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Effect of Fabric Hairiness and Pretreatment on Quality of Digital DTG (Direct to Garment) Printing

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Abstract

Direct to garment printing is expanding its presence on the textile market today due to the markets search for sustainability, print on demand, fast response, mass customization and inventory reduction. While this type of printing in terms of quality may be enough for the promotional market, brands are still struggling with both quality and performance of the DTG prints on natural fibers, especially on dark colors.

This paper is focused on research of print quality of the digital direct to garment printing based on the fabric hairiness and pretreatment level, which are the main obstacles for quality and sustainable printing.

Open End and Ring spun yarn types of the same count 30/1 Ne are chosen. They are knitted with the same knitting parameters (stitch length and gauge) and dyed on the same dying batch. Hairiness values coming from the yarn production and fabric dying process are respectively compared. Swatches with different opacity level (25%- 50%-75% and 100%) of CMYK are printed on all fabrics with and without White underbase. In addition the effect of 3 different amounts of pretreatment are added for evaluation. The research gives the comparison of values of L lightness value (for dark colored fabrics) and S saturation value on 10 different fabric types.

The result showed that wet pretreatment processing on fabric treated with enzyme gives the best results based on L values on ring spun fabrics on both enzyme treated and untreated fabrics. Important finding is that there is a need for pretreatment optimization of Open Endfabrics while ring fabrics gave the same result on 3 different pretreatment amounts. This conclusion is valid for dark fabrics only, while there was found no significant difference for white fabrics both on ring spun and open end.

The brushed fabric (which had the highest hairiness level) gave the poorest printing results (based on L and S values measurements) showing the negative effect of hairiness value to print quality.

Keywords: Digital printing on cotton, DTG, Hairiness of knitted fabrics, pretreatment.

Introduction

Natural fibers when compared to the synthetic ones, have an advantage on air permeability, hand feel, comfort and look. Especially when it comes to the clothes which are in direct contact with our skin the majority of the market still relies on cotton. With a trend going towards natural, cotton fabrics have remained popular with their potential of use and are even more widely used in today's printing industry. Fabrics from natural fibers have more hairy surfaces which adds to a better hand feel but on the same time negatively effects the printing performance on them both before and after wash. Hairiness is defined as sum of the fiber ends or loops standing out from the main yarn (or fabric) body.

DTG has been the favorable option for printing especially on one offs and short production runs of the e-commerce sites. Even bigger amount of online promotional market is using DTG as the printing method on cotton, the penetration of this production type for the brands is still very low due to some performance limitations. The request from the brands today is that the print should be strong in color, soft in touch, should have clean and smooth surface and should resist several wash cycles. The hairiness of the fabric is one of the main parameters for not achieving these quality demands. There have been attempts to bypass this obstacle but most of them are scarifying the main advantage coming from the DTG which is speed and sustainability.

There is a constant search on the possibility of using the DTG for printing on cotton garments with higher quality performance.

Materials and methods

For this research:
-Two different yarn types with
-Same knitting characteristics
-Dyed on the same batch
-3 different finishes are applied

Different levels of hairiness are achieved for better understanding of its effect to the final print. There are two main areas where that hairiness is coming from:
-yarn production method
-fabric dying

10 different fabrics (Table 2) were analyzed based on their hairiness and pretreatment level based on:
-5 ink colors (WCMYK)
-3 different levels of pretreatment
-4 opacity levels of CMYK (%25-%50-%75-%100)

Spinning

Ring Spun and Open End yarn types of the same count: 30/1 Ne are compared for their difference in hairiness. Open and yarns are less hairy and less costly for manufacturing but they don't have the comfort, softness and smoothness which is coming from the looser twist of the ring spinning method. Generally 2 main types of hairiness testers are being used in the industry, Uster which gives an average value of the hairiness per 1 cm and Zweigle tester which counts number of hairs of defined lengths giving the higher precision.

