Digitally printed cotton fabric - the influence of washing conditions

Digitalno otisnuta pamučna tkanina - utjecaj uvjeta pranja

Scientific paper / Znanstveni rad

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Abstract

The aim of this study was to investigate the effects of washing on cotton fabric digitally printed in blue colour. The study included several important steps: the selection of the most suitable detergent and washing temperature, the analysis of the effects of detergents on colour fastness and the physical properties of the cotton fabric after five washes. Detergents with different formulations and physical forms were used. The results showed that powder detergents containing optical brighteners caused the strongest changes due to their abrasive effect on the pigment layer. To preserve colour integrity, washing at 40 °C with detergents without optical brighteners is recommended.

Keywords: digital pigment printing; detergents; washing; washing fastness; washing recommendations

Sažetak

Cilj ovog rada bio je istražiti učinke pranja na pamučnu tkaninu digitalno otisnutu u plavoj boji. Istraživanje je obuhvaćalo nekoliko važnih koraka: odabir najprikladnijeg deterdženta i temperature pranja, analizu utjecaja deterdženata na postojanost obojenja i fizikalna svojstva pamučne tkanine nakon pet pranja. Korišteni su deterdženti različitih formulacija i fizikalnih svojstava. Rezultati su pokazali da praškasti deterdženti koji sadrže optička bjelila uzrokuju najjače promjene zbog njihovog abrazivnog djelovanja na pigmentni sloj. Kako bi se očuvala postojanost obojenja, preporučuje se pranje na 40 °C s deterdžentima bez optičkih bjelila.

Ključne riječi: digitalni pigmentni tisak; deterdženti; pranje; postojanost na pranje; preporuke za pranje

1. Introduction

Printing as an art form has been known since ancient times. In China, patterns were printed on silk around the 5th century BC. The oldest known printing technique is woodblock printing, which originated in China during the Han dynasty. In this technique, images or texts were carved into wooden blocks, coloured, and pressed onto materials such as paper or silk [1]. Although the Han dynasty did not fully develop woodblock printing as it is known today, its innovations paved the way the Tang dynasty [2-4].

The earliest printed Egyptian textiles date back to the 4th century and are a child's tunic from Akhmim, found during Egyptian excavations. In the middle of the 20th century, however, there was a great dynamic in the development of printing technology and today textile printing accounts for a large part of the market [1,5]. These textiles, which are mainly made from linen, feature intricate patterns applied using techniques such as block printing and resist dyeing with natural dyes.

Textile printing has evolved considerably over the centuries, from traditional block printing in ancient times to rotary screen and roller printing in the industrial era. These methods laid the foundations for the precision and efficiency of modern textile production. The advent of digital printing in the late 20th century was a turning point as it enabled intricate designs, reduced water consumption and minimised environmental impact [6-10]. Unlike conventional methods, digital printing applies dyes or pigments directly to the fabrics, which enables a high degree of customisation and fast production, known as *quick response*.

As a natural and widely used textile, cotton is particularly suitable for digital printing due to its absorbency and compatibility with various dye systems. Digitally printed cotton fabrics have revolutionised textile design by offering unparalleled precision, bright colours and sustainable production techniques. Unlike conventional printing methods, digital printing uses very little water and chemicals, making it an environmentally friendly production method. However, the durability of these prints under different washing conditions remains a critical issue [11,12].

Washing processes have always played an important role in the longevity of printed textiles. In the past, printed textiles have experienced problems such as colour fading and bleeding. Washing factors such as temperature, type of detergent, agitation and drying can significantly affect the colour fastness, clarity and longevity of the print [13-15]. Research has shown that high temperatures and powder detergents can lead to fading and loss of detail, while gentle washes and mild detergents preserve print quality. Understanding the interaction between washing conditions and printing technology is crucial for optimising textile care and extending the life of digitally printed textiles.

DOI: 10.34187/ko.74.1.1

The aim of this paper is to investigate the effects of powder and liquid detergents with and without optical brighteners on the durability of cotton fabrics digitally printed with blue colour. For this purpose, the printed samples were subjected to five washes and the spectrophotometric changes of the prints were observed after the first and fifth wash. The results were analysed to determine the optimal care to maintain the durability of the prints.

