FOR POLYESTER FABRICS**

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**ABSTRACT:** This rising in the emergence of hospital required infections led to search new antimicrobial agents, including the probiotics, to combat nosocomial pathogens and to treat their infections. In this paper, probiotic agents were printed on a polyester fabric by means of screen-printing. Then the viability of the probiotics after printing process was determined. The applicability of the produced fabric was evaluated on the basis of their water absorbency, abrasion resistance and washing durability properties. The results showed that it is possible to produce printed fabrics using probiotic agents.

**Keywords:** Probiotic, functional printing, competitive exclusion, viability

**POLYESTER KUMAŞLAR İÇİN PROBİYOTİK BASKILARIN GELİŞTİRİLMESİ**

**ÖZET:** Hastane kaynaklı enfeksiyonlarda görülen artış, nozokomiyal patojenlerle mücadelede ve bu patojenlerden kaynaklanan enfeksiyonları tedavi etmekte probiyotikler de dahil olmak üzere yeni antimikrobiyallerin araştırılmasına yol açmıştır. Bu yayında, probiyotik maddeler polyester kumaş üzerine düz baskı tekniği kullanılarak basıldı. Ardından, baskı işlemi sonrasında probiyotiklerin canlılığı belirlendi. Üretilen kumaşların kullanılabilirliği su geçirgenliği, aşınma dayanımı ve yıkama haslıkları temelinde değerlendirildi. Temel bulgular, probiyotik baskılı kumaşların elde edilmesinin mümkün olduğunu göstermiştir.

**Anahtar kelimeler:** Probiyotikler, Fonksiyonel baskı, Biyokontrol, Yaşam kabiliyeti testleri

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## 1. INTRODUCTION

Probiotics are defined as microorganisms generally bacteria that believe provide health benefit effects for human and animals [1, 2]. They play an important role in the production of the organism to combat pathogenic microorganisms. Although the term probiotic is more related to lactic acid bacteria as *Lactobacillus* and *Bifidobacterium*, it can be extended to other microorganisms such as *Bacillus* spores for instance, Enterogermina® which is Italian product and commercialized for at least 50 years [3]. The main advantages of the bacterial spores are resistances against environmental condition such as heat and pressure. Also they are able to store in dried form at room temperature [4]. Probiotics especially their spore forms have wide range of application including dietary supplements to cleaning products [4-6]. Microbial-based cleaning products containing *Bacillus* strains have effect on the reduction of antibiotic resistant bacteria strains. They 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 [6]. The inhibition mechanisms of the probiotics are still poorly understood, but there are some theories on that such as a competitive exclusion and a secretion of antimicrobials such as coagulins, ampicillin and subtilisin [4]. This rising in the emergence of drug-resistant pathogenic bacteria led to search the nonantibiotic treatment ways, including the probiotics, to combat the bacterial antibiotic resistance and to treat the infection [7, 8].

In this research, the potential of probiotics spores in production of screen printed fabrics for functionalizing them against the growth of pathogen bacteria. For this purpose, the certain amounts of probiotic agent were entrapped in the printing pastes then they were printed on the fabric surface as a thick layer according to the prepared pattern.

## 2. EXPERIMENTAL

### 2.1. Material

For screen-printing process, Tubivis DL 600 (as a thickening agent), Tubiassist Fix 157 W (as a cross linker) were provided from CHT R. Beitlich GmbH (DE) and Permax 232 (as a binder) were provided from Lubrizol Advanced Materials Inc (US). Tana® Biotic DC (as a probiotic agent) were provided from Tanatex (NL).

For the textile substrate it was chosen for polyester multifilament woven fabric with carbon yarns in both warp and weft direction obtained from F.O.V. Fabrics AB (SE). Fabric properties; 146 g/m<sup>2</sup> weight, 40 picks/cm and 55 ends/cm density and 1/23 picks and 1/25 ends carbon yarn density and 2/2 twill weave.