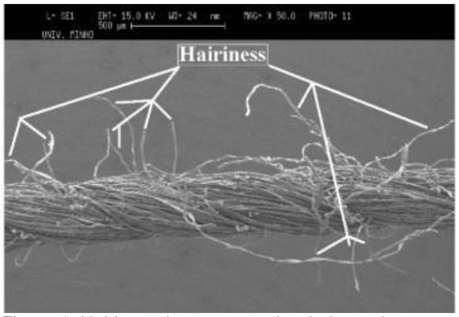


Figure 1. Hairiness (www.semanticscholar.org)

Our measurements were made with:
Zweigle G567
Length: 100 met
Speed: 50 m/min
Tension: 5 cN
%100 Cotton
Sample 1: 30/1 Ne OE Sample 2: 30/1 Ne Ring

Table 1. The yarn hairiness comparison between 30/1 Ne Ring spun versus 30/1 Ne Rotor spun yarn

30/1 Ne	**1 mm**	**2 mm**	**3 mm**	**4 mm**	**6 mm**	**8 mm**
Open end	8.667	1.286	350	131	20	3
Ring spun	15.192	2.607	663	243	34	5
Difference % :	175,29%	202,72%	189,43%	185,50%	170,00%	166,67%

Knitting

Garments used the most in the promotional market today are made of 30/1 open end yarn with weight of 150 g/m². The same yarn count and the fabric weight was used for our research. Fabrics are knitted with 2 different yarn types. The yarn count and the stitch length are kept as the standard for controlled comparison. Both yarns are knitted on the same 28 gauge knitting machine with the stitch length of 25 cm/100 needles.

Dying-Finishing

The hairiness level of the fabric is not only related to the yarn production method. Dying process also plays a big role in final result of hairiness.

To reduce the hairiness enzyme treatment is a potential solution but this requires adding another step in the production process which adds costs of chemicals energy, requires extra water usage for washing off of the free fibers and increases the waste water thus, the environment pollution and the overall cost. Dying process can be made with several types of dying machines and methods, some more aggressive than the others to the fabric surface. Over flow Jet dying machines are even more aggressive to the fabric surface have the best reproducibility, shade control and softness characteristics and this is the reason that they are used the most for fabric dying.

For our testing Black and White fabrics are dyed on overflow machines for analyzing of printing with both white and colored printing inks.

Finishing

Three types of finishing are applied to both white and black fabrics:

a) Softening
b) Softening and enzymatic treatment to reduce the hairiness value
c) Softening and brushing effect to increase the hairiness value.

Fabric testing and evaluation of hairiness is done with:
Pilling Resistance Adidas Method 4.07: 2006
Evaluation for Knitted Fabrics
EMPA Standards SN198525: Reference K2
The pilling will be rated on a scale 1-5. The photographic rating is a half grade rating therefore:
No pilling - Grade 5
Standard photo reads 4-5 - will be rated 4
Standard photo reads 3-4 - will be rated 3
Standard photo reads 2-3 - will be rated 2
Standard photo reads 1-2 - will be rated 1

Table 2. Hairiness value of 10 different fabrics

					Hairiness Value
BLACK	101	Black	Ring spun	Enzyme	4
	102	Black	Ring spun	No enzyme	3/4
	103	Black	Ring spun	Brushed	3
	104	Black	Open end	Enzyme	4
	105	Black	Open end	No enzyme	3/4

WHITE	201	White	Ring spun	Enzyme	4/5
	202	White	Ring spun	No enzyme	3/4
	203	White	Ring spun	Brushed	3
	204	White	Open end	Enzyme	4
	205	White	Open end	No enzyme	3/4

Wet Pretreatment

Three different alternatives are used for analyzing of the pretreatment effect:
For Black fabrics:

i) Printing with 10 % pretreatment

ii) Printing with 30 % pretreatment
iii) Printing with 60% pretreatment
For white fabrics:
i) Printing without pretreatment
ii) Printing with 10% pretreatment
iii) Printing with 30% pretreatment

Print

Photo 2. Print design consist of different patches of WCMYK inks on different percentages (percent 25% 50% 75% and 100%) The details of the different percentages of CMYK with and without pretreatments are given at Photo 3.

