1287 Textile Material Engineering: Ecotextiles from the Naturally Colored Cotton

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Rationale During the last decade a concept of **ecotextiles** based on the protection of environment and human health in all processing steps starting from obtaining the raw cotton up till the production of textile product has become a subject of the high priority. Naturally colored cotton as a natural raw material is characterized by wonderful physiological, using friendly properties and can be applied in all basic groups of utility goods, among the others in clothing.

Objectives The aim of research was an elaboration of processing technology of naturally colored cotton of the Greek origin and a production of new ecological fabrics destined for the summer apparel. The elaborated technology will create a possibility of introducing the naturally colored cotton into the industrial processing; and next, a production of novel, ecological, using friendly clothing of physiological properties assuring the utility comfort with simultaneous, elimination of danger for the human being's health and natural environment.

Methods Fiber parameters were measured on the HVI, AFIS and MDTA-3; for yarns the standard analyses were performed, among the others on the Uster tester; fabrics besides the standard analyses were evaluated in the aspect of heat transfer and vapor permeability to compare with the analogous behavior of white color fabrics; a catalogue of collection of summer clothing was created and the model clothing was sewn.

Results Naturally colored cotton of the Greek origin was characterized by a big percentage of SFC and a big variation of cotton length, big amount of neps, SCN, trash, dust and VFM, but quite a good tenacity – 25 cN/ tex. Produced industrially rotor yarns were in a majority of cases on the satisfactory level according to the Uster Statistics; woven fabrics were characterized by a good aesthethics and assured a good heat transfer and vapor permeability, so they were a good material for the summer clothing.

Conclusions The naturally colored cotton fibers quality were good enough to perform the industrial process of rotor yarn production without any disturbances; the obtained yarn quality was good enough to weave the fabrics; the sewn ecological summer clothing was characterized by the physiological comfort.

Keywords: comfort of the summer clothing, fiber properties, naturally colored cotton, thermal resistance, vapor permeability.

1. Introduction

Although a big development of synthetic fibers has been lately observed the importance of natural fibers in the world still grows. According to the statistics related to the production of natural raw materials for textiles the major share belongs to cotton, what creates about 50% of the world consumption of all fibers. An assessment of physical and chemical properties of cotton is interesting for producers, technologists as well as the users. Technologists should be able to create using friendly for the human being and environment goods from the given type of fibers.

During the last decade a concept of **ecotextiles** based on the protection of environment and human health in all the processing steps starting from obtaining the raw cotton up till the production of textile product has become a subject of the high priority. Since 1980s in many countries, the conscious consumers have started to prefer the textile products, which are not detrimental to the environment and human health during the production stages, usage and disposing the waste material.

Naturally colored cotton inhibits the formation of disturbances in the human ecology, pollution of environment by synthetic dyestuffs; also eliminates the bleaching and dyeing costs and an excessive energy usage.

With the development of dyeing industry the conversion of white colored fibers into desirable and fashioned colors inhibited studies of the researchers on the naturally colored cotton having not a good yield performance and fiber quality. However, such factors like disturbances in the human ecology, pollution of environment by synthetic dyestuffs and dyeing costs caused the turn of the attention of researchers to the naturally colored cotton germplasm. The naturally colored cotton created new alternatives in the textile industry to obtain the healthy and using friendly clothing, furnishing and household products (Święch and Frydrych, 1998; 1999; Święch et al., 1999; Vreland, 1999).

The cultivation of naturally colored cotton was a subject of interest of many researchers: Brown in 1938 wrote about the brown and dark-cream cotton, Christidis and Harrison in 1955 – about green, brown, dirty grey and mahogany red cotton, Kohel and Lewis in 1984 – about brown cotton, Fox (1996) cultivated all of these naturally colored cottons (Natural…, 1996). In the period of cotton development, yield and fiber quality characteristics of naturally colored cottons within the populations were worse than of white cottons. Fibers were too short and too weak to be spun by a machine. They were usually blended with the white cotton in order to increase the yarn strength, to facilitate the processing and to reduce costs. Blending the white and naturally colored fibers had also disadvantages, for example, a reduction of the product color intensity.

