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ULTRASONIC DYEING OF COTTON FABRICS WITH RED REACTIVE DYESTUFF

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Abstract: *In this study, comparison of dyed 100% cotton knitted fabrics according to two different methods named "ultrasonic-conventional" and "conventional" methods is done by conducting rubbing fastness, washing fastness and water absorption tests. As well, color measurement of samples is measured with a spectrophotometer. Red DE2GF Remazol brand reactive dye is used as dyestuff. NaCl salt and Na_2CO_3 soda ash contents are kept constant during dyeing of samples. The variants during this study are selected as amount of dyestuff and time duration in sonication application. With the variants, we had 5 different samples for the "ultrasonic-conventional" dyeing method and 4 samples for the "conventional" dyeing method. With the comparison of both methods, the color depth of samples dyed with "ultrasonic-conventional" method gave higher results and it is concluded that target color shades might be obtained using less dyestuff amounts by the "ultrasonic-conventional" method. In this study, as the cost of "ultrasonic-conventional" method is calculated and not found high; the "ultrasonic-conventional" method has potential to be a promising method due to its less dyestuff amount consumption and less polluting effect to the environment.*

Key words: *Ultrasound, dyeing, cavitation, colour measurement, fastness.*

1. INTRODUCTION

Ultrasound is sound that human beings cannot hear and that are between 20 Hz and 20 kHz. Ultrasound waves have high energy and are used in many applications in several industries including diagnostic imaging in health sector [1].

Thakore experimented ultrasound in dyeing and concluded that the chemicals necessary for dyeing process are less when ultrasound is used for dyeing [2]. Zhao and Zhang found that during desizing with ultrasound there is a time saving and the process is applicable at a lower temperature [3]. Sanoop et al managed to produce coated anti-fungal cotton by applying ultrasound to the biopolymer solution and they proved that the fabric was cleaned with ultraviolet light [4].Dumitrescu et al dyed fabrics with ultrasound using annatto plant extracts and found that the fabrics were dyable ecologically without using enzymes and they achieved higher color values with the sonication dyeing method compared to conventional dyeing [5]. Coman et al compared ultrasonic dyed and conventionally dyed fabrics using red onion extracts and concluded that sonication dyeing gave better results and higher color shades [6]. In this study, we aimed to compare

sonication applied dyeing with conventional dyeing in terms of fabric properties and energy consumption.

2. EXPERIMENTAL APPROACH

Two dyeing methods were applied to cotton fabrics and compared in this study: "ultrasonic-conventional" dyeing and "conventional" dyeing. In "ultrasonic-conventional" dyeing ultrasound was applied to cotton in water that has dyestuff and sonicated solution together with the fabric was taken to conventional dyeing machine to complete the "ultrasonic-conventional" dyeing process. In "conventional" dyeing, the dyeing process was done with the conventional dyeing machine without sonication application. In dyeing experiments, Red DE2GF Remazol brand reactive dye is used as dyestuff for red coloring. NaCl salt and Na_2CO_3 soda ash contents are kept constant during dyeing of samples. The variants during this study are selected as amount of dyestuff and time duration in sonication application. Dyestuff weights used were: 0.003g (sample R01); 0.006 g (sample R02); 0.009 g (sample R03) and 0.012 g (sample R04) in conventionally dyed samples; while sonication durations were: 1 min (RE1), 3 min (RD1), 5 min (RC1), 10(RB1) min and 15 min(RA1) durations with 0.003 g of dyestuff Red DE2GF.

2.1 Materials and Method

10 grams of 100% single jersey knitted cotton fabric at 180 g/m^2 is used in each dyeing experiment in 250 ml distilled water. Salt at 1 g and ash contents at 1 g weights are kept constant during dyeing of samples; dyeing procedure was 50 min at 60C^o and rinsing was applied after dyeing, the "conventional" dyeing procedure is given in Figure 1. In the conventional dyeing, dye solutions are prepared by mechanically stirring at 400 rpm for 3 minutes before dyeing.