Printing is done on Kornit Storm DTG machine with the parameters given bellow:

Print head frequency: High
Direction: Bidirectional
Color printing mode: Interface
Color saturation: Normal
Sharpen: No
White print mode: Single
Bias (V):
CMYK: 99, 98
White: 114, 90
Pulse width (microsec): 8
545x540 resolution

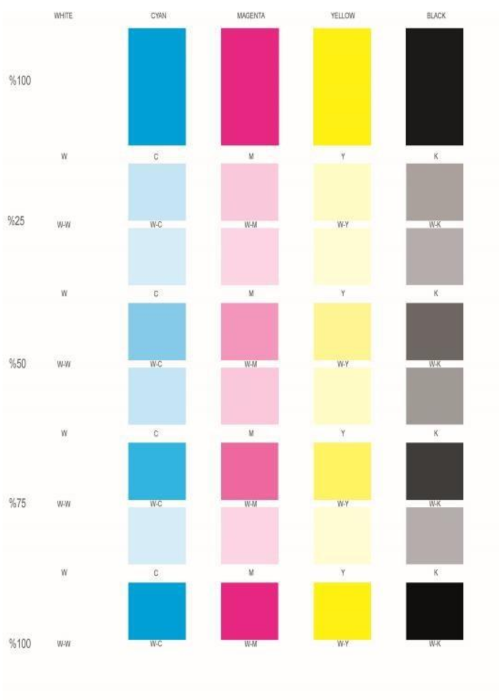


Figure 2. For each color (WCMYK) patches of 25%-50%-75% and 100% are printed with and without underbase on white and black fabrics.

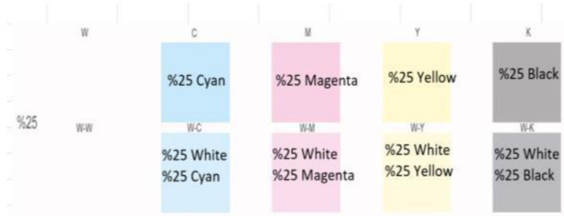


Figure 3. The details of %25 of CMYK with and without white underbase.

Evaluation

L* and S values are measured with Spectrophotometer Data color SF 800 for:
-10 different fabrics
-4 different opacity levels
-3 different pretreatment percentages Sample of chart is given at the Table 3.

Table 3. Lightness and Saturation Values for CYAN of black and white fabrics pretreated in 3 methods

COLOUR	CYAN	Lightness				Saturation			
Fabric Types	pretreatment %	25%	50%	75%	100%	25%	50%	75%	100%
101	10%	46,6	54,1	52,3	50,9	21,7	31,3	45,9	66,4
	30%	53,2	61,8	62,3	57,3	20,5	34,2	52	73,3
	60%	48,6	58,3	57,7	53,3	21,7	31,3	50	71,9
102	10%	45	54,2	55,9	52,9	21,4	33,4	52,5	83,3
	30%	53,1	63	61,9	56,9	20,4	32,8	51,4	71
	60%	48,1	56,7	54,7	53	22,1	32,2	49,2	77,5
103	10%	39	40,9	38,6	36,1	20,6	30,3	38,8	46,3
	30%	45,7	54,5	56,7	52,9	21,6	31	49,5	72,9
	60%	42,6	45,3	43,5	41,4	22,8	30,1	38,8	51,5
104	10%	8,5	13,7	15,7	40	21,1	32,6	41,3	50,6
	30%	51,3	61,3	60,1	56,5	21,5	33,5	55,5	82,6
	60%	44,2	48,7	47,5	46	23	33	45,6	60,4
105	10%	41,1	45,2	18,3	42	22	34	45,1	56,7
	30%	51,5	61,9	60,1	56,6	22,2	34,3	56,5	80,2
	60%	45,8	49,3	47,4	45,6	24,1	33,4	46,7	59,3
201	0%	78,3	70,5	64,4	60,2	20,6	43,8	66,2	76,6
	10%	79,3	70,7	64,2	58	19,4	42,2	63,2	86,6
	30%	80	72,2	64,5	58,7	17,8	38,3	61,3	81,3
202	0%	76,9	68,3	61,2	60,1	21,1	46,4	68,5	80,5
	10%	77,6	70,3	63,7	58,7	19,1	41	63,4	83,7
	30%	75,2	67,1	61,7	55,8	17,3	38,8	62,3	83
203	0%	77,8	68,9	62,3	58,2	20,6	48,6	77,6	100
	10%	78,1	70,7	63,9	56	18,9	41,6	67,1	96,9
	30%	78,8	71,4	63,1	57,3	17,3	39,1	61,9	93,1
204	0%	77,4	70	62,8	59,5	21,3	47,4	74,7	83,5
	10%	79	71,3	62,4	56,9	19,3	44,2	65	97,5
	30%	77,3	69,4	693,3	56,4	17,7	39,7	65	92,8
205	0%	77,5	68,9	62,4	58,2	21,8	47,6	72,9	82,4
	10%	78,3	69,1	62,8	57,2	19,3	43	47,8	97
	30%	78,3	70,4	63,3	56,6	18	40,7	65,3	99,8