### 2.2. Method

#### 2.2.1. Printing process

The thickener was dissolved in water using a plain stirrer. Then the other components were added in this solution and stirred for

30 min at 400 rpm. The amount of the ingredients of the different pastes and their application parameters are shown in Table 1. The obtained printing paste was applied to the PET fabric using a printing screen with 43 threads/cm mesh. The total number of passes was six. After application, the printed fabrics were dried then all were cured.

**Table 1.** Ingredients and process parameters of the samples

	P1	P2	P3
Binder (g)	6	6	6
Thickener (g)	1.8	1.7	1.7
Cross linker (g)	-	1	-
Tana®Biotic DC (mL)	25	25	25
Pigment (g)	2	2	2
Water(g)	65.2	64.3	65.3
Drying temperature (°C)	80	80	80
Drying period (min)	15	15	60
Curing temperature (°C)	150	150	150
Curing period (min)	5	5	5
pH	6-7	6-7	6-7
Viscosity (Pas)	1360	1030	720

#### 2.2.2. Characterization tests

The morphology of the printed samples was examined using Quanta 250 FEG (from FEI, U.S.) Environmental Scanning Electron Microscope (ESEM) with an acceleration voltage of 10 kV. The applicability of the obtained fabric was evaluated on the basis of wettability and abrasion resistance. In order to determine the wettability of the samples, the water contact angles of printed surfaces were measured using the Theta Optical Tensiometer (Scientific Biolin Holding AB) with a sessile drop with a volume of 3 µl. The abrasion resistance tests were performed using the Martindale 2000 Abrasion Tester (Cromocol Scandinavia) according to the standard EN ISO 12947-2/AC: 2006 to determine the durability of the prints on the obtained fabric. The evaluation was carried out visually checked and the changes in surface appearance were rated from 1 to 5, where 1 represents a higher wear and the pattern was no longer visible and 5 no wear and the pattern was clearly visible.

#### 2.2.3. Viability tests

The viability of the probiotics on the printed fabrics was evaluated in the agar plate test method. Five different specimens (5 x 5 cm) were prepared from all samples and they were heated in an aluminum foil at 75 °C for 1 h, to clean any kind of bacterial contamination. Afterwards the specimens were put into tryptic soy agar (TSA) plates. In order to fully cover the specimens, it is additionally overlaid with 4.5 mL of a 1% triphenyl tetrazolium chloride (TTC) solution. After the agar plates were incubated at 30°C for 48 h, grown out colonies of probiotics in the printed pattern were stained red.

The washing tests were performed using Wascator FOM 71 MP (Electrolux) according to the standard ISO 6330:2012 and the durability of probiotics and the prints were evaluated. The fastness to washing was determined after 3 and 5 washes. For the

analysis, the viability of the probiotics on the fabric was evaluated in the agar plate test method. In addition, weight losses after each wash were calculated.

### 3. RESULTS & DISCUSSION

#### 3.1. Surface morphology

The surface morphology of the printed samples is shown in images of the SEM (Table 2). Although the paste was spread evenly during application, the images clarified spots of completely unaffected fibers. All samples indicated closed capillary pores where the paste settled around and between the fibers.

#### 3.2. Wettability

The results of the contact angle measurement are shown in Figure 2. The contact angle results of the reference polyester fabric exhibited a high wettability and an average contact angle of  $42.7^\circ$  was observed. Regarding the results of the printed parts of the treated fabrics, they revealed high angles indicating a low wettability. The results revealed that the printed pattern had a negatively effect on the wettability of the fabric. However, the droplet did not last for a long time and wetting occurred within at least 20 seconds for all samples. Uddin et al. obtained similar results and they mention that the wettability of the fabrics decreased with the formation of cross linkers on the surface of the fabrics[10].

