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Study on the comparison of naturally coloured cotton and traditional off white fibre in manner of process in the apparel industry

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ABSTRACT:Naturally colored cotton increased its popularity again when textile industry absorbed on ecology and sustainability concerns. One of the greatest significant properties of naturally colored cotton is the avoiding of dyeing process and skipping some pre-treatment steps in the dye house. So limited chemical treatments will result less usage of water, less waste water, less consumption of chemicals, shorter treatment times, less usage of energy and will add great to the protection of environment besides cost beneficial.In this study an assessment of a natural brown colored cotton knitted fabric with a white one was made in manner of procedure steps and cost by the data and methods of a dye house. Calculations were made by taking the treatment steps of the fabrics in the production into account. Naturally colored cotton was assessed by washing and softening steps. The white cotton fabric dyed with the same color of naturally colored cotton in the laboratory and was evaluated by bleaching, dyeing, washing and softening steps. Assessment and comparisons were made by taking energy, water, labor, electricity, chemical, auxiliary agent and dyestuff costs into account. As the result all the flowcharts in the dye house were appraised. It was found that treating the naturally colored cotton fabric is 2 to 5 times less expensive than treating white cotton fabric in thedye house.

KEYWORDS: Waste water**,** Naturally colored cotton, environment protection, ecological textile production, reactive dyeing

I. INTRODUCTION

Cotton is used by almost everyone in the world every day. It is the most important natural fiber. It supports 250 million people's livelihoods. It is one of the world's leading fiber crops grown in more than 80 countries. It's a renewable natural resource, but it should be managed responsibly. When the data about the period of 8 years between 2007- 2014 was examined, it is seen that cotton is cultivated in the area of 33,5 million hectare averagely. According to the 2014 Cotton Report, 26 million tons of cotton was produced in the season of 2013/2014 in the world. The estimations about the next seasons are similar around 25 tons.Cotton fibre's color history is very old and interesting because the priorities of textile industry have been changeable during eras depending upon the trends. The age of the naturally colored cotton is about 4500 years. Firstly, they were used by the Incas, Aztecs, and by some other old civilizations of America, Asia, Africa, and Australia. Although production of this type of cotton fiber is very old, later then textile industry preferred white cotton in order to get every color. It is very easy to say that yields and fiber quality of naturally colored cotton varieties are not good when compared with the white cotton ones, mostly because the traditional white cotton has been improved and studied for centuries, while studies about naturally colored fibers are recent. In the past, even in some countries cotton plants with colored fiber were considered as contaminants because they could cross and bring some color to white varieties. Naturally colored cotton has attracted the attention of textile industry in latest years again because there is a social trend of eco-friendly living and well-being. Now the researchers and industrialists focus on the advantages and disadvantages naturally colored cotton.

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The work that started the interest again to the colored cotton was made by Sally Fox in the United States in 1988. Sally Fox succeeded to develop naturally colored cotton fibers tolerant to machine processing. Until that time naturally colored cotton was known as the one that had inferior characteristics to white cotton. After that development, some other countries such as Israel, Brazil, Greece and Turkey also worked with genetic modifications in order to develop new colored fibers with good quality. Recently about 30 countries conduct research on naturally colored cotton and trying to add new colors to the commercially available two basic colors, green and brown (there are some mocha and red tones, too). A few of these colors which are in the step of development are gray, black, mahogany, purple, orange, red, pink, blue, green, grey and cream. These naturally colored cotton types can be commercially available after genetic development.