Conclusions

Under same printing conditions given below:
Print head frequency: High
Direction: Bidirectional
Color printing mode: Interface
Color saturation: Normal
Sharpen: No
White print mode: Single
Bias (V):
CMYK: 99, 98
White: 114, 90
Pulse width (microsec): 8
545x540 resolution

1) Black Fabrics, each colors (WCMYK) were examined for 3 pretreats and 4 opacity levels. Best printing results based on the L and S values are achieved with ring spun fabrics. (Sample Graph1)
2) Black Open End fabric: results showed variation on their print quality depending on the amount of the pretreatment. Best results were achieved with %30 pretreatment when compared with %10 and %60.

Ring spun fabrics gave similar results for different pretreatment levels.

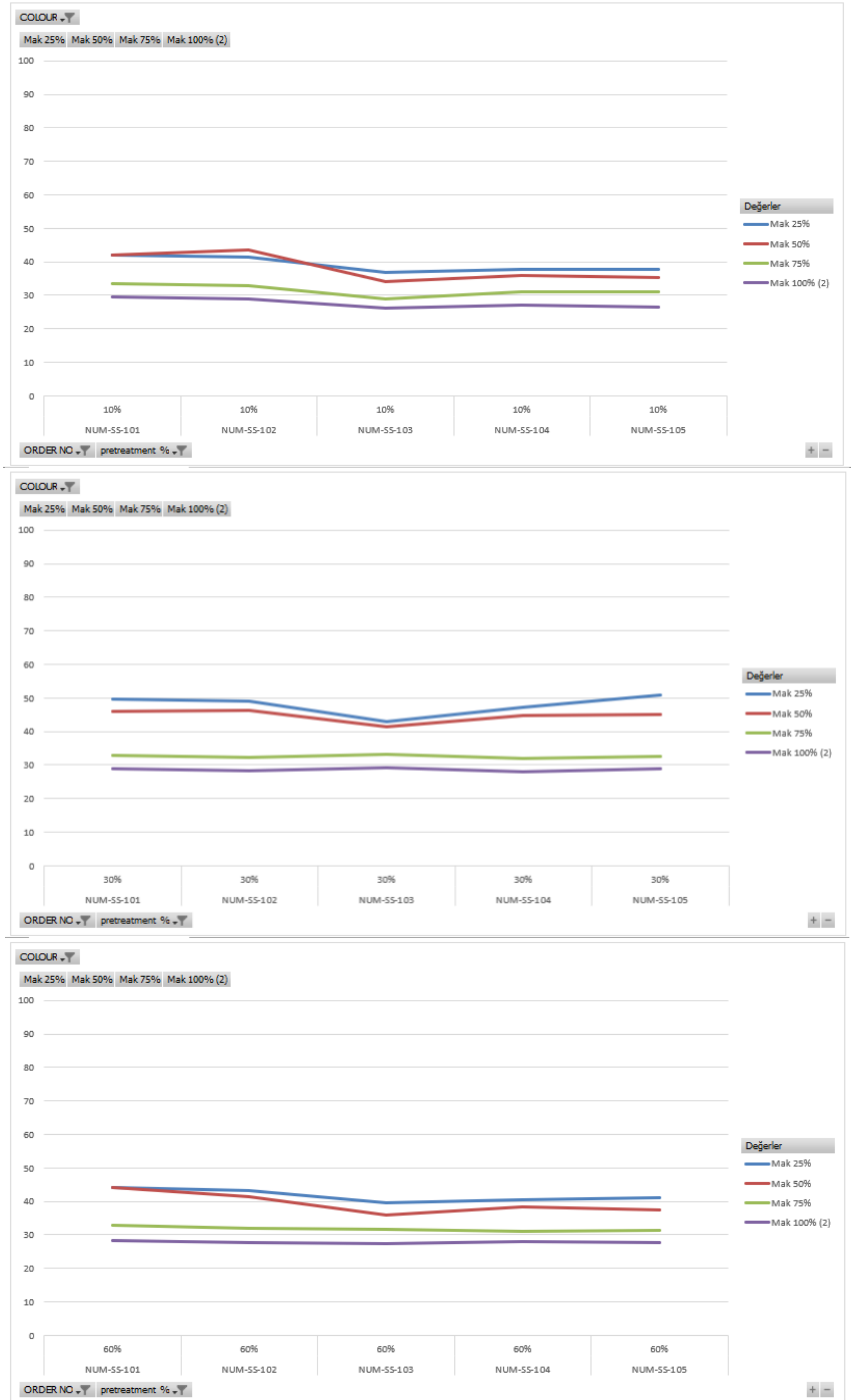
As a result, for Open End fabrics, extra effort for optimization of pretreatment amount is required.