2. Experimental part

2.1. Material

For the study, a fabric made of bleached cotton yarn in plain weave, raw material composition 100% cotton, basic weight 130.67 g/m^2, produced in Arilje, Serbia, was used.

2.2. Methods

Blue standardised water-based pigment ink was used for printing on cotton fabric, as recommended by the manufacturer of the InkJet device. The commercial product Azon Pigment Pre-treatment Solution from Azonprinter d.o.o., also water-based, was used as a binder. The main purpose of the binder is to improve the interaction between the fabric and the pigment ink to ensure high quality and durable prints.

Four commercially available detergents in liquid (L) and powder (P) form, with (OB) and without optical brighteners were used to test the wash fastness of the print. For comparison, a standard detergent (ECE) with a known composition according to HRN EN ISO 105-C06:2010 (ECE Reference detergent with Phosphates) was used, Table 1.

The washing process (w) was carried out in accordance with HRN EN ISO 105-C06:2010: Textiles - Tests for colour fastness - Part C06: Colour fastness to domestic and commercial laundering, in a Turbomat laboratory machine, P 4502, Mathis, according to the wash test programme. The samples were washed at 40 and 60 °C in 5 cycles of 30 minutes in tap water and a bath ratio of 1:50. The amount of detergent used was calculated according to the manufacturer's recommendation for the specified bath volume.

Table 1. Detergents used and purpose.

Detergent	Description	Purpose
L	Liquid detergent without optical brightener	For black and dark fabrics
LOB	Liquid detergent with optical brightener	For white and colored laundry
P	Powder detergent without optical brightener	For colorful clothes
POB	Powder detergent with optical brightener	For white clothes
ECE	Standard detergent without optical brightener	For color fastness test

The influence of the washing process and the detergents used on the spectral properties of the tested pigment paste was determined using a DataColor® SF 600 UV+CT remission spectro-photometer after the first (1w) and fifth (5w) washing cycle.

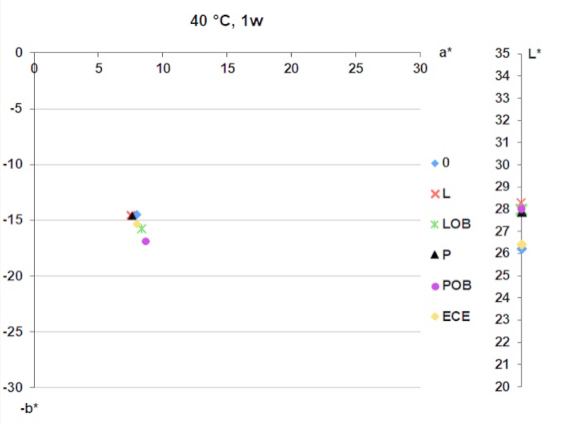
3. Results and discussion

Colour is a psychological experience caused by a physical cause (light) and is defined by three values: hue (h*), chromaticity (C*) and lightness (L*). The CIEL*a*b* space is defined by three axes: two chromatic axes a* and b* and the achromatic axis L*, which indicates the brightness and ranges from 0 (black) to 100 (white). The positive a* axis is in the direction of the red stimulus, while the negative b* axis is in the direction of the blue stimulus. The centre of the chromatic axes is achromatic and the further it moves away from the centre, the more the chromaticity of the colours in the CIEL*a*b* space increases.

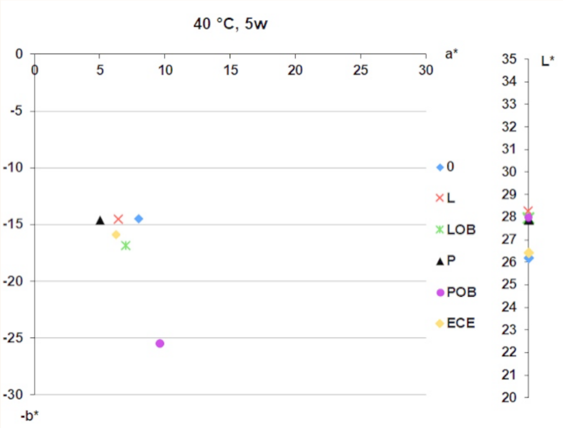
In order to determine the changes that occur in digitally printed samples during the washing process, the prints of the washed samples were analysed. Figures 1 and 2 and Tables 2 and 3 show the results of the changes in hue, chromaticity, brightness and total colour difference after the 1st and 5th wash.