Today cotton breeders have developed naturally colored cotton genotypes using the conventional plant breeding techniques such as a selection, crossing and mutation. They have also started to try biotechnology.

Over the last 15 years the improvements of yields and fiber quality parameters such as fineness, length, strength, color intensity and variations of these kinds of genotypes have been obtained by the researchers and actually these fibers are good enough to be spun successfully on the rotor and ring spinning frames for a great range of textile applications.

The production of expensive, ecological products from the naturally colored cotton will fulfil so called "niche" on the world market. There is actually a big interest of naturally colored cotton as well as white organic cotton, so their share on the world market grows. It is due to the better fiber parameters and better color uniformity. The naturally colored cotton fibers are used for the production of yarns and further - woven and knitted fabrics as well as nonwovens.

MATERIAL AND METHODS

1. Naturally colored cotton of Greek origin

The research was carried out in the frame of international project Eureka! NAGREFIAT titled "An application of naturally colored cotton of Greek origin for ecological yarn and fabric production" (Fig.1.). The breeding of naturally color fibers took place in the NAGREF (Thessaloniki, Greece). Parameters of the sent by NAGREF four naturally colored cotton bales as well as of the white cotton from the Central Asia (for the comparison purpose) were measured in the accredited metrological laboratory of the Institute of Textile Architecture on the AFIS system, HVI line and MDTA-3 device.

2. Rotor yarns from the naturally colored cotton

2.1. Produced in a laboratory scale

From obtained fibers the sliver was prepared on the MDTA-3 device; and next, the laboratory yarns were manufactured on the rotor spinning frame. The produced yarns were analyzed in a metrological laboratory to assess their quality.

2.2. Produced in an industrial scale

The rotor yarns for woven fabrics were produced from 4 cotton bales in the spinning mill Bełchatów. The produced yarns were examined in an accredited metrological laboratory of the IAT.

3. Fabrics with the naturally colored cotton content

From the rotor yarns produced in the Bełchatów spinning mill there were produced fabrics according to the plan of experiment in the technological plant of IAT on the MAV looms. In Fig.2, there is presented a photo of example of fabrics from the naturally colored cotton.

Naturally colored cotton processing eliminates some of finishing processes like dyeing. Such a simplification of technology could influence biophysical properties of fabrics and clothing. The standard treatment of white cotton fabrics gives the apparel of known microclimate characteristics in the clothing layers being close to the human being skin. Therefore, the laboratory measurements of thermoinsulation properties and vapor permeability were done. Since we would like to design the summer apparel collection the fabrics should be characterized by a low heat resistance and high vapor permeability. The thermoinsulation parameters were measured on the Alambeta device (Hes et al., 1990) in the Clothing Department of the Technical University of Lodz.

The human being perspires in every condition. In the relaxation state there is so called *perspiration insensibilis,* which can not be controlled by the organism. The amount of perspiration generated in such conditions is about 40 g per hour. In the case of a big effort the amount of sweat increases to 1.5 l per hour. There appears a problem of removing it from the layers being close to the human skin (Więźlak et al., 1996). Sometimes, it is in the form of liquid, what intensifies a discomfort. Therefore, this ability is so important for the human being. The measurement of vapor permeability was done on the device similar to the "skin model" constructed in the Clothing Department of the Technical University of Lodz (Zieliński and Majewski, 1997; Zieliński, 2001).

The vapor permeability through the fabric measured on this device was calculated according to the equation:

$$\lambda = \frac{\int_0^{t_o} w_n(t)dt}{\int_0^{t_o} w_p(t)dt} \quad (1)$$

where: λ_v - vapor permeability,

w_n – absolute humidity above the sample, g/kg,

w_p – absolute humidity at the measurement cylinder fulfilled by the moisture without the samle, g/kg,

t_o – time of observation, min.

4. Catalogue of clothing collection from the naturally colored cotton

Clothing creates a barrier between the human organism (body surface) and environment, which regulates a heat and humidity transfer. This regulation should be effective, i.e., it should stimulate the microclimate close to the human being skin in changing climate conditions at changeable level of his physical activity and different environmental parameters (temperature, relative humidity, air pressure, wind velocity and sun radiation).