The main reason of increasing interest to the naturally colored cotton wasn't the nostalgia. After the success of Sally Fox by the development of a fiber quality suitable to be processed in textile plants, naturally colored cotton The work that started the interest again to the colored cotton was made by Sally Fox in the United States in 1988. Sally Fox succeeded to develop naturally colored cotton fibers tolerant to machine processing. Until that time naturally colored cotton was known as the one that had inferior characteristics to white cotton. After that development, some other countries such as Israel, Brazil, Peru, and Turkey also worked with genetic modifications in order to develop new colored fibers with good quality. Recently about 30 countries conduct research on naturally colored cotton and trying to add new colors to the commercially available two basic colors, green and brown (there are some mocha and red tones, too). A few of these colors which are in the step of development are gray, black, mahogany, purple, orange, red, pink, blue, green, grey and cream. These naturally colored cotton types can be commercially available after genetic development. The main reason of increasing interest to the naturally colored cotton wasn't the nostalgia. After the success of Sally Fox by the development of a fiber quality suitable to be processed in textile plants, naturally colored cotton attracted the attention of scientists, technologists and industrialists for their ecological and economic advantages. Meantime Sally Fox established a firm, obtained a certificate of plant variety protection for her cotton and a registered trademark for the naturally green and brown cotton fibers. After then the needs for ecology and sustainability have led the naturally colored cotton begin a new journey in textile world. In today's textile world, everybody knows that there are many environmental concerns on the production of cotton beginning from the cultivation, until turning into a textile product. By the development of naturally colored cotton, the hopes of fulfilling the environmental needs for cotton fiber increased. The naturally colored cotton created new alternatives in the textile industry to obtain the healthy and using friendly clothing, furnishing and household products. Naturally colored cotton and ordinary white cotton may be compared in many points. The differences between them aren't sourced only from being colorful or colorless. Their chemical compositions, structures and some other properties are very similar. But there are some important differences between them.As everyone knows that the most significant difference between two types of cotton is color which is controlled by a dominant gene (the genetic factor). The environmental factors affect mainly the intensity of the color.

The pigments in colored cotton have not yet been clearly defined. There are some studies with the aim of determining the composition and characteristics of the natural pigment in the colored cotton. It was defined that the brown color of colored cotton lints was obtained from tannin vacuoles in the lumen of the fiber cells and the color of green colored cotton was mainly from caffeic acid that was a derivative of cinammic acid and found in the suberin layer. The pigment amount is greater for brown cotton than for green cotton. This is one of the reasons to choose brown cotton fabrics in this study. When the other differences were examined and checked, it can be easily concluded that there are some important advantages and disadvantages of naturally colored cotton compared with the white cotton.

II. THE ADVANTAGES OF NATURALLY COLOREDCOTTON

Because naturally colored cotton's properties have been improved for better yield and qualities of strength, length, and micronaire to be competitive against conventional white cotton, cultivation of naturally colored cotton as a commercial crop is increasing due to its reduced environmental impact. After the usage of naturally colored cotton fibers in the production of yarns, it was possible to use these yarns for woven and knitted fabrics as well as nonwovens. Naturally colored cotton can be grown by using organic farming methods because one of the inherent properties of it is the high resistance to insects and diseases. The avoiding of some chemical treatment

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stages is also a great advantage for ecological and/or organic textile production. Because of its natural colors, this type of cotton does not have to be dyed or bleached. By this way it is also beneficial for the human health, clothes made of naturally colored organic cotton have been found effective in preventing skin diseases, such as atopic dermatitis. Some researchers define that such kind of clothes protects the skin from ultraviolet radiation. There are some other interesting characteristics of naturally colored cotton besides UV protection. Anti-Flammability and anti-mildew properties are some of them which depend or partially depend on their intrinsic biological pigments. It also has insect and disease resistant quality which accordingly requires less need for pesticides. A very dramatic difference between traditional dyed white cottons and naturally colored cotton is the deepening natural color after washing. Naturally colored cottons do not fade in laundering as is typical of most conventionally dyed cottons. After laundering, the color becomes stronger and more intense. During laundering the molecules will reorient to become smoother, causing the color to appear brighter and more intense.

Naturally colored cottons have a soft hand or "feel." This feature combined with their unique non-fading and environmentally friendly properties, has helped to assure their niche market. In addition to the unique characteristics given above, environmental factors that make naturally colored cottons advantageous should be described. The presence of natural pigments eliminates the need for dyeing textile products, thus saving not only a large amount of energy but also preventing many chemicals from polluting the environment and causing health problems. Dyeing may be considered as one of the costliest steps in fabric finishing so the elimination of chemical dyeing from textile manufacturing could make the textile product cheaper. In addition to the dyeing process some process steps such as bleaching and softening could be avoided. Only an effective prewashing step is enough in most cases. And because naturally colored cotton has an inherent softness, sometimes finishing with softeners is not needed. As the result of skipping these steps, a remarkable amount of water, energy and chemical redeemable is obtained. The combination of these natural characteristics– certain biological defense mechanisms and pigmentation – in naturally colored cottons isattractivefromanenvironmentalperspective.