Lower the amount of the applied pretreatment brings more sustainability to the process requiring less energy for drying of the garments. (Graph2)

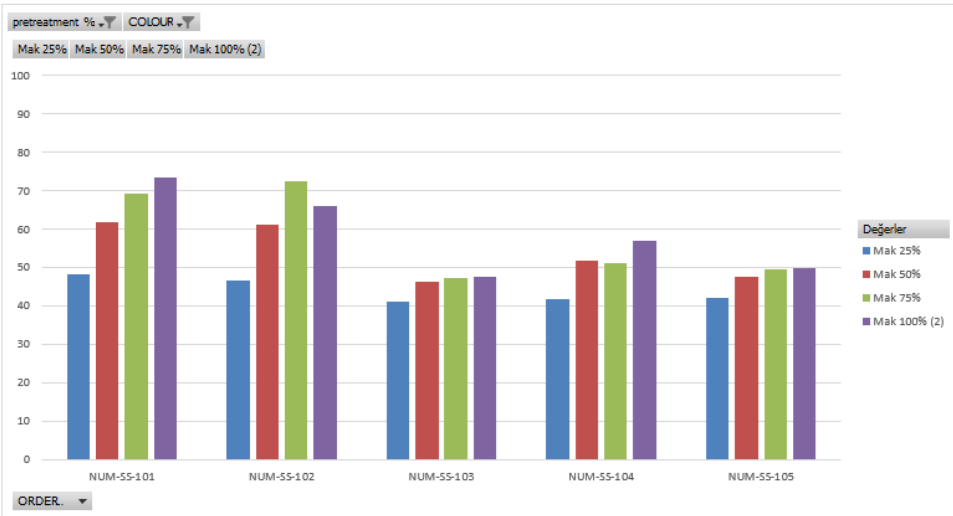
3) Brushed fabrics showed the poorest results confirming the negative effect of the fabric hairiness on print quality. (Sample Graph3)
4) White Fabrics, saturation values were analyzed for each color (WCMYK) ,3 pretreats and 4 opacity levels.

The findings are that there is no difference on values between different fabrics/colors/pretreatment values for white fabric. (Sample Graph4)

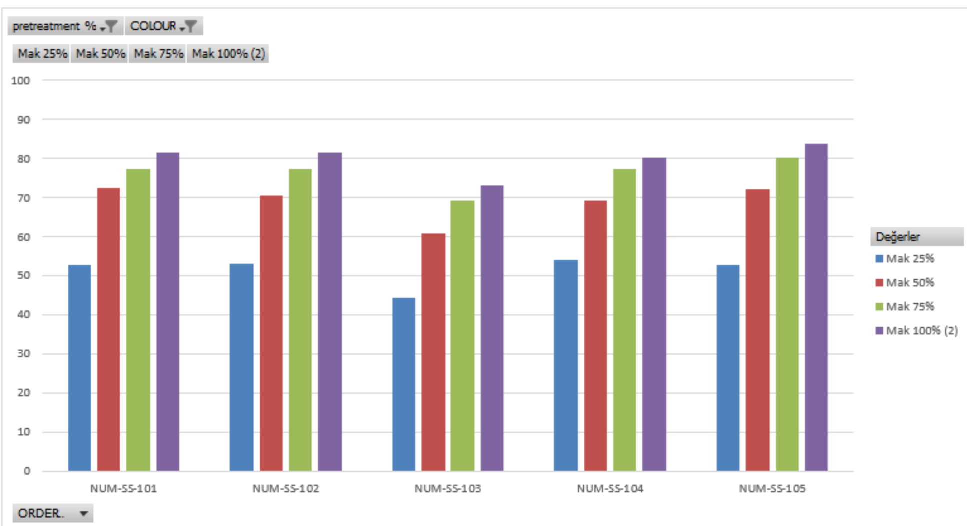
GRAPH 1. Lightness values for black fabrics (graphics were also made for cyan, magenta, yellow and white)



