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Study of print paste composition for natural and synthetic textiles. Part 1: Printing of cellulosic fabrics

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Abstract. Reactive dyes have proven to be one of the most commonly applied classes of modern synthetic dyes. Unlike other dye classes for cellulosic textiles dyeing and printing, the reactive dyes provide excellent wash-fastness for a very wide shade gamut. One of the most important components of print paste, especially for reactive dye printing of cellulosic textiles, is urea. Despite urea's great importance in adjustment of dye distribution in the paste, it can cause environmental problems. In this study, the application of polyethylene glycol (PEG) (10, 30 and 50 g/100 g) was examined for urea's replacement in reactive dye print paste. The optimal concentration of sodium bicarbonate, as pH buffer, was found. Testing results of colour fastness and colour measurements approved PEG application possibility.

1. Introduction

Textile printing is the most diverse and important of the methods used for introducing colour and design to textiles. It is a process, which combines a design idea, one or more colorants, and a textile substrate, using a technique for applying the print paste with some precision.

The composition of dye-based print paste is a complex combination of multiply constituents [1]. Among water, dye, thickener and pH buffers, the paste contains fixation agents and other auxiliaries. One of the most important components of print paste, especially for reactive dye printing of cellulosic textiles, is urea, which is used as a swelling agent during the steaming process, dye solubilizing and disaggregation agent. However, because of high nitrogen content, it can cause environmental problems. Thus, investigation in the field of optimization of textiles printing technology towards cleaner process is of current importance.

In continuation of the investigation of twill weave 50% cotton/ 50% polyester blended fabric one-step one-bath dyeing technology elaboration using a single dye class [2], the present study covers 100% cotton (Part 1) and 100% polyester (Part 2) fabric print pastes' recipe elaboration for direct printing method. The main goal of the research was to avoid the application of conventionally used constituent – urea, replacing it with polyethylene glycol.

2. Materials and methods

2.1. Printing technology

Prior to printing, the cotton fabric was scoured in non-ionic liquor solution Felosan NOF (1 g/L) (CHT Bezema, Switzerland) at 55-60°C for 60 min, at liquor ratio 1:30, rinsed and dried at ambient conditions.

In this study, reactive dye-based print paste was applied for 100% cotton fabric (100 g/m^2 surface density, and 0.11 mm average thickness). Print paste contained of distilled water, reactive dye Cibacron Navy W-B (CHT Bezema, Switzerland), sodium alginate (George Weil & Sons Ltd, UK) as thickener, sodium bicarbonate (Sigma-Aldrich Co., USA) as pH buffer, sodium 3-nitrobenzenesulphonate (Sigma-Aldrich Co., USA) as resisting salt, urea (Merck KgaA, Germany) as dye solubilizing agent, and polyethylene glycol (M_w = 400) (Kremer Pigmente, Germany) as substituent of urea. Examined print paste recipes are shown in Table 1.

Table 1. Recipes of screen print paste for cotton fabric [1, 3]

Print paste constituents	Print paste composition, g/100 g paste	
Reactive dye	5	
Urea	10, 30, 50	-
PEG	-	10, 30, 50
$NaHCO_3$	1, 1.5, 2	
3-nitrobenzenesulphonate	1	
Sodium alginate thickener	up to 100 g	

Each printed sample was labelled, depending on urea or PEG, and $NaHCO_3$ concentration. Examples of sample labelling are given in Table 2. Each series consisted of 3 parallel samples; total number of samples was 54.

Table 2. Examples of sample labelling

Sample label	Urea concentration, x g/100 g paste	PEG concentration, x g/100 g paste	$NaHCO_3$, x g/100 g paste
U-10-1	10	-	1
U-30-1.5	30	-	1.5
P-10-1	-	10	1
P-30-1.5	-	30	1.5

The direct ‘all-in’ method was applied for cotton fabric printing at the laboratory level (Fig. 1).

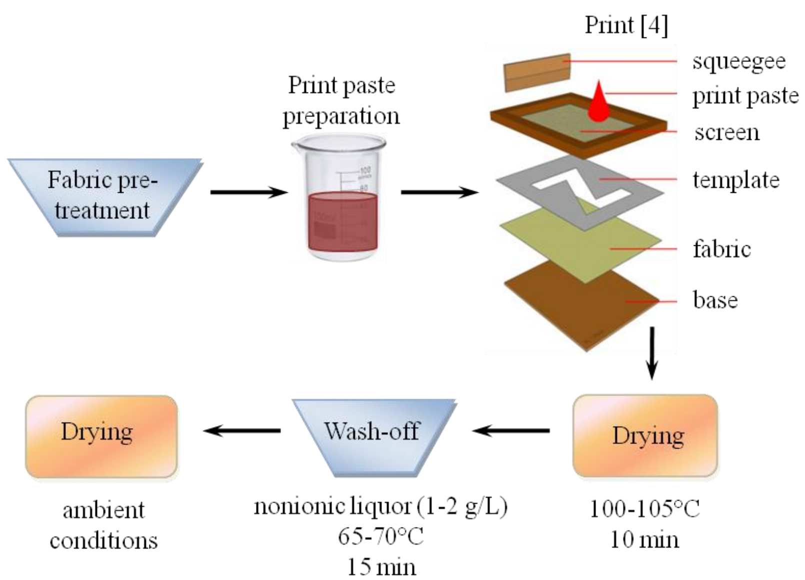

Figure 1. Flow-chart of applied screen printing on cotton fabric

2.2. Testing methods
Colour measurements of printed area, colour fastness to rubbing, washing and artificial light were determined according to national and international standards, as described in [2]. Organoleptic estimation of printing quality, using point scale from 1 (poor) to 5 (excellent) for printed fabric handle, paste spread homogeneity, penetration and sharpness of contours was evaluated.