III. THE DISADVANTAGES OF NATURALLY COLOREDCOTTON

In the past cotton plants with colored fiber were considered a contaminant in several countries because they could cross and bring some color to white varieties. This thought is changing today because of the rise of naturally colored cotton's advantages. As the traditional white cotton has been improved and studied for centuries and yields and fiber quality ((strength, length, micronaire, etc.) of naturally colored cotton varieties are not as good as the white cotton ones, production of naturally colored cotton remained insufficient but studies about colored fibers have been increasing. Although the demand for colored cotton is increasing day by day, its cultivation is not increasing accordingly because farmers do not like it for some aspects such as low lint yield, negative fiber properties. As the result of low cultivation, the amount of commercially available naturally colored cotton with sufficient quality is very limited on the market. There is also still limited range of colors, although about ten cotton varieties with different colors have been reported breeding successfully worldwide, on commercial scale brown and green shades are mostly used. Shades may also change depending on seasonal and geographical factors. Some additional disadvantages, such as the absence of resistance to wilt diseases, lower moisture absorbency also limit the production of naturally colored cotton. As a result, naturally colored cottons have not yet been commercialized on a large scale due to some limitations, such as low productivity, poor fiber characteristics, non- uniformity of colors, and so on. In this study, a comparison of brown naturally colored cotton knitted fabric with a white one was aimed to make by taking the process steps and cost of these steps into account by the evaluation methods of a dye house, older than 10 years. Naturally colored cotton and the white cotton whose color was matched with the color of the naturally colored cotton were assumed to be treated in the dye house and the treatment sets were compared to interpret theadvantages.

IV. MATERIALS ANDMETHODS

Materials

Naturally colored cotton fabric and white fabrics are 100 % cotton Ne 30/1 Interlock fabrics, 210 gr/m^2. Naturally colored cotton fabric is Brown and white fabric was obtained from both of the fabrics are in the raw (grey fabric) form. Levafix Amber CA-N, Levafix Blue CA, Levafix Fast Red CA trichromatic reactive dyestuffs of Levafix CA (Dystar) were used. These dyestuffs are bi-functional, containing functional groups of vinyl sulphone andmonofluortriazine. Auxiliary agents

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from various firms and chemicals of technical grade were used.

Methods

Color MeasurementProcess

Color matching works was made in the laboratory by taking the naturally dyed cotton fabric as original sample. White cotton was dyed with the same color of the original sample in laboratory type sample dyeing machine Termal Polimat- 612N-HT, with the recipebelow:

0,55 % Levafix Amber CAN + 0,27 % Levafix Fast Red CA + 0,11 % Levafix Blue CA Color measurements were made by the X-rite Ci 7800 spectrophotometer. Illuminants were D65, TL83 and A-10. Pass-Fail results were calculated according to Δ E cmc formula.

In laboratory conditions a simple pretreatment was applied to the naturally colored cotton. The white cotton fabric was bleached and reactive dyed in brown color matching with the color of the naturally colored cotton in laboratory sample machine Flowcharts in theDye house

The treatments in the laboratories were adapted to the dye house conditions in order to compare two types of cotton fabric in manner of processes and process costs in the dye house. By this adaptations process steps were planned. The flowchart of the assumed process steps in whole production is:

Batching the fabric in the grey house Opening the weighed fabric Treatment in the dye house Cutting the tubular fabric Drying in the stenter Sanforizing Packaging.

In every step one worker is needed, except then the drying step, two workers work in this step. The flowchart of the chemical treatments in the dye house differs according to the type of fabrics. For the chemical treatments a HT-jet machine of 150 kg. was taken into account. The flowchart of the assumed chemical treatments in the dye house for naturally colored cotton is: Oil removing Washing Softening.

The flowchart of the assumed chemical treatments in the dye house for white cotton is:

Hydrogen Peroxide bleaching 1st Rinsing 2nd Rinsing Reactive Dyeing Cold Rinsing Neutralization Washing at 70°C Washing at 95°C Soaping at 95°C Washing at 40°C Softening

Chemical Treatment Process of the Naturally Dyed CottonFabric

Chemical treatments of naturally dyed cotton fabric were assumed to be at HT-Jet Dyeing Machine (150 kg) successively as 3 baths with the recipes below:

1st bath: oil removing agent (2,00 ml/L) + sodium Carbonate (0,5 g/L).
2nd bath: no chemicals
3rd bath: acid buffer (0,5 g/L) + nonionic softener (2,7 %)

Total time was 1 hour and 46 minutes and calculated automatically by the system, including waiting times.