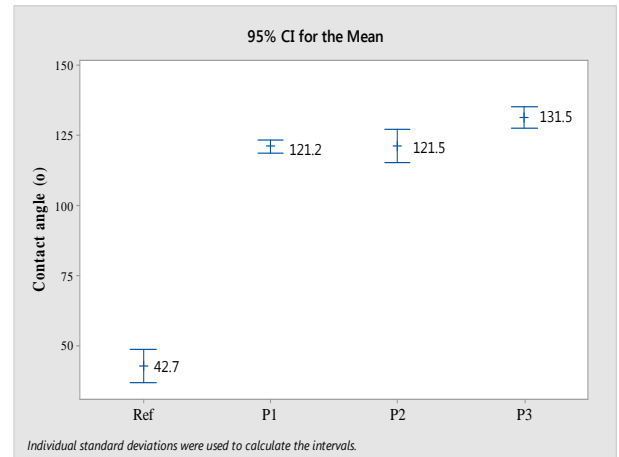


Figure 2. Contact angles of the samples

#### 3.3. Abrasion Resistance

The resistance to abrasion is evaluated in Table 2. Abrasion results showed that the abrasion resistance of the reference polyester fabric gave the worst result and specimen breakdown occurred after 15000 rubs with broken fibers in warp and weft direction on all samples. However, the printed fabrics did not reveal broken fibers in both directions after 15000 rubs but a significant decrease in the intensity of the print. Thereby, the pattern was no longer visible after 8000 rubs. Furthermore all samples had in common were protruding fibers after 4000 rubs and a greyish change of colour, which can be attributed to the abrasion.