Figures 1 and 2 show the spectral characteristics of the digitally printed cotton fabric washed at two different temperatures and measured after the 1st and 5th wash. Tables 2 and 3 show the values for chromaticity and hue values of the same samples.

From the graphical view of the CIEL*a*b* colour space, Figure 1 and 2, can be seen that all samples are located in the IV quadrant, which is defined by the red (a*) and blue (-b*) coordinates. Washing causes changes and shifts.



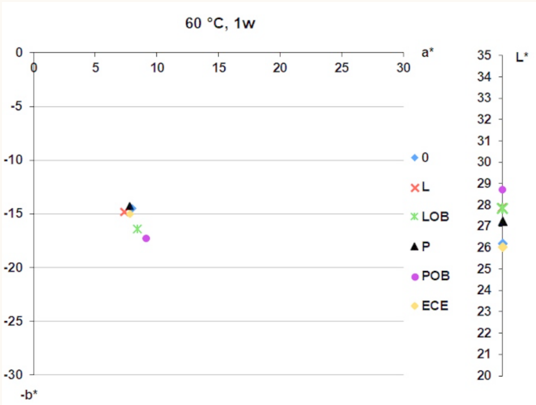
a)



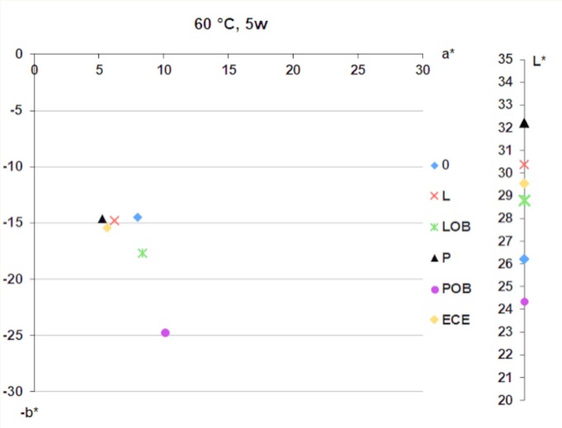
b)

Figure 1. Spectral characteristics of samples at 40 °C after: a) 1st, and b) 5th wash cycle

For most samples, the lightness (L*) increases from the 1st to the 5th wash, indicating a lighter appearance, probably due to the degradation of the surface or the removal of the pigment ink during the wash. The a* values are positive (red) and generally decrease, indicating a shift towards a less reddish tone. The -b* values (blue) remain fairly stable, except for POB, where the 5th wash shows a noticeable increase in the negative b* value, indicating a stronger blue shift.



a)



b)

Figure 2. Spectral characteristics of samples at 60 °C after: a) 1st, and b) 5th wash cycle

Figure 2 shows similar trends with increasing L*, but the changes are more pronounced at 60 °C, reflecting greater lightening due to the temperature effect. For the POB sample, the b* values shift significantly and follow the same behaviour as at 40 °C. The changes are more pronounced with increasing number of washes.

It was confirmed that the greatest changes occur when washing with a detergent containing optical brighteners, with a stronger shift towards blue (-b*). Larger changes occur after the 5th wash cycle, which can be explained by the accumulation of optical brighteners from the detergent on the textile, or by the mechanical action of the powdery components on the pigment print during washing. The washing results with ECE detergent are relatively stable at both temperatures, with a moderate increase in L* and slight shifts in a* and b*.