Chemical Treatment Process of the White CottonFabric

Chemical treatments described above and isothermal reactive dyeing at 60° C, were assumed to be at HT-Jet Dyeing Machine (150 kg) successively as 10 baths with the recipes below:

1st bath: combined scouring auxiliary agent (0,5 ml/L) + crease inhibitor (1ml/L) + caustic soda 49° Be (2,0 ml/L) + hydrogen peroxide 50 % (2,0 ml/L),
2nd bath: no chemicals
3rd bath: acetic acid %80 (0,5 ml/L) + peroxide killing enzyme (0,2ml/L)
4th bath: sequestering agent (0,325 ml/L) + sodium sulphate (35 gr/L) + 0, 55 % Levafix Amber CAN + 0,27 % Levafix Fast Red CA + 0,11 % Levafix Blue CA + sodium bicarbonate (10 gr/L)
5th bath: acetic acid (1 ml/L) 6th bath: nochemicals
7th bath: nochemicals
8th bath: washing soap used in reactive dyeing (0,5 gr/L) 9th bath: nochemicals
10th bath: acid buffer (1,2 gr/L) + weak cationic softener (1,8 %)

Total time was 7 hours and 22 minutes and calculated automatically by the system, including waiting times.

V. RESULTS ANDDISCUSSION

ColorMeasurements

L*, a*, b* values of the naturally dyed cotton sample, reactive dyed cotton sample and the pass-fail results,

Naturally colored cotton fabric was taken as original. Dyed white cotton fabric's color was measured against the original. According to the pass-fail results, Δ E under the day-light was 0, 37. The color of the white cotton matched well with the naturally coloredcotton Constants and Variables of ProcessSteps. In order to calculate the costs of process steps, some constants and variables were used and some considerations were made. Energy, water, labor and electricity costs were calculated for every step of the dyehouse treatments according to the real data and methods of an active, long living and successful dyehouse.

Formulas used in the calculations:

- Q = m .c.(t2-t1) (to calculate energy used forheating)

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- Volume of the roller = л r² h (to calculate energy used for waitingtimes)
- Circumference of the roller = л 2r (to calculate energy used for waitingtimes)

The constants and variables that are used in the calculations:

- C = 4,18 J/g°C
- 1 calory = 4,184J
- 1m ³ natural gas = 8250kcal
- 1 sm³ (standard m³ natural gas) = 1 m³ *1,98
- 1 sm³ natural gas = 0,83TL
- 1 tone water (including water treatment) = 2,4TL
- The temperature of the water coming to the dye machine was taken as 30°C.
- Energy consumed in 60 minutes for heat permeability of 5 mm Cr/Ni surface in the area of 1 m² in 60 minutes = 40kcal. The machine used in this work was taken as a machine of 150 kg and the total surface was calculated as 6m².
- The calculations were made over 100 kg fabric and the unit cost wascalculated.
- The fabric was assumed as open-width, values of width and weight were considered as width = 150 cm and weight = 210 g/m². Linear meter of the fabric was calculated as 315 g/m. 100 kg fabric was 317m.
- The total power of the machine of 150 kg was 15,5 kw/h and it used 70% of the totalpower.
- Electricity price was taken as 0,172TL/kw.
- Liquor ratio=1:10.

To calculate the process costs by the methods and data of the dye house water consumption values (in liters), process temperatures (° C) and process times (in minutes) should be given. Energy used for heating and waiting steps of the machine should also be calculated by using the formulas and data. These results are given for naturally colored cotton in Table 1, for white cotton in Table 2. Besides these variables, unit prices of chemicals, auxiliary agents and dyestuffs used in the recipes are also needed. They are given in Table 3

Table 1. Data of the chemical treatments and the energy consumption of naturally colored cotton fabric

Bath	Treatment Step	Water Consumption (L)	Process Temp (°C)	Process time (minutes)	Energy Used For Heating (kcal)	Energy Used for waiting Steps(kcal)
1.	Oil Removing	1000	95	20	55000	180
2.	Washing	1000	40	5	10000	50
3.	Softening	1000	40	20	10000	200
	TOTAL	3000			85000	450
	GENERAL TOTAL				85450 kcal	

Table 2. Data of the chemical treatments and the energy consumption for dyeing of the white cotton fabric

Bath	**Treatment Step**	**Water Consumption (L)**	**Process Temperature (°C)**	**Process time (minutes)**	**Energy Used For Heating (kcal)**	**Energy Used For Waiting Steps (kcal)**
1.	H2o2 bleaching	1000	95	30	65000	300
2.	1st Rinsing	1000	40	5	10000	50
3.	2nd Rinsing	1000	40	10	10000	100
4.	Reactive Dyeing	1000	60	150	30000	1500
5.	Cold Rinsing-Neutralization	1000	Room temperature	10	0	0
6.	Washing at 70 C	1000	70	10	40000	100