A catalogue of summer clothing for men and women, which will be sewn from the naturally colored cotton fabrics, was elaborated in the Clothing Department of the Technical University of Lodz. A phase of clothing collection designing was based on the rules of creating the new clothing structures with application of so called catalogue of functional groups invented in the Clothing Department (Rybicki, 2001). The collection consists of ten examples of ecological summer cloth.

5. The Model of Clothing

The last stage of technological process, i.e., the creating the model of clothing were performed in the Clothing Department of the Technical University of Lodz.

RESULTS AND DISCUSSION

1. Naturally colored cotton of Greek origin

The obtained on the AFIS, HVI and MDTA-3 fiber parameters are presented in Fig.3-5.

Summing up the results of naturally colored cotton parameters, it can be noticed the following:

- cotton C has a big percentage of SFC and a big value of variation coefficient of fiber length,

- the naturally colored cotton has shorter fibers than the cotton from the Central Asia,
- the naturally colored cotton has a low value of Maturity Ratio,

- cotton B has a big amount of neps and SCN, trashes, dust and VFM,

- assessed on the HVI line the naturally colored cotton is characterized by a big amount trash, shorter fibers than those of the white cotton, but of uniform length, good strength - 25 cN/tex, and Micronaire index < 4.

- according to MDTA-3 the most trashy is cotton D; whereas the most dusty - cotton B.

2. Rotor yarns from the naturally colored cotton

2.1. Produced in a laboratory scale

The basic yarn parameters are presented in table 1; whereas in table 2 there are presented quality parameters of these yarns in comparison to the Uster Statistics 2001.

Analyzing the quality of yarn produced in a laboratory scale we can state that:

- during the rotor yarn production in a laboratory scale we didn’t observed any difficulties in a technological process,
- rotor yarns from the naturally colored cotton were characterized by similar properties as yarns from the white cotton.

2.2. Rotor yarns produced in the industrial scale

The basic parameters of produced industrially rotor yarns are presented in table 3; whereas in table 4 there are presented quality parameters of these yarns according to the Uster Statistics 2001.

Summary concerning the quality of cotton yarns produced industrially:

- an industrial process of rotor yarn production from the naturally colored cotton was performed without any disturbances,
- the quality of rotor yarns produced in the industrial conditions is on a satisfactory level according to the Uster Statistics with an exception of the yarn neps.

3. Fabrics with the naturally colored cotton content

An assessment of biophysical properties of fabrics was performed in the Clothing Department of the Technical University of Lodz.

The fabric samples got from the IAT chosen for clothing creation are presented in Fig.6. The mass per square meter as well as the number of threads in warp and weft directions are given in Table 5.

The values of thermoinsulation parameters measured on the Alambeta device are given in Table 6. In Fig. 7 there are presented the values of thermal resistance and fabric thickness.

It is seen that there is a correlation between these values. In order of comparison purpose we measured also the thermal resistance of the white cotton fabric.

Analyzing the mean values of parameters characterizing the fabric thermal insulation, there are not big differences in the conduction coefficient values, which are confined in the interval (42.5-51.5) 10^{-3} W/mK, but the minimum value is stated for the white cotton fabric; whereas the maximum – for the fabric made from naturally colored cotton, designated as CL 3591 wz.3. Concerning the thermal resistance four fabrics made of naturally colored cotton (CL 3591 wz.3, CL 3591 wz.3, CL 3592/140 wz.2, CL 3592/140 wz.4) were more or less on the same level as the white cotton fabrics.

In Fig. 8, there are presented the thermal resistance and a mass per square meter. It was stated a lack of relationship between those parameters.

As a selection criterion there was assumed the lowest value of thermal resistance; therefore, fabrics of gofer weave and the knitted fabrics were rejected. The conclusions obtained in this analysis were verified by the measurement of vapor permeability.

