Study of print paste composition for natural and synthetic textiles. Part 2: Printing of polyester fabrics

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Abstract. Urea, as dye disaggregation and solubilizing agent, plays an important role in direct printing process, though it has negative environmental impact due to ammonia nitrogen emission. Not only cotton reactive dye printing involves application of urea. Also disperse dye print pastes consists of it, mainly applied by professional artists and designers. In this study, the possibility of urea replacement with polyethylene glycol (PEG) for polyester fabric printing was examined. The action of glycerine, as additional dye dissolving agent, was also explored. With variation of urea and PEG concentration (25, 50 and 100 g/1000 g paste), and addition of glycerine (20 g/1000 g paste), an impact on results of colour measurements and fastness was analysed. With application of PEG to polyester printed fabrics higher colour fastness to washing and artificial light can be obtained.

1. Introduction
The dye-sublimation printing is the most common method of synthetic textiles decoration worldwide. According to recent global investigation from Smithers Pira [1], growth in the amount of dye-sublimation printed materials is forecasted to be 18.4% across the next five years. Despite overall positive aspects of dye sublimation, it has some technical restrictions [2-4]. Besides, there will always be a large group of professional artists and designers, who implement their ideas, using different printing techniques, e.g. direct style, which covers textile printing of positive image, applying one or more print pastes [5].

In continuation of the research of cotton/polyester one-step one-bath dyeing with disperse dyes [6], this study covers investigation of urea, as dye disaggregation and solubilizing agent, possible replacement with less hazardous chemical - polyethylene glycol, for polyester screen-printing method. For textile design projects, glycerine is recommended as dye dissolving agent with or without combination of urea [5]. Thus, the action of addition of glycerine was also examined. This study aimed print paste recipe elaboration with less negative environmental impact, avoiding ammonium nitrogen emission, caused by application of urea in print pastes.

2. Materials and methods
2.1. Pre-treatment and surface modification
Prior to printing, the polyester fabric was scoured in solution at liquor ratio 1:30, at 90-95°C for 60 min, containing sodium hydroxide (5 g/L) (PPH Stanlab Sp.j, Poland), sodium hexametaphosphate (0.5 g/L) (Chempur, Poland) and non-ionic liquor Felosan NOF (1 g/L) (CHT Bezema, Switzerland)
according to [7]. Following rinse, samples were neutralized in 30% acetic acid (1 mL/L) at ambient conditions for 10 min, rinsed again and dried.

2.2. Printing technology
In this study, disperse dye-based print paste was applied for 100% polyester fabric (125 g/m² surface density, and 0.2 mm average thickness). Print paste contained of distilled water, disperse dye Itosperse Blue Rap and dispersing agent Itosolt LJ 557 (LJ Specialities Ltd., UK), sodium alginate (George Weil & Sons Ltd, UK) as thickener, glycerine (Sigma-Aldrich Co., USA) as dye dissolving agent, sodium 3-nitrobenzenesulphonate (Sigma-Aldrich Co., USA) as resisting salt, urea (Merck KgaA, Germany) as dye dissolving agent, and polyethylene glycol (M₆₀ = 400) (Kremer Pigmente, Germany) as possible substituent of urea. Examined print paste recipes are shown in Table 1.

Table 1. Recipes of screen print paste for polyester fabric [5, 8]

| Print paste constituents | Print paste composition, g/1000 g paste |
|--------------------------|---------------------------------------|
| Disperse dye             | 5                                     |
| Dispersing agent         | 10                                    |
| Urea                     | 25, 50, 100                           |
|                           | 25, 50, 100                           |
|                           | 25, 50, 100                           |
|                           | 25, 50, 100                           |
|                           | 25, 50, 100                           |
| PEG                      | -                                     |
|                           | 25, 50, 100                           |
|                           | 25, 50, 100                           |
| Glycerine                | 20                                    |
|                           | 20                                    |
| 3-nitrobenzenesulphonate | 10                                    |
| 40°C distilled water     | 150                                   |
| Sodium alginate thickener| up to 1000 g                          |

Each printed sample was labelled, depending on urea or PEG concentration, and glycerine presence. Examples of sample labelling are given in Table 2. Each series consisted of 3 parallel samples; total number of samples was 36.