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7.	Washing at 95 C	1000	95	10	65000	100
8.	Soaping at 95 C	1000	95	20	65000	200
9.	Washing at 40 C	1000	40	5	10000	50
10.	Softening	1000	40	20	10000	200
	TOTAL	10 000			305000	2600
	GENERAL TOTAL				307600 kcal	

Table 3. Unit prices for dyestuffs, auxiliary agents and chemicals used in the recipes

Name	**Price**	**Name**	**Price**
Combined scouring auxiliary agent	2,3 EU/kg	Caustic soda 49° Be	0,215 USD/kg
Crease inhibitor	0,25 EU/kg	Hydrogen Peroxide 50 %	0,5 EU/kg
Sequestering agent	0,65 EU/kg	Acetic Acid %80	0,34 USD/kg
Washing soap used in reactive dyeing	0,6 EU/kg	Sodium Sulphate	0,365 TL/kg
Oil removing agent	1,7 EU/kg	Sodium Bicarbonate	0,98 TL/kg
Acid buffer	0,95 EU/kg	Sodium Carbonate	0,775 TL/kg
Peroxide killing enzyme	0,7 EU/kg	Levafix Amber CAN	22 USD/kg
Weak cationic softener	0,56 EU/kg	Levafix Blue CA	30,2 USD/kg
Nonionic softener	0,35 EU/kg	Levafix Fast Red CA	23,5 USD/kg

Calculations of Process StepCosts

Costs of process steps other than the treatments in the dye house was calculated as Euro per 1 kg fabric. Batching the fabric in the grey house and Opening the weighed fabric are made in the grey house and calculated together as batchpreparation. Batch preparation, cutting the tubular fabric, drying in the stenter, sanforizing and packaging were calculated by taking into account of all the variables in the dye house such as energy, electricity, maintenance, labor etc. The results are below:

Batch preparation. 0,010EU/KG
Cutting thetubularfabric. 0,021 EU/KG
Drying inthestenter 0,055EU/KG
Sanforizing. 0,027EU/KG
Packaging. 0,035EU/KG

Total Cost of Processes for Naturally Colored Cotton Fabric:

Batchpreparation 0,010EU/KG
Treatments inthedye machine 0,17EU/KG
Cutting thetubularfabric 0,021EU/KG
Drying inthestenter 0,055EU/KG
Sanforizing 0,027EU/KG
Packaging 0,035EU/KG
TOTAL 0,318EU/KG

Total Cost of Processes For Dyed White Cotton Fabrıc:

1- Batchpreparation 0,010EU/KG
2- Treatments inthedyemachine 0,78EU/KG
3- Cutting thetubularfabric 0,021EU/KG
4- Drying inthestenter 0,055EU/KG
5- Sanforizing 0,027EU/KG
6- Packaging 0,035EU/KG

TOTAL 0,928EU/KG

When total costs were compared including all the steps, white cotton fabric is 2,9 times more expensive.

VI. CONCLUSION

There is no necessity to dye naturally

colored cotton fabrics because the color is already present in the fiber. It is known that dyeing costs are higher than the other treatments in fabric finishing with respect to energy and water and consumption, chemical, auxiliary agent and dyestuff costs, labor costs and waste water treatment prices.

In this study a comparison was made between naturally colored cotton fabric with a white one dyed in the same color of the natural brown fabric, in manner of process steps and costs by up to date data and methods of an active and hardworkingdye house.As the result of cost calculations by using realistic values and considerations, it was found that in manner of chemical treatments naturally colored cotton is very advantageous. Energy, water, labor, electricity, chemical, auxiliary agent and dyestuff costs were all lower than the ones of the white cotton fabric. Dyeing the white fabric in the dye house is 2,9 times more expensive than treating the naturally colored cotton with simple processes. This ratio of about "3" is striking,andintoday'sworlditistheresponsibilityofevery person working in the industry to take care of the environment and do something for the sustainability.Because Turkey is one of the most important naturally colored cotton producer countries in the world, the researches and studies about this special product should go on and Turkish textile industry should sustain its competitive position in the global textile market which faces a pressing challenge of low cost, high quality and environmentally benign production.

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