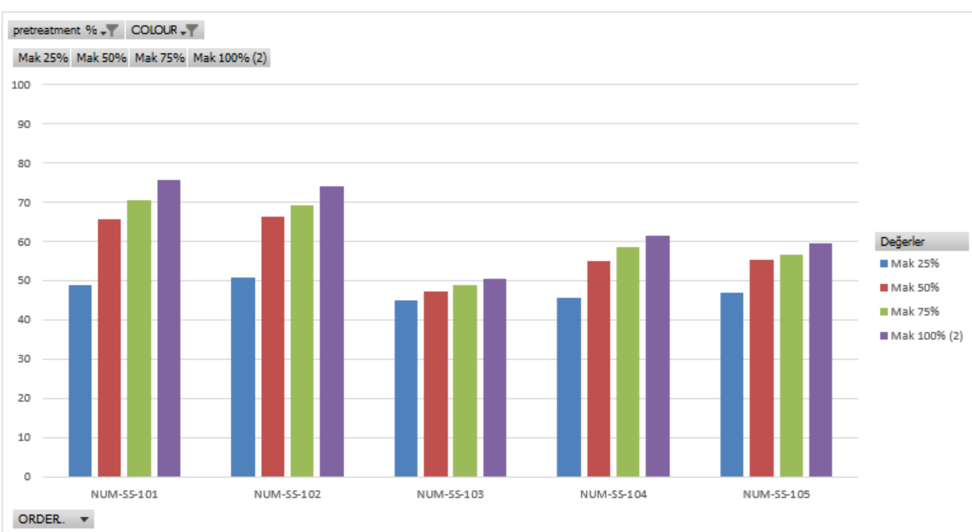
GRAPH 2. Lightness and Saturation Comparison – White Ink – Black Fabric