The results of vapor permeability with their standard deviation for the chosen variants of naturally colored cotton fabrics and two white cotton fabrics are presented in Fig. 9. The mean value of vapor permeability is in the interval (0,492; 0,541), and the minimum value was for the fabric designated by CL 3591 wz.5; whereas the maximum value of the vapor permeability have the knitted fabric A and the fabric CL 3592/140 wz.1. The difference between the best and the worst fabric vapor permeability is 14 %. It should be pointed out that all the fabrics made of naturally colored cotton are characterized by the lower value of vapor permeability than the fabric made of white cotton. In Fig.10 there is presented a set of results of vapor permeability and thermal resistance of naturally colored cotton fabrics.

After analyzing fabric thermoinsulation properties and their vapor permeability the following variants were chosen for creating the summer clothing collection:

- CL 3591 wz.5,

    - CL 3591 wz.3,
    - CL 3592/140 wz.1., wz.2, wz.4.

4. Catalogue of clothing collection from the naturally colored cotton

The designed collection consists of ten examples of ecological summer cloth. In Fig.11, you can see one of the clothing designs from the clothing catalogue.

5. The Model of Clothing

To sew the model of clothing the threads were chosen basing on the material strength (Elmrych-Bocheńska, 2006; PN-EN ISO13935-1, 2002). The seam shouldn’t be stronger than the fabric. The second condition was the thread color. Taking into account both conditions in result the PES threads were chosen for the sewing process.

In Fig.12, there is a photo of ready summer suit for women.

Figure1. Participants of Eureka project on the field of naturally colored cotton

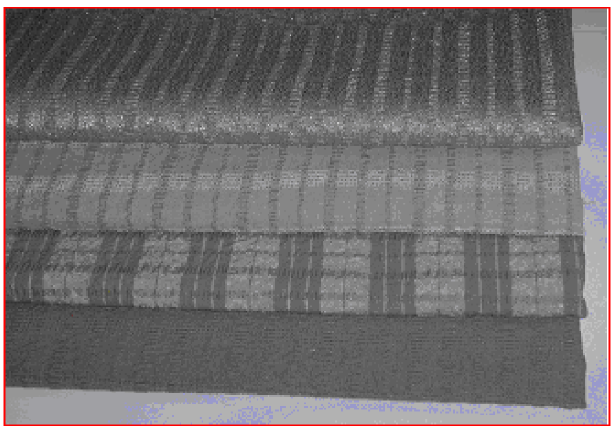


Figure 2. A photo of fabrics from the naturally colored cotton

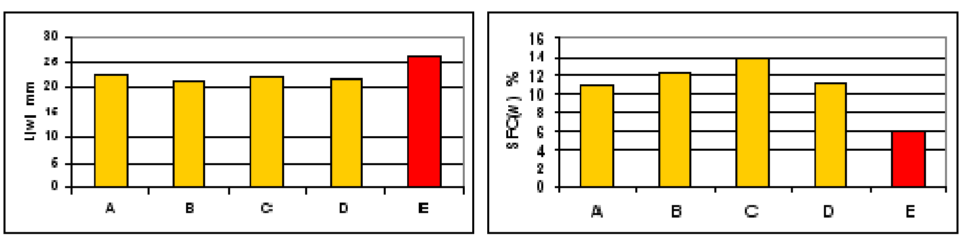


Figure 3a. Chosen length parameters of naturally colored cotton of Greek origin from the AFIS system

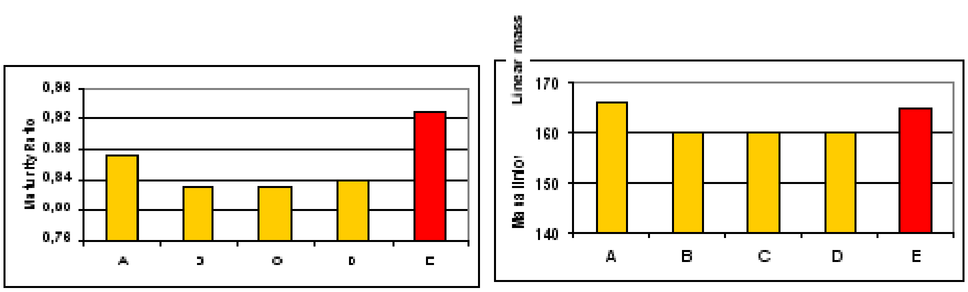


Figure 3b.Fineness and Maturity Ratio of naturally colored cotton of Greek origin from the AFIS system