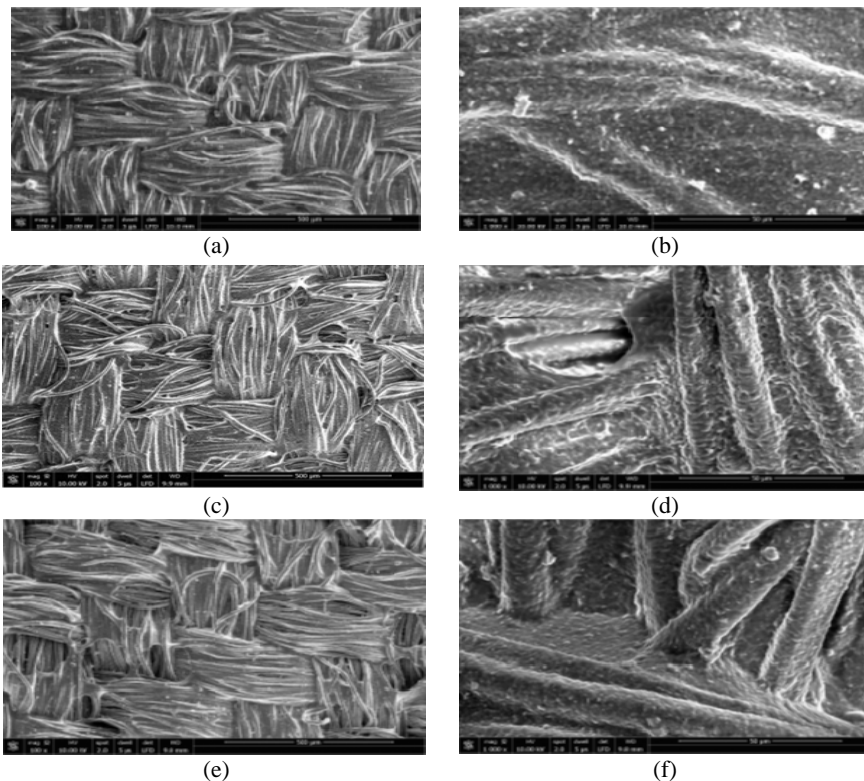


Figure 1. SEM images of the printed samples (a, b):P1, (c, d):P2, (e, f):P3

**Table 2.** Abrasion resistance of the sample

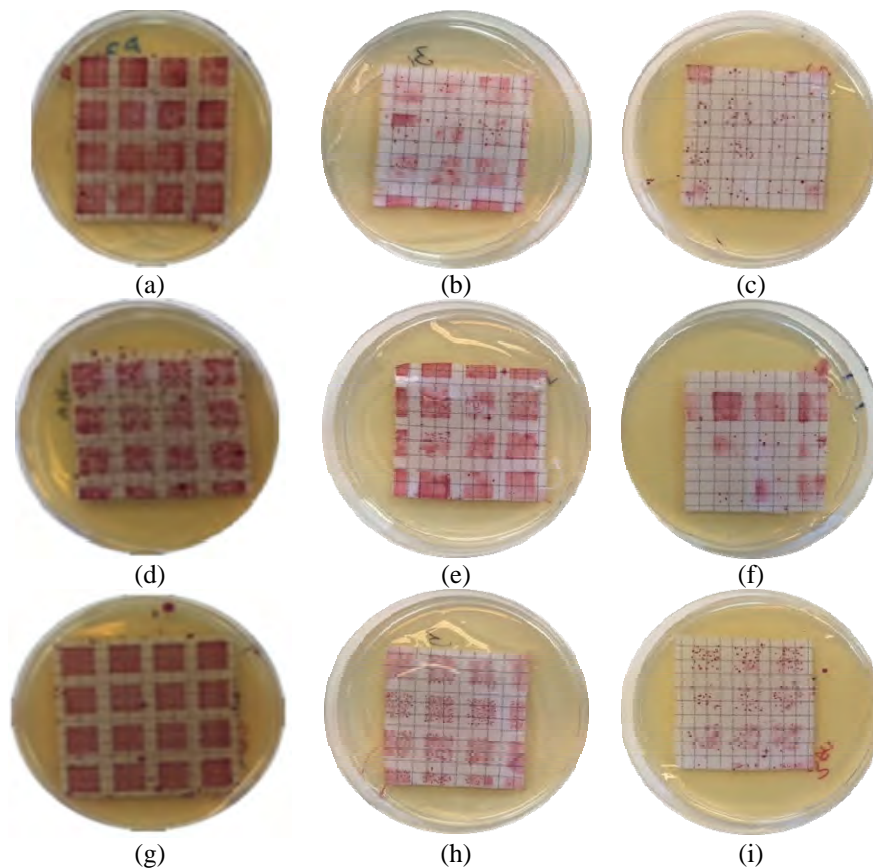
Sample \ Rubs	Ref	P1	P2	P3
2000	5	2	5	4
4000	4	2	3	3
6000	4	2	3	2
8000	4	2	2	1
10000	2	1	2	1
12000	2	1	1	1
14000	2	1	1	1
15000	1	1	1	1

### 3.4. Viability of probiotics

The viability of the probiotics was evaluated depending on the paste content and process parameters. As seen in Figure 2, all samples exhibited a certain growth. When the results of samples with different drying procedures were evaluated, it is clearly seen that drying time didn't directly affect the growth of probiotics. However, the viability results showed that the content of the printing pastes affects the growth of probiotics (Table 3). The samples with cross linkers exhibit respectively less growth than the others. These results showed that spores have shown to be the most suitable option for industrial applications as their natural

capsule makes them resistant towards environmental conditions [9]. Especially their higher resistance towards process parameters including higher temperatures and shear stresses, which is reported in a study by Ciera et al. (2014), leads to a detection of viable spores after processing. The results of this work support and augment these findings by showing that the majority of the viability results exhibited a growth of probiotics on the polyester fabric. The spores survived the printing parameters, such as higher shear stresses during paste application and the subsequent drying and curing of the fabric at temperatures of 80°C and 150°C. Contrary to the outcomes of the study by Ciera et al. where a correlation between a higher temperature (300°C) and an increasing residence time (10 min.) is detected, this study showed no significant differences in the viability results of a fabric dried for 15 minutes or 60 minutes [10].