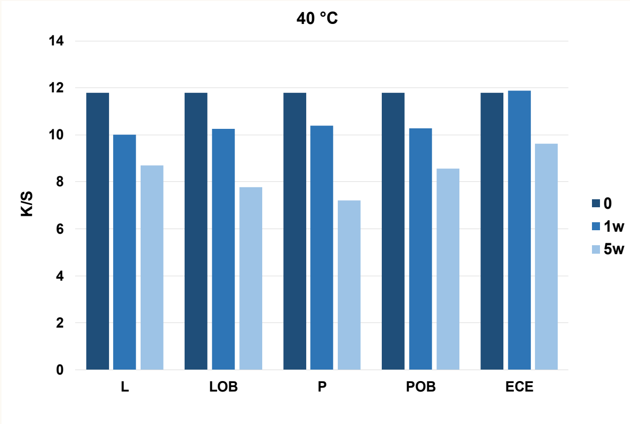
The largest shifts in chromaticity (C*) are visible after washing (1st and 5th) at 40 and 60 °C with a powder detergent containing optical brightener (POB). The washing cycles have only a minimal effect on the hue value (h*), which proves the consistency of the print in relation to the spectral properties of the colour itself, Tables 2 and 3. The h* values remain relatively stable during washing, indicating that there are no major colour changes.

Table 2. Values of C* and h* of cotton samples washed at 40 °C, after the 1st and 5th wash cycle

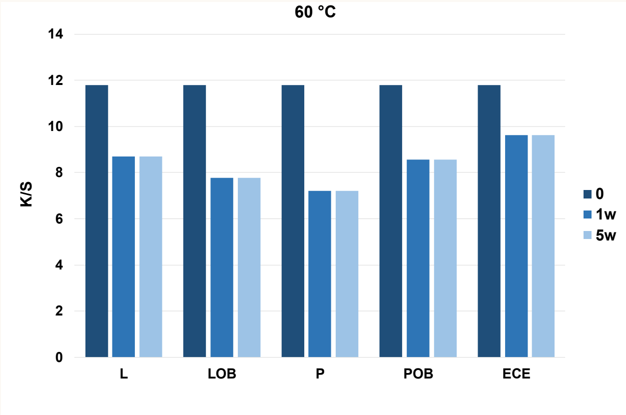
	1w		5w	
	C*	h*	C*	h*
0	13.98	296.23	13.98	296.23
L	12.85	293.98	13.14	294.33
LOB	15.54	294.98	15.03	292.99
P	13.88	295.97	13.84	293.39
POB	18.49	295.60	22.99	295.53
ECE	14.94	296.85	14.74	295.47

Figure 3 shows the histograms of the samples before washing compared to the samples after the 1st and 5th wash cycle with different detergents (L – liquid detergent, LOB – liquid detergent with optical brightener, P – powder detergent, POB – powder detergent with optical brightener and ECE – standard detergent) at temperatures of 40 and 60 °C.

The colour strength (K/S) value is defined as the colour depth resulting from the amount of pigment covering the samples. Washing leads to the removal of loosely bound surface pigments, the breaking of chemical bonds or physical damage to fibres, all of which reduce the colour. Powder detergents generally cause more fading due to their higher alkalinity and abrasive particles. Optical brighteners are fluorescent compounds that initially enhance colour depth, but cannot fully compensate for dye loss over multiple cycles.



a)

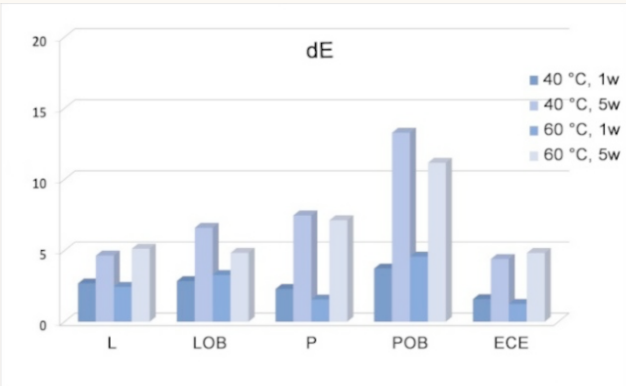


b)

Figure 3. K/S histograms of cotton samples washed at: a) 40 °C, and b) 60 °C

The highest value for K/S was reached after the 5th wash cycle at 40 and 60 °C for samples washed with powder detergent with optical brightener (POB). During washing, the colour depth should gradually decrease, which can be seen more clearly in samples washed 5 times, e.g. at a higher washing temperature (Fig. 3a vs. Fig. 3b). The change in colour depth is initially greater at a higher temperature, but when looking at the difference between the number of washes, the difference is smaller at a higher temperature (Fig. 3b). Powder detergents are more abrasive than liquid detergents, resulting in a greater loss of pigment dye or damage to the fibres. The brightener in POB can mitigate fading by compensating for the loss of pigment dye through fluorescence or light-reflecting properties.

