MEASUREMENT OF NATURALLY COLORED COTTON BY DIFFERENT TESTING METHODS

Malgorzata Matusiak
Textile Research Institute
Lodz

Abstract

Naturally colored cotton refers to a natural cotton fiber that grows in colors. Color of cotton is due to the natural pigmentation of fibers. Naturally colored cottons do not have to be dyed in fabric manufacturing. Elimination of dyeing can save up to one half of the cost of the textile preparation and also saves disposal cost of toxic dye waste. There are some limitations of usage of the naturally colored cotton. First of all the majority of naturally colored cotton varieties are of lower quality than most conventional white cottons. The problem is also how to assess the quality of naturally colored cotton. Are the methods commonly applied for white cotton measurement suitable also for colored cotton? There are not any rules and criteria for the quality classification of the naturally colored cotton.

The aim of work was to analyze the basic quality properties of naturally colored cotton of different origin. Moreover, the relationships between the results of measurement of the naturally color cotton by different methods were assessed and discussed.

Introduction

Naturally colored cotton refers to a natural cotton fiber that grows in colors. Colored cotton agriculture began around 2700 B.C. Because of low yields, the inability of the fiber to be machine spun, and the availability of inexpensive dye-stuffs, naturally colored cottons have not been utilized for commercial textile production. In 1982 in the United States Sally Fox rediscovered a small amount of brown cotton seeds. Fox began to research creating commercially viable long-fibered colored cotton. The invention was called FoxFibre, strong long-fibered colored cotton. Nowadays naturally colored cottons are also being bred and grown in many other countries e.g., Israel, Brazil, Peru, Greece, Turkey and the former Soviet Union.

Naturally colored cottons do not have to be dyed in fabric manufacturing. Elimination of dyeing can save up to one half of the cost of the textile preparation and also saves disposal cost of toxic dye waste. In spite of the mentioned above the economical and ecological benefits of application of naturally colored cotton in the textile industry the textiles made of naturally colored cotton are considered as a niche market. There are some limitations of usage of the naturally colored cotton. First of all the majority of naturally colored cotton varieties are of lower quality (strength, length, *Micronaire*, etc.) than most conventional white cottons. The problem is also how to assess correctly the fiber properties and quality of the naturally colored cotton.

The measurement systems like AFIS and HVI applied most frequently for the assessment of white cotton are based of the optoelectronic principles. Are the standard measurement methods and systems suitable for an assessment of the naturally colored cotton? How influences the natural pigmentation of fibers the results of the measurement by means of the optoelectronic measurement techniques?

Experimental

The aim of work was to analyze the basic quality properties of naturally colored cotton of different origin:

- brown cotton from Greece – 4 samples: GB 1 ÷ GB 4,
- light brown short (TLBS), light brown long (TLBL), brown (TB) and green (TG) cotton from Turkey,
- brown (BB), reddish brown (BRB) and green (BG) cotton from Brazil.

For the comparison the middle staple white cotton originated fro the Central Asia (CAW) were measured. This cotton is the most frequently processed in the Polish spinning mills.

For the assessment of the properties of naturally colored cotton different measurement techniques were applied. The measurement of the basic properties of naturally colored cotton was done by means of the AFIS (Advanced Fiber Information System) and HVI (High Volume Instrument). Colors of naturally colored cotton as well as the color

differences between particular samples of the naturally colored cotton were measured by means of the spectrophotometer *Datacolor 650*. Assessment of cotton contamination was performed by means of AFIS, HVI and MDTA (Microdust and Trash Analyzer). Additionally the fiber maturity was determined by means of the microscopic method using polarized light microscope.
Due to the small amount of Brazilian color cottons their measurement by HVI and MDTA device was impossible. Brazilian cottons were measured only by means of AFIS, spectrophotometer and microscopic method.

Results

Determination of maturity degree

Fiber maturity is an important factor in cotton classification as well as fiber and textile processing. Maturity refers to the degree of development or thickening of the fiber cell wall relative to the perimeter or effective diameter of the fiber [8]. Maturity of cotton fiber can be determined by the measurement of the maturity degree as well as the maturity ratio based on the measurement of the circularity coefficient of fiber cross section. Cotton fiber maturity can be also expressed in the indirect way by the measurement of *Micronire* index.
In the frame of the presented work the following measurements were done:

- *Maturity Ratio* measurement by means of AFIS,
- *Micronaire Index* from HVI,
- *Maturity Degree* determination using polarized light microscope.