3. Results and discussion
Table 3 shows colorimetric data of printed cotton samples in dependence of urea or PEG, and sodium bicarbonate concentration. It can be seen that increasing sodium bicarbonate concentration in the case of urea-based print paste, samples proved to have darker shades (L* values) (see Table 3). This correlation conforms to findings of Xie K et al. [5].

Table 3. Colorimetric data of printed cotton fabric samples

Sample	L*	a*	b*	C^*_{ab}
U-10-1	60.58	-0.72	-17.41	17.42
U-10-1.5	55.32	-1.67	-18.96	19.04
U-10-2	26.81	0.12	-16.22	16.22
U-30-1	48.72	-2.25	-20.09	20.21
U-30-1.5	29.09	-0.50	-17.26	17.27
U-30-2	29.31	-0.22	-18.04	18.04
U-50-1	57.62	-1.38	-17.63	17.69
U-50-1.5	55.07	-1.35	-18.48	18.53
U-50-2	21.09	1.82	-11.41	11.55
P-10-1	29.88	1.03	-19.11	19.14
P-10-1.5	30.93	0.87	-19.47	19.49
P-10-2	39.93	-1.61	-21.63	18.46
P-30-1	32.84	-1.11	-20.40	20.43
P-30-1.5	48.97	-2.61	-20.72	20.88
P-30-2	28.39	0.60	-18.28	18.29
P-50-1	73.30	2.01	-11.53	11.70
P-50-1.5	37.59	-1.77	-21.05	21.12
P-50-2	66.82	-0.44	-15.85	15.85

Increasing urea and sodium bicarbonate concentration in the print paste, colour fastness to artificial light, dry/wet rubbing and washing increased (except U-10-2 and U-50-1.5 samples), though, print handle properties deteriorated (see Table 4). For traditional, urea-containing print paste, the combination of urea (50 g/100 g) and sodium bicarbonate (2 g/100 g) was found to be an optimal one, though U-50-2 samples were the stiffest among all printed cotton samples.

Table 5 shows that in the case of PEG-containing paste it was found, that with increase of PEG concentration for samples with equal sodium bicarbonate amount, colour fastness to artificial light and washing decreased (higher ΔE^*_{ab} values). The correlation between sodium bicarbonate concentration and colour fastness parameters couldn't be found. Though, results of colour rub fastness were comparable for urea- and PEG-based pastes (see Table 4 and Table 5).

Table 4. Printed cotton fabric colour fastness, visual and handle parameters in dependence of urea-containing paste recipe

Sample	Total colour differences ΔE^*_{ab}		Colour fastness to dry | wet rubbing	Organoleptic estimation			
	72 h of artificial light exposure	5-cycle washing		Paste spread	Paste penetration	Sharpness of contours	Print handle (stiffness)
U-10-1	18.06	3.65	5 | 5	3	1	2	5
U-10-1.5	14.08	3.62	4 | 5	3	1	3	4
U-10-2	36.31	12.33	5 | 4	3	3	2	3
U-30-1	8.64	12.43	5 | 5	2	2	2	4
U-30-1.5	7.55	2.02	5 | 4	2	2	2	3
U-30-2	7.01	7.96	5 | 4	3	3	2	3
U-50-1	15.3	6.59	5 | 5	3	1	1	4
U-50-1.5	17.33	6.05	5 | 4	3	3	2	4
U-50-2	3.33	3.30	4 | 4	4	5	4	2

For PEG-containing print paste, the combination of PEG (30 g/100 g) and sodium bicarbonate (2 g/100 g) proved to be possible substituent of urea-containing paste. It can be seen from Table 5, that in comparison with optimal urea-based recipe, i.e. U-50-2 sample, PEG-containing print paste provided lighter colour (L* value was higher for 26%), lower light fastness (ΔE^*_{ab} value was higher for 57%), but better wash-fastness (ΔE^*_{ab} value was lower for 12%), print contour sharpness and handle properties. Colour rub fastness results of P-30-2 sample were comparable with Zhang et al reported [6].

Table 5. Printed cotton fabric colour fastness, visual and handle parameters in dependence of PEG-containing paste recipe

Sample	Total colour differences ΔE^*_{ab}		Colour fastness to dry | wet rubbing	Organoleptic estimation			
	72 h of artificial light exposure	5-cycle washing		Paste spread	Paste penetration	Sharpness of contours	Print handle (stiffness)
P-10-1	7.90	1.88	5 | 4	4	4	4	3
P-10-1.5	12.20	3.42	4 | 4	2	3	3	3
P-10-2	7.65	6.55	5 | 4	2	2	3	4
P-30-1	13.94	2.74	5 | 4	3	3	3	3
P-30-1.5	12.68	1.61	5 | 4	4	3	3	5
P-30-2	7.70	2.90	5 | 4	4	5	5	3
P-50-1	13.15	3.52	5 | 5	4	3	3	4
P-50-1.5	15.08	4.97	5 | 4	4	4	4	4
P-50-2	14.15	2.14	5 | 4	5	3	5	4

4. Conclusions

The present study aimed to decrease environmental impact of direct cotton printing by replacement of urea, as reactive dye solubilizing and disaggregation agent, with PEG.

Print paste with urea (50 g/100 g) and sodium bicarbonate (2 g/100 g) proved to provide darker colour, better colour fastness to artificial light and 5-cycle washing, but the stiffest handle among all printed cotton samples in this study.

As alternative, print paste with PEG (30 g/100 g) and sodium bicarbonate (2 g/100 g) can be recommended, providing better wash-fastness, sharpness of print contours and handle properties for cotton fabric.

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