However, in this study the temperature was limited to 80°C. Since also the other paste ingredients could influence the spores' viability, all ingredients were formaldehyde-free because this chemical is known to kill the spores [11]. The viability of the spores is important to exhibit inhibition activity. Recently, researches have shown that probiotics, either non-spore formers such as vegetative cells or spore-formers such as *Bacillus sp.*, have an inhibition effect against pathogens, which can be related to their competitive exclusion of pathogens [12,13] or to their production of antimicrobial substances [14, 15].



**Figure 2.** Viability results of the samples:  
Unwashed samples (a):P1, (d):P2, (g):P3, 3 wash samples (b):P1, (e):P2, (h):P3, 5 wash samples (c):P1, (f):P2, (i):P3

**Table 3.** The viability of the probiotics on the printed samples

	P1	P2	P3
Viability of probiotics before washes(CFU/surface)	> Log 4 Heavy growth	Log 1-2 Weak growth	Log1 Very weak growth
Viability of probiotics after 3 washes (CFU/surface)	Log 2- 3 Growth	Log 2-3 Growth	Log 1- 2 Weak growth
Viability of probiotics after 5 washes (CFU/surface)	>Log 4 Heavy growth	Log 2-3 Growth	Log 1- 2 Weak growth

The fastness to washing of the printed parts of the fabric and the viability of the probiotics after three and five washes is shown in Table 3. According to the results of a research the Swedish Chemical Agency, which concern the leakage of antibacterial substances, including silver, triclosan and triclocarbon in washing water, the concentration for all three biocides fell after washing and a leakage of about 60-80% compared to the original measured content of triclosan was observed. Results of silver-treated samples showed that after three washes already more than 50% leaked out. For this reason it was further not possible to determine the significance of the results. All samples exhibited certain viability after three washes. Considering the formulation P2 and P3, they exhibit the best results and a growth was observed on both samples. However, the intensity of the pattern on the fabric was not considerably influenced and still clearly visible. Obtained results after 5 washes showed that the sample P1 showed a very weak growth of probiotics and the samples P2 and P3 indicated a weak growth of grown out probiotic colonies on the fabric (Figure 2). Moreover, the weak fastness can be attributed to the fact that the spores are not sufficiently bound in the paste. It is assumed that they released from the paste during washing and therefore a decreased viability was observed. This would agree with the fact that the intensity of the printed pattern was not considerably influenced and still clearly visible after five washes.

Nevertheless, a distinction is necessary between the viability of probiotics and the appearance of the print after washing. It was observed that the print after three and five washes was still visible on the fabric, whereas the viability decreased. The better appearance of the print after washing was especially related to samples prepared with a paste containing a cross linker. To confidently say, that the cross linker maintains a higher occurrence of the print, SEM images after washing could provide further conclusions.

#### 4. CONCLUSION

The viability of probiotics printed on a textile material was achieved by printing a paste containing probiotic spores on a polyester substrate. The viability on the fabric was analyzed and it was found that almost all samples exhibited viability and about  $10^4$  CFU of probiotics were counted on each sample. In order to investigate the applicability of the fabric, the effect of the print on the wettability and abrasion resistance of the fabric was explored. Printed parts of the polyester samples were found to

exhibit higher contact angles and thus a lower wettability than the reference polyester samples. The abrasion resistance of the printed samples exceeded the amount of rubs were specimen breakdown occurred for the untreated polyester sample. In the majority of the samples, the print was almost gone after 15000 rubs. In addition, the durability of the print and the probiotic viability is evaluated after three and five washes. Both of them, the appearance of the print and the viability of probiotics, decreased with increasing washes. Additionally, the occurrence of probiotic spores in the print was evaluated. SEM images did not exhibit structures in the printed parts of the fabric that could be assigned to probiotic spores. However, it gave an impression of the print quality that appeared partly uneven including air bubbles. As a final remark it was feasible to produce screen-printed polyester fabrics with viable probiotics, where the spores were successful in the survival and may play an important role in the inhibition of nosocomial pathogens on the polyester fabric.

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