Method of maturity degree assessment with the use of the polarized microscope relies on observations of 300-400 fibers under the microscope in the polarized light, qualification them into the appropriate maturity classes according to Table 1 and color patterns (fig.1) and next on calculation of the mean maturity degree.

Table 1. Classification into the maturity groups according to standard PN-88/P – 04675/04

Maturity groups	Cotton fiber maturity	Cotton fiber color	Shape of fiber and lumen
1	Too mature Mature	orange – gold-yellow with green parts	cylindrical with narrow lumens
2	Slightly mature	green, blue, yellow and green with blue and blue green parts	sliver type with wide lumen
3	Not mature	violet, and blue with violet or green parts	sliver type with wide lumen
4	Totally not mature (dead)	violet with transparent, red parts, transparent-red	sliver with wide lumen

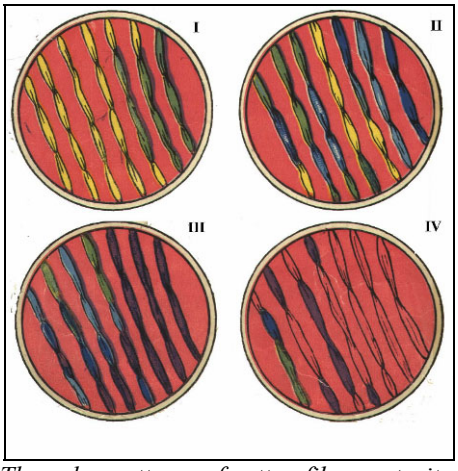

Fig.1. The color patterns of cotton fiber maturity degree

In figure 2 there are presented the examples of microscopic pictures in the polarized light of the naturally colored cotton fibers. In contrast to the Uzbek white cotton, in naturally colored cotton, especially Turkish and Brazilian green we can see a lot of fibers in blue and blue with violet or green parts.

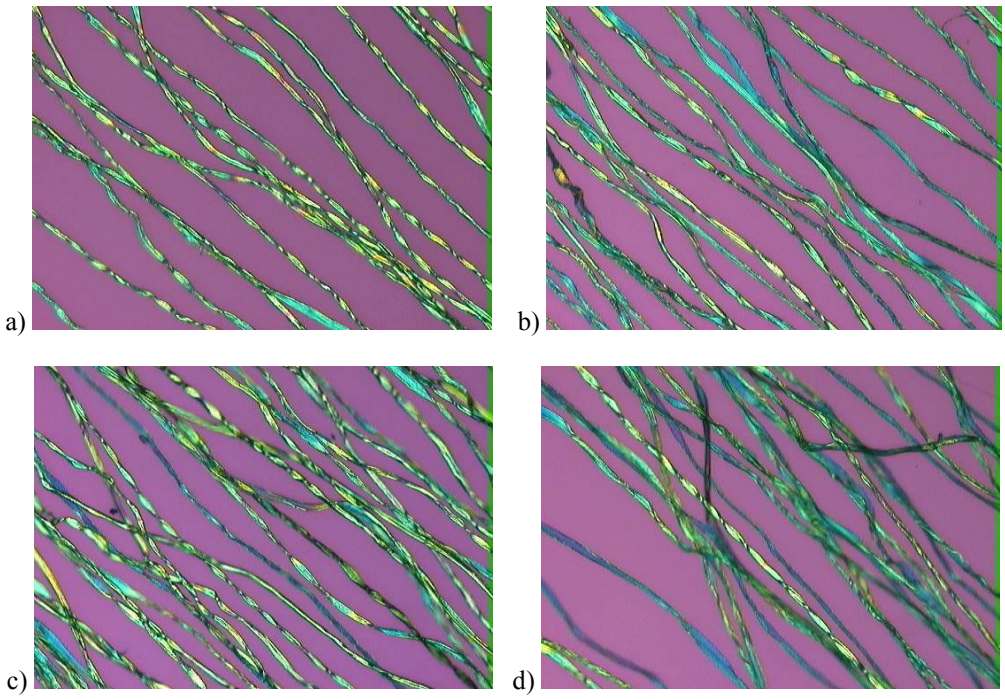

Fig. 2. Microscopic pictures of cotton fibers: a) Uzbek white, b) Turkish green, c) Brazilian brown d) Brazilian green

Results of maturity measurement are presented in table 2.