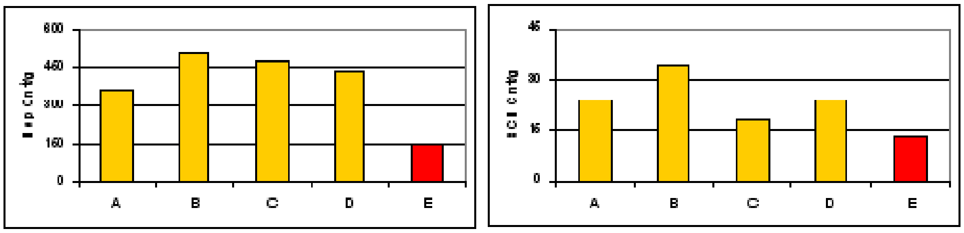


Figure 3c. Chosen neps parameters of naturally colored cotton of Greek origin from the AFIS system

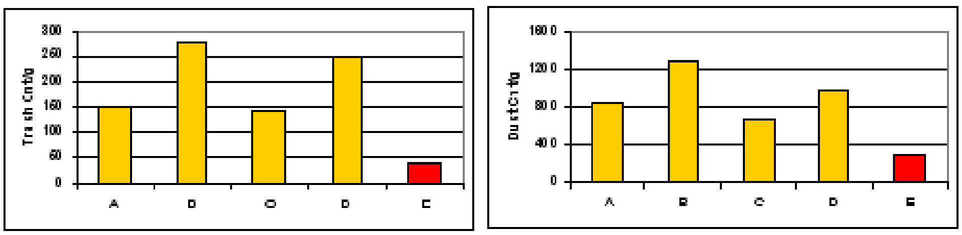


Figure 3d. Chosen trash parameters of naturally colored cotton of Greek origin from the AFIS system

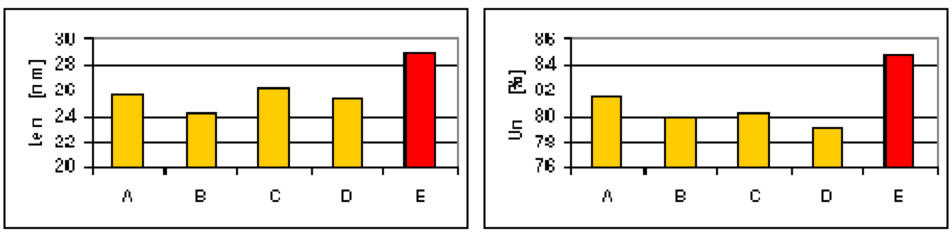


Figure 4a. Length parameters of naturally colored cotton of Greek origin from the HVI line

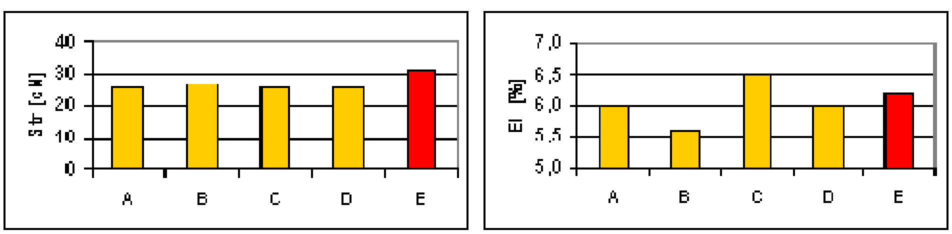


Figure 4b. Strength parameters of naturally colored cotton of Greek origin from the HVI line