%10 pretreat

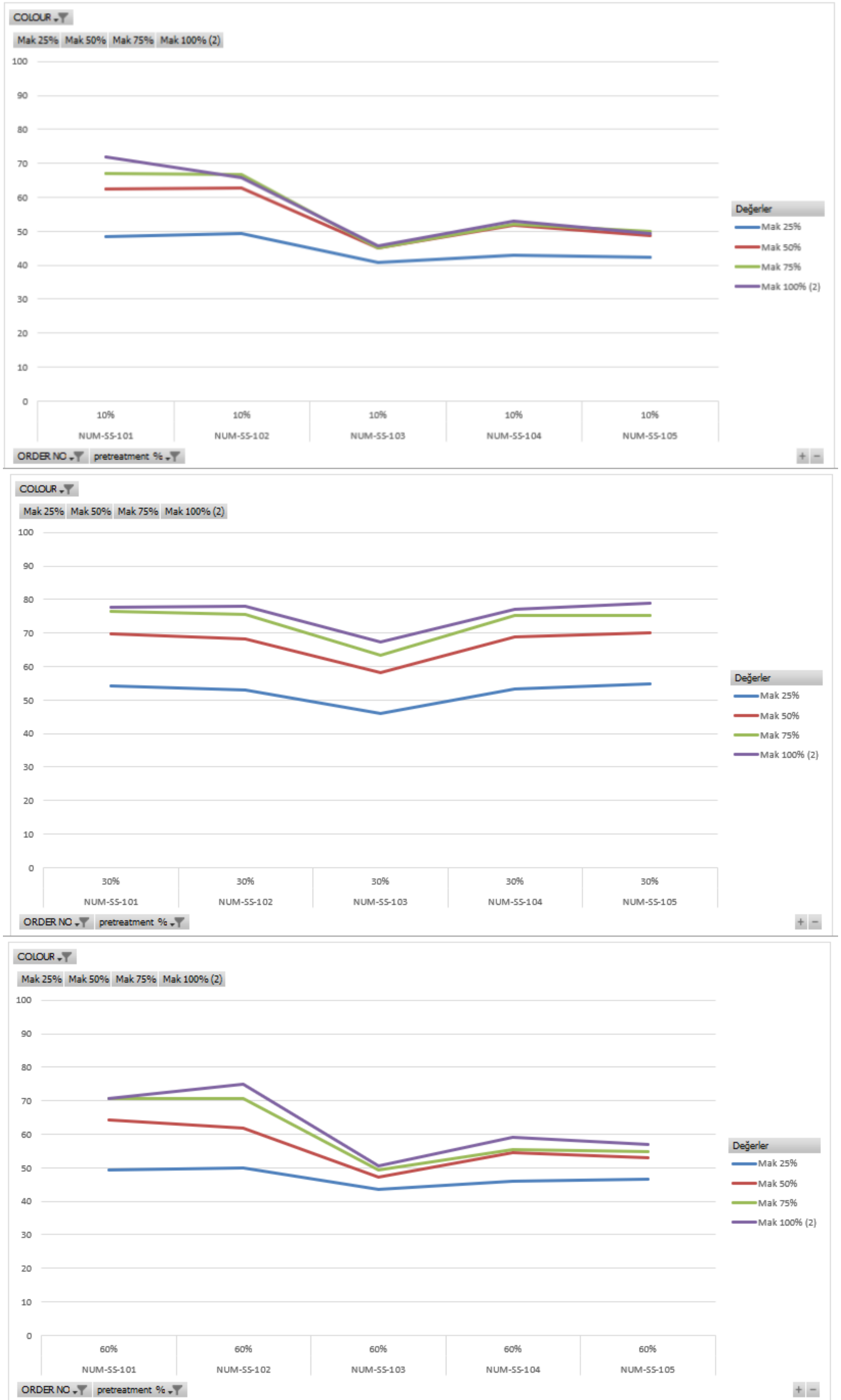


%30 pretreat

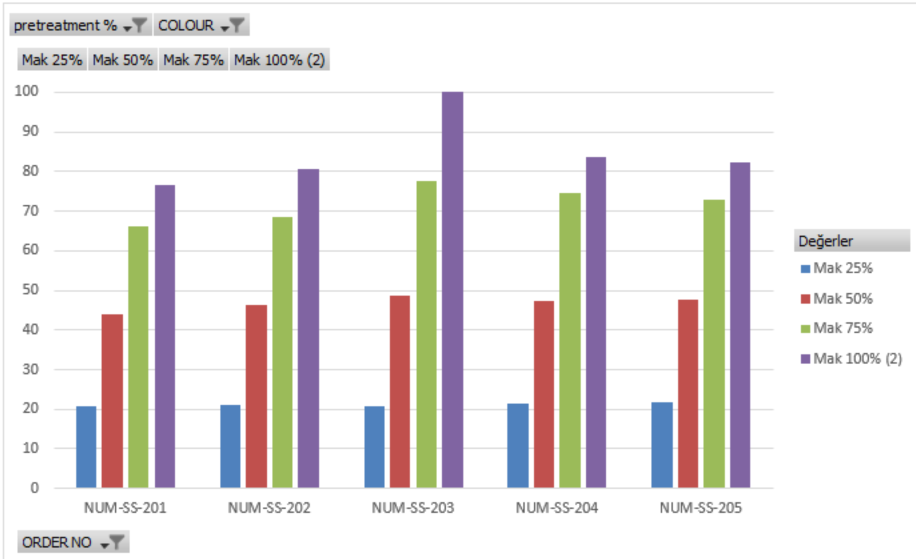


%60 pretreat

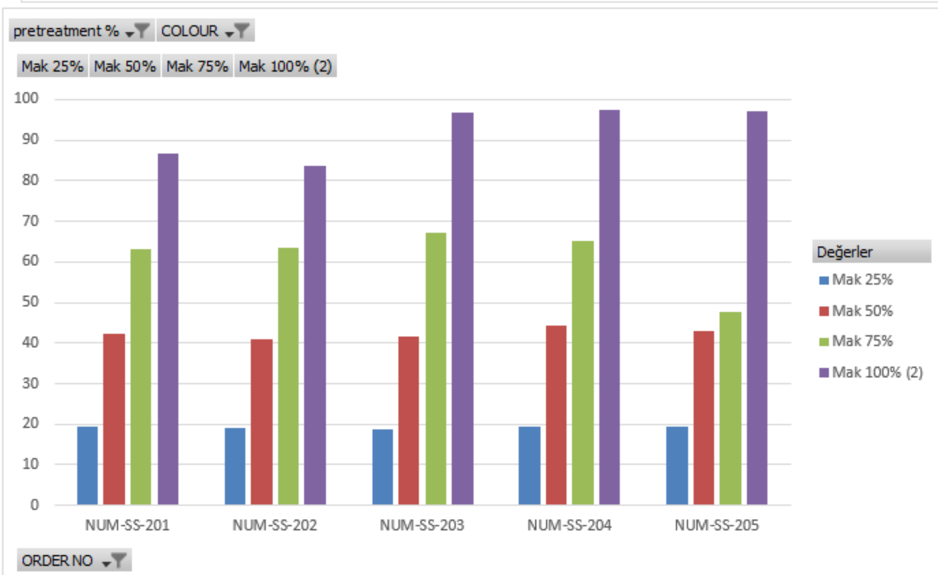
Graph 3. Lightness Value on Black fabric - Color Yellow. Brushed fabric shows the poorest result.