Table 2. Results of maturity measurement

No	Sample	Symbol	*Maturity Ratio* acc. to AFIS	Micronaire acc. to HVI	*Maturity Degree* acc. to microscopic method
1.	Central Asia white	CAW	0.93	4.8	1.82
2.	Greek brown 1	GB1	0.87	4.0	1.73
3.	Greek brown 2	GB2	0.83	3.4	1.53
4.	Greek brown 3	GB3	0.83	3.6	1.76
5.	Greek brown 4	GB4	0.84	3.4	1.55
6.	Turkish brown	TB	0.92	4.0	1.78
7.	Turkish light brown short	TLBS	0.92	4.3	1.72
8.	Turkish light brown long	TLBL	0.93	3.9	1.82
9.	Turkish green	TG	0.84	3.4	1.24
10.	Brazilian reddish brown	BTG	0.84	-	1.20
11.	Brazilian brown	BB	0.78	-	1.55
12.	Brazilian green	BG	0.78	-	1.13

The AFIS measurement showed big differences between particular samples of the naturally colored cotton in the range of fiber maturity (fig. 2). The highest maturity was stated for Turkish brown and light brown cottons. Their average maturity is at the same level to the maturity of the Uzbek white cotton. The lowest maturity was stated for Brazilian cotton: brown and green.

According the measurement by the polarized light microscope the highest *Maturity Degree* was observed for Turkish light brown long cotton (MD = 1.82). It is equal to the *Maturity Degree* of Uzbek white cotton. Maturity of Turkish brown and light brown short cotton is somewhat lower than the maturity of white cotton. The results are in agreement with the results from AFIS. The lowest *Maturity Degree* was stated for Turkish green and Brazilian reddish brown and green cotton. The value of *Sperman's correlation index* $r_s = 0.76$ indicates the *rank correlation* between results of maturity measurement by means of AFIS and microscopic method.

Color measurement

Color is one of the most important property of cotton. It is a basic criterion which decides about the quality classification of white cotton. In the case of the naturally colored cotton important property is not only the color of fibers but also the color evenness and its repeatability.

Color characteristics: reflectance (Rd) and yellowness (+b) can be determined by the HVI. Measurement is based on the comparison of color of measured sample with color of official color standard for white cotton.

In the presented work the measurement of color of the naturally colored cotton was done by means of HVI and spectrophotometer Datacolor 650. The results of measurement of Greek brown cotton – samples GB 1, GB 3 and GB 4 are presented in table 3.

Table 3. Color parameters determined by HVI

No	Sample	Rd	+b
1.	GB1	40.2	13.0
2.	GB2	-	-
3.	GB3	40.7	13.4
4.	GB4	40.1	13.0
5.	CAW	77.1	12.9

In the case of Greek brown cotton – sample GB 2 and Turkish cotton: brown and green the determination of color parameters was unsuccessful. For Greek brown cotton GB 1, GB 3 and GB 4 the results of reflectance (Rd) measurement are practically below the scale of Nickerson-Hunter diagram. Carried out investigation confirmed that the measurement of color of naturally colored cotton by HVI is questionable or even impossible.

Then the color parameters of the naturally colored cotton were determined by means of spectrophotometer. The set of color coordinates measured in day light (D 65) is given in table 4. *CIELAB color difference dE* was assessed separately for 2 groups of cotton raw materials: green and brown. The difference between the green cottons: Turkish and Brazilian is not high: dE = 3.33. Higher values of dE were stated for brown cottons. The biggest differences occurred between the Greek brown cotton sample 1 (GB1) and Brazilian reddish brown and brown cotton.