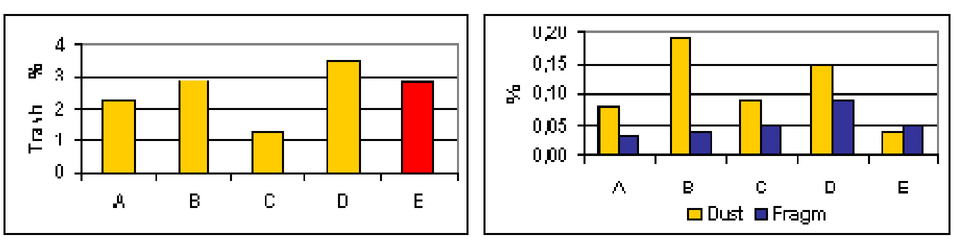
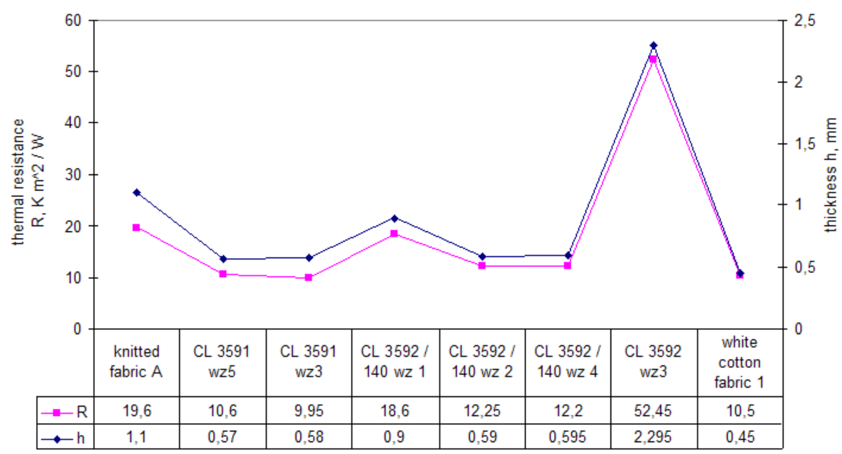


Figure 5. Contaminations of naturally colored cotton of Greek origin according to MDTA-3

Figure 6. Naturally colored cotton fabric samples



	knitted fabric A	CL 3591 wz5	CL 3591 wz3	CL 3592 / 140 wz 1	CL 3592 / 140 wz 2	CL 3592 / 140 wz 4	CL 3592 wz3	white cotton fabric 1
R	19,6	10,6	9,95	18,6	12,25	12,2	52,45	10,5
h	1,1	0,57	0,58	0,9	0,59	0,595	2,295	0,45

Figure7. Comparison of mean values of thermal resistance in the aspect of their thickness.

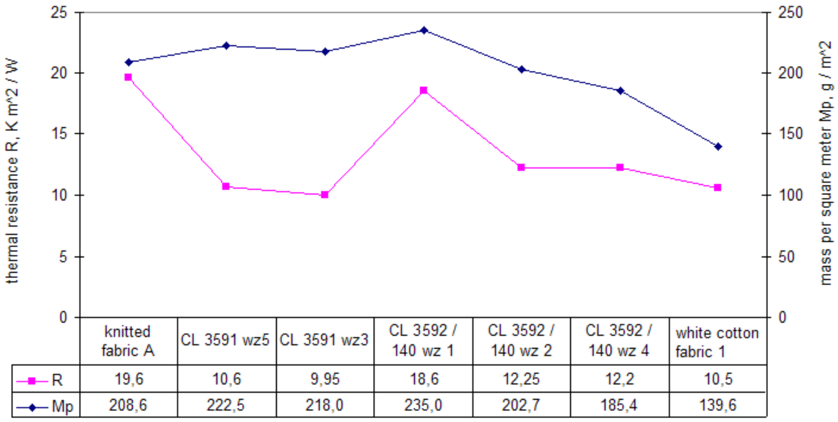


Figure 8. Comparison of mean values of thermal resistance in the aspect of mass per square meter.