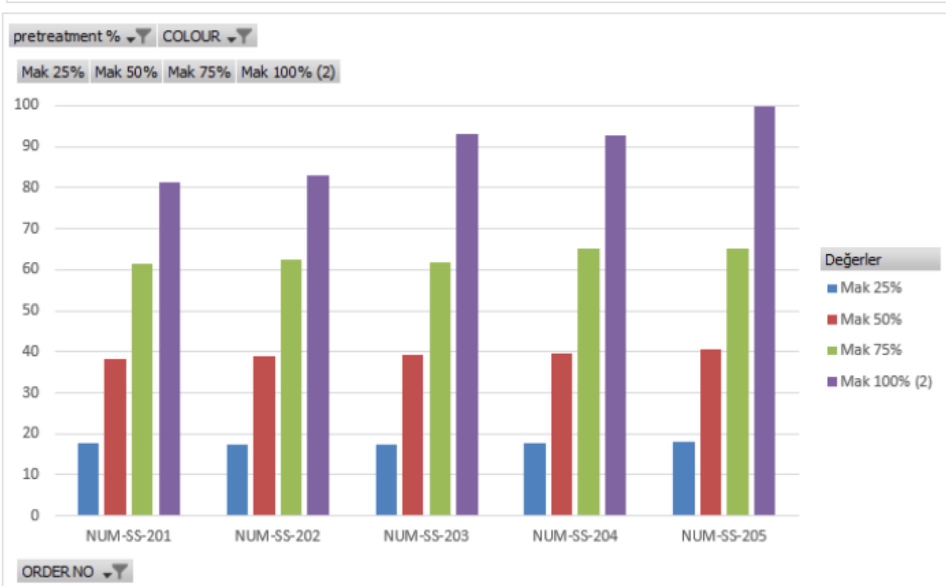
Graph 4. Cyan's Percentage Saturation Changes in Different Pretreatments and in Different White Fabrics(graphics were also made for magenta, yellow and white) – The result show no significant difference



%0 pretreat



%10 pretreat



%30 pretreat

Author Biography

After graduating from Istanbul Technical University - Electrical and Electronics Eng. BSc and MSc, Samir Sadikoglu has started his career in a new born family company with a dedicated passion for a graphic T-Shirt manufacturing. European T-shirt Factory does just as the name states is a vertically integrated garment manufacturing company focused on the manufacturing of graphic T-shirts. They operate a world class screen printing department and have been producing graphics for more than 20 years. The company has become an indispensable T-shirt producer for a number of famous brands around the world. Samir has been inducted into Academy of Screen and Digital Printing Technologies in 2012. ASPDT is a body which recognizes individuals who have contributed to the technical growth and/or advancement of the screen printing industry. In 2013 he was chosen for the FESPA's biggest award "Hall of Fame".

He is also frequent speaker at industry events and trade show expositions both domestically and international; conducts regular workshops and holds onsite and hands on training for customers; chairman of EMSIAD (Istanbul Screen Printing Association) 2016-2018 -Board Member of EMSIAD (Istanbul Screen Printing Association) since 2004; Technical Consultant of ITKIB (Istanbul Textile and apparel exporters association) since 2001; Technical Specialist/ Consultant for Textile Screen Printing of ISO (Istanbul chamber of industry); board member of the steering committee of FESPA EurAsia; active as a part time lecturer at ITÜ (Istanbul Technical University) Textile and Textile Technologies Faculty; and a member of Advisory Board of ITÜ (Textile and Textile Technologies Faculty).