Higher temperatures (60 °C) of liquid detergent (L) do not lead to additional fading compared to 40 °C, which indicates that the effect of this type of detergent is primarily due to the chemical effect and not the temperature. The liquid detergent with optical brightener (LOB) is more effective at higher temperatures, and the colour depth decreases. ECE standard detergents contain the highest initial and final colour depth among all detergents (11.876 → 9.612).



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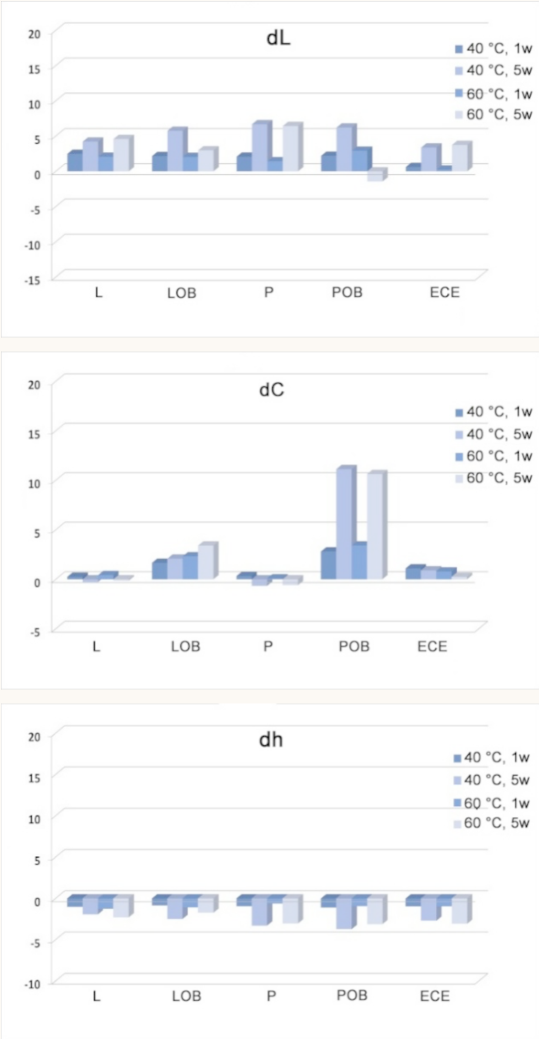

Figure 4. Differences in the colour of the samples after the 1st and 5th wash cycles depending on the detergents used

The colour differences of the printed and washed samples after the 1st and 5th wash cycles at 40 and 60 °C are shown in Figure 4. All results are outside the tolerance limits defined by dE<1. The colour differences are greatest in the samples that were washed with powder detergent with optical brightener. It not only has an abrasive effect on the fabric surface, which has a negative impact on the strength of the pigment coating, but also changes the colour shade of the pastel pigment.

4. Conclusions

The aim of this paper was to research the problem of washing digitally printed textiles in blue colour, whereby the process itself takes place in several steps: researching the most suitable detergent, selecting the optimal washing temperature and analysing the effect of detergents on the textile material by determining the changes caused by a certain number of washing cycles and analysing the digitally printed textile material for its colour fastness.

During washing, the depth of colouring should gradually decrease. It has been shown that the K/S value increases in samples washed with powder detergent and in the presence of optical bleaching agents. This phenomenon is more pronounced at a higher temperature and a greater number of washes. It was found that the colour differences were greatest in the samples washed with powder detergent with optical brightener, which means that this type of detergent has an abrasive effect on the printed surface of the fabrics and thus negatively affects the strength of the pigment coating. The standard detergent proved to be satisfactory, i.e. it did not show any deviations from detergents intended for the care of more delicate textiles.

From the results obtained, it can be concluded how important the choice of detergent is for washing digitally printed textiles. Taking all the above facts into account, the recommendation for washing digitally printed textiles in blue colour is a temperature of 40 °C with detergents without optical brighteners.

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