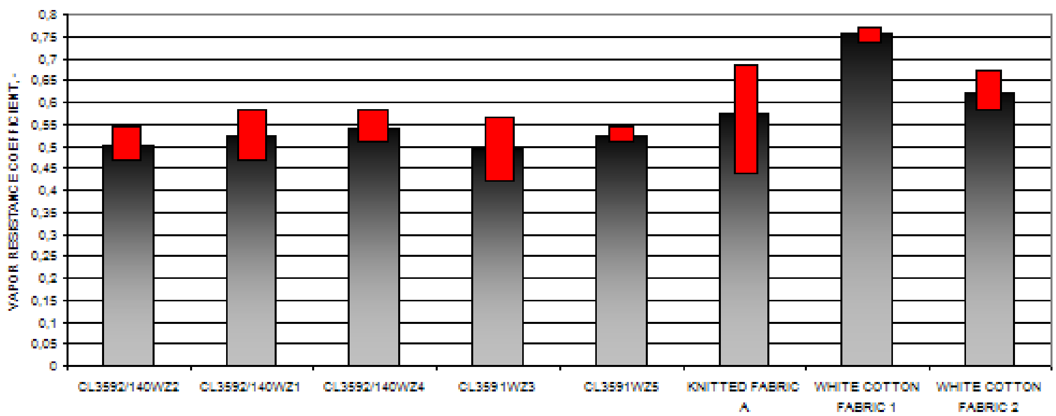


Figure 9. The results of vapor permeability of naturally colored cotton fabrics and two white cotton fabrics

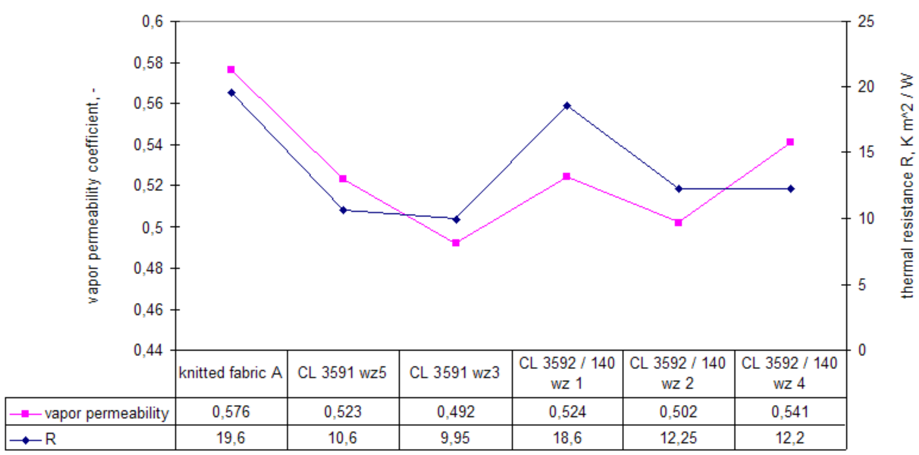


Figure 10. The set of results of thermal resistance and vapor permeability for naturally colored cotton samples

Figure 11. A design of summer clothing from the naturally colored cotton fabrics

Figure 12. Photo of ready summer suit for women.

Table 1. Parameters of yarns produced in a laboratory scale

Lp.	Parameter	Unit	Sample				
			A	B	C	D	E
1	Yarn linear density	tex	30.2	32.2	30.1	30.2	30.9
2	Linear density variation coefficient	%	8.02	4.94	6.36	4.20	2.99
3	Tenacity	cN/tex	8.36	7.98	6.66	7.97	11.10
4	Breaking force variation coefficient	%	9.29	10.90	8.00	9.27	7.65
5	Strain	%	8.14	9.02	7.46	8.48	7.72
6	Elongation variation coefficient	%	5.68	6.48	4.57	5.80	6.01
7	Twist	m^{-1}	761	775	758	703	750
8	Metric twist parameter	-	131.8	139.1	131.5	122.2	131.9
9	Twist variation coefficient	%	1.32	4.81	2.50	4.11	1.93
1	CV	%	15.6	16.2	15.8	16.3	16.3
1	Thin places/1000 m	-	416	640	376	232	368
1	Thick places/1000 m	-	108	204	80	180	280
1	Neps/1000 m	-	16	48	16	52	160