Table 2. Examples of sample labelling

| Sample label | Urea concentration, x g/1000 g paste | PEG concentration, x g/1000 g paste | Glycerine, x g/1000 g paste |
|--------------|-------------------------------------|-------------------------------------|------------------------------|
| U-25-G       | 25                                  | -                                   | 20                           |
| U-50         | 50                                  | -                                   | -                            |
| P-25-G       | -                                   | 25                                  | 20                           |
| P-50         | -                                   | 50                                  | -                            |

The direct ‘all-in’ method was applied for polyester fabric screen printing at the laboratory level, following by drying at 100-105°C for 10 min and thermal fixation at 190°C for 1 min. Samples were rinsed and scoured in non-ionic liquor Felosan NOF (1-2 g/L) at 65-70°C for 15 min, and dried at ambient conditions.

2.3. Testing methods
All testing procedures were implemented according to national and international standards, as described in Part 1 of the present work. Additionally, non-printed area’s cross-staining after 5-cycle washing was examined using grey scale, according to ISO105-A03:1993.
3. Results and discussion

Table 3 shows colour measurement results for printed samples in dependence of urea and PEG concentration, and glycerine addition. Comparing urea- and PEG-containing print paste samples, traditional application of urea resulted darker fabric colouration (lower L* values). Obtained results indicate that concentration of urea almost didn’t influence lightness (L*) and chroma (C*ab) values. Addition of glycerine to urea-containing print paste led to slightly darker, but less saturated shades.

In the case of PEG-based print paste, with an increase of PEG concentration, colour lightness values increased for 16% in average. Samples printed with glycerine addition had lighter (higher L* values) shades (see Table 3) and less homogenous spread of print paste (see Table 4).

Table 3. Colorimetric data of printed polyester fabric samples

| Sample | L*   | a*   | b*   | C*ab |
|--------|------|------|------|------|
| U-25   | 47.26| 5.42 | -36.26| 36.67 |
| U-50   | 46.57| 6.44 | -35.66| 36.24 |
| U-100  | 48.11| 5.52 | -34.87| 35.30 |
| U-25-G | 43.63| 6.30 | -36.35| 36.89 |
| U-50-G | 49.31| 4.09 | -34.59| 34.83 |
| U-100-G| 48.81| 4.78 | -34.46| 34.79 |
| P-25   | 45.23| 5.37 | -28.73| 29.23 |
| P-50   | 54.68| 3.00 | -30.55| 30.70 |
| P-100  | 53.36| 2.83 | -30.94| 31.07 |
| P-25-G | 50.96| 5.24 | -34.80| 35.19 |
| P-50-G | 52.15| 3.50 | -31.91| 32.10 |
| P-100-G| 51.78| 3.86 | -32.28| 32.51 |

Correlation of total colour differences (ΔE*ab) with print paste recipe is shown in Figure 1. With the increase of urea concentration in print paste, print colour fastness to 5-cycle washing improved (lower ΔE*ab values) for 68% in average.

As stated above, glycerine is recommended as additional or separate dye disaggregation agent. Results in Figure 1 indicate that application of glycerine in urea- and PEG-containing print paste tended to reduce its colour light fastness. That can be explained with too amplified dye solubilizing action, which led to weak dye bonding with fibre.

Analysing PEG concentration impact, samples printed with PEG (100 g/1000 g - sample P-100) had lower for 65% in average light fastness values and moderate paste spread homogeneity in comparison with P-25 and P-50 samples. Application of glycerine almost didn’t change colour wash-fastness results for PEG-containing print pastes (see Table 4).

Samples printed with PEG (25 and 50 g/1000 g) proved to have better colour fastness to washing and artificial light. That can be attributed to similarities in chemical composition of PEG and polyester, i.e. one of the main components of polyester is ethylene glycol. Polyglycol is water soluble, but majority of it tends to be trapped inside the fibre structure [9], which can be the possible reason of fibre blocking from dye desorption.
4. Conclusions

This study aimed to examine possibility of urea replacement with PEG in print paste for polyester fabric.

Despite excellent results of colour fastness to dry and wet rubbing for all printed samples in this study, cross-staining tests showed that PEG application led to non-printed area’s tinting (see Table 4). However, addition of glycerine to PEG-containing print paste slightly improved cross-staining results. In the case of urea-containing paste, concentration of urea and addition of glycerine didn’t affect these parameters.
Achieved results show that application of PEG is possible in concentration up to 50 g/1000 g paste. These samples showed better results of colour fastness to 5-cycle washing and artificial light, print handle and paste spread properties. PEG concentration in the amount of 50 g/1000 g paste can be recommended as substitution of urea.

Addition of glycerine to urea- and PEG-containing print pastes decreased colour light fastness and didn’t improve colorimetric parameters. Thus, application of glycerine in print pastes for polyester can’t be recommended.

Achieved results are promising as an alternative cost-effective and less environmentally hazardous print paste option and can be suggested for application in textile printing design projects.

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