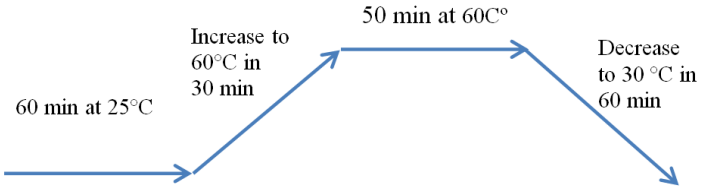

Fig. 1: *Dyeing procedure followed during experiments*

In the "ultrasonic-conventional" dyeing process, sonication was followed with the same dyeing process used in the "conventional" dyeing. Sonication was applied to the dye solution at 30 C^o and at 100 W power with a tip sonicator, Sonics VCX500, at 1 second working 1 second stopping mode to avoid over-heating during sonication. The energy values during sonication for each time interval is given in Table 1.

Table 1: *The energy values during sonication applied in the study*

Sonication time	1 min	3 min	5 min	10 min	15 min
Released energy (joule)	119	359	867	1120	1801

Color measurement is done with spectrophotometer Datacolor 600 at D65 light and 10^o angle settings. In color measurement: L givens lightness value, a* gives red-green axis values and b* gives yellow-blue axis values. Water absorption was tested with TS EN 14697 standard method;

as samples were mounted on a 45º angled base, the method was applied with a modified sample holder. Washing fastness tests were done according to TS EN ISO 105-C06 standard. Dry rubbing testing was done according to TS EN-ISO 105-X12 standard method.

The released energy values were given for 10 g of fabric and 250 ml of water. For energy consumption comparison, joules are converted to kilocalories with the given calculation method in Formula 1. The total energy consumption during reactive dyeing is given by Gulumser's research as 30 000 kcal for 60 ºC per 150 kg [7].

$$calory = joule\ x\ 4.184 \quad \text{.....} \quad \textbf{(1)}$$

2.2 Results

The color differences are compared with greige cotton fabric samples. The L, a, b and ΔE values of samples are given in Table 2. Hassan and Bhagvandas observed color depth increased with sonication applied during wool dyeing [8]. The dry rubbing fastness results of all samples were grade 5, which means dry rubbing fastness results were the best for all samples. As well, washing fastness results were all rated 5 for wool, acrylic, PES (polyester), nylon, cotton and acetate multifibres; accept for staining of R04 on cotton that was still at a good value of 4-5.

Table 2: *The L, a, b and Δ**E** values of samples in the study*

Sample	L	a*	b*	ΔE
RA1	76	22	4.2	5.2
RB1	76.4	22	4.3	4.6
RC1	76.9	21.8	4.5	4.5
RD1	77	21.5	4.6	4.3
RE1	77.3	20	5.2	_
R01	76.8	23	4.9	0.3
R02	73.2	28	3.02	8
R03	70.8	33.6	2.2	13.2
R04	69.5	34.6	2.1	15.6

A comparison between energy consumptions of conventional dyeing and ultrasonication process is given in Table 3; energy consumed by ultrasonication is far less then the dyeing process.

Table 3: *Comparison of energy consumption of conventional dyeing and the sonication process*

Process	Water (liter)	Temperature (ºC)	Fabric (kg)	Time (min)	Energy (kcal)	Energy/kg (kcal/ kg)
Conventional dyeing	1000	60	150	150	30 000	200
Sonication	0.25	29 (max)	0,01	1	0,50	50

Hassan and Bhagvandas (2017) studied ultrasonication in wool dyeing and concluded that dyeing with ultrasonication is a more sustainable method compared to conventional dyeing as sonication consumes less water, less energy and lower amounts of chemicals [8].

3. CONCLUSIONS

The samples dyed with the "ultrasonic-conventional" method were water repellent while samples dyed with "conventional" method were water absorbent; this result has not been stated before in any study, according to our knowledge. Water repellency is a desired property in some end-uses depending on customer expectations.

Washing fastness and dry rubbing fastness results were good for both dyeing methods compared. In color measurements, increasing the sonication duration resulted in lower color reflectance values which mean sonication increases color depth [8]. The energy consumption of sonication process is rather lower compared to conventional dyeing. Regarding the positive effect of sonication application, the lower energy consumption of sonication might be an opportunity to decrease costs of dyeing and finding a "greener" method for textile dyeing.

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