Table 2. Yarn quality according to Uster Statistics 2001

Lp.	Sample	Color	Quality level			
			CV %	Thin places	Thick places	Neps
1	A	Brown	71	>95	74	33
2	B	„	84	>95	>95	75
3	C	„	75	>95	58	33
4	D	„	85	>95	94	76
5	E	White	85	>95	>95	95

Table 3. Metrological parameters of industrially produced rotor yarns

Lp.	Parameter	Unit	30 tex	40 tex	50 tex
1	CV	%	14.1	16.0	16.3
2	Thin places/1000 m	-	22.4	4.8	20.8
3	Trick places/1000 m	-	88.8	90.4	63.2
4	Neps/1000 m	-	812.0	507.2	269.6
5	Tenacity	cN/tex	9.65	9.13	8.96
6	Breaking force variation coefficient	%	11.19	13.81	13.03
7	Twist	m^{-1}	946	781	668

Table 4. The quality of rotor yarns produced industrially according to the Uster Statistics 2001

Lp.	Tex	Color	Quality level			
			CV %	Thin places	Thick places	Neps
1	30	Brown	25	68	63	>95
2	40	Brown	95	30	80	>95
3	50	Brown	>95	>95	58	>95

Table 5. Characteristics of fabrics made of naturalny colored cotton

Kind of Fabric	g_o [dm^{-1}]	g_w [dm^{-1}]	Mp [g/m^2]
White cotton fabric 1	218.7	157.3	139.6
CL 3591 p. 3	266.7	257.8	218.0
CL 3591 p. 5	265.5	243.3	222.5
CL 3592/140 wz. 4	262.2	207.8	185.4
CL 3592/140 wz. 1	258.7	216.7	235.0
CL 3592/140 wz. 2	206.0	268.7	202.7
Knitted fabric A*	-	-	208.6
White cotton fabric 2	286.7	243.3	155.0

- In the case of knitted fabric A it was determined density of rows and columns [9]: density of rows = 145.3, density of columns = 182.7

Table 6. The Alambeta results

Lp	Kind of material	Measured parameter: Mean value Variation coefficient						
		λ	a	b	R	h	P	q_s
		Unit/ multiply by						
		$Wm^{-1}K^{-1}$ $/ 10^{-3}$	$m^2 s^{-1}$ $/ 10^{-6}$	$Wm^{-2}s^{1/2}K^{-1}$ / 1	$W^{-1}Km^2$ $/ 10^{-3}$	mm / 1	- / 1	KWm^{-2} $/ 10^3$
1.	Knitted fabric A	51.50 2.00	0.199 19.35	117.00 9.45	19.60 4.10	1.10 3.50	1.46 4.15	0.573 5.35
2.	CL3591 wz.5	54.10 2.55	0.089 15.50	183.00 7.70	10.6 4.15	0.57 2.45	1.36 4.30	0.912 4.85
3.	CL3591 wz.3	58.50 4.60	0.1155 22.10	175.00 11.20	9.95 7.35	0.58 4.10	1.31 4.85	0.935 8.15
4.	CL3592/ 140 wz.1	48.60 3.90	0.1076 12.90	148.50 7.80	18.60 5.55	0.90 3.65	1.595 5.90	0.6665 7.70
5.	CL3592/ 140 wz.2	48.35 2.60	0.089 24.75	166.50 10.75	12.25 4.80	0.59 3.65	1.32 5.45	0.7845 4.70
6.	CL3592/ 140 wz.4	48.95 3.10	0.0985 20.85	158.50 9.70	12.20 4.5	0.595 2.65	1.32 3.3	0.786 5.4
7.	CL3592 wz.3	43.80 6.85	0.230 16.65	92.70 11.40	52.45 6.80	2.295 7.55	2.29 17.50	0.337 22.00
8.	White cotton fabric 2	42.5 2.65	0.1425 37.15	119.0 17.25	10.5 7.45	0.45 6.50	1.115 5.8	0.7645 5.55

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