Table 4. Color characteristic of naturally colored cotton at illuminant D 65

Sample	lightness	green/red	blue/yellow	chroma	hue	CIELAB color difference
	L	a	b	C	h	dE
TG	67.47	0.65	18.26	18.28	87.97	standard green
BG	64.22	1.33	18.47	18.52	85.88	3.33
GB1	70.54	7,57	23.45	24.64	72.12	standard brown
GB 2	69.98	8.47	24.71	26.12	71.08	1.65
GB 3	70.60	7.07	22.49	23.58	72.54	1.08
GB 4	69.01	8.54	23.97	25.44	70.38	1.89
TB	64.21	9.66	24.65	26.48	68.60	6.77
TLBS	74.06	6.43	21.44	22.39	73.31	4.21
TLBL	67.41	8.90	23.71	25.33	69.42	3.42
BTG	47.59	15.82	27.71	31.91	60.28	24.76
BB	53.63	13.42	27.17	30.30	63.72	18.28

Measurement of fiber tenacity

Fiber tenacity was assessed by means of HVI and the tensile tester DSzU according to GOST standard. The method relies on the determination of breaking force of single fibers or fiber bundles. The breaking force of single fiber is calculated as a ratio of the bundle breaking force and the number of fibers in the bundle. Then tenacity is calculated on the basis of breaking force of single fibers.
The results of measurement of fiber strength of brown Greek cotton are presented in table 5.

Table 5. Results of fiber tenacity measurement

No	Sample	HVI		DSzU	
		Breaking strenth cN/tex	Breaking elongation %	Breaking force for single fiber cN	Fiber tenacity cN/tex
1.	GB1	25.4	6.0	4.77	25.3
2.	GB2	26.4	5.6	4.34	23.5
3.	GB3	25.7	6.5	4.77	24.9
4.	GB4	25.6	6.0	4.64	26.0

On the basis of the results it was stated that the fiber tenacity determined by both applied methods are at the similar level (fig. 3). The significant difference occurred in the case of sample GB 2. Breaking strength of fiber according to HVI is 2,9 cN/tex higher than fiber tenacity according to tensile tester DSzU.

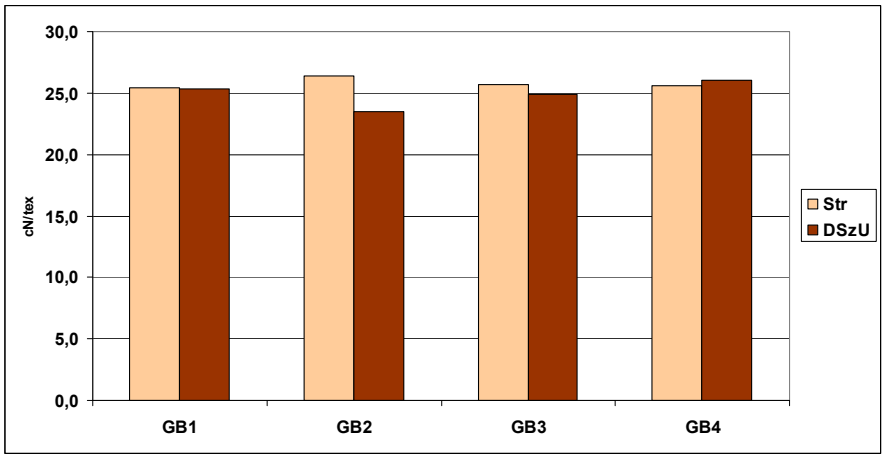

Fig. 3. Fiber tenacity according to HVI

Measurement of cotton contamination

Measurement of cotton contamination was done for Uzbek, Greek and Turkish cotton. Results are presented in table 6.

Table 6.Results of measurement of cotton contamination

Cotton sample	Total Cnt AFIS	Mean Size AFIS	Dust Cnt AFIS	Trash Cnt AFIS	VFM % AFIS	Area HVI	Cnt HVI	Lint % MDTA	Trash % MDTA	Dust % MDTA	Fragm % MDTA
CAW	314	287	273	41	0.97	0.02	7	97.10	2.81	0.04	0.05
GB1	1000	321	850	149	2.87	0.86	286	97.63	2.25	0.08	0.03
GB2	1563	319	1286	278	5.13	1.39	311	96.87	2.90	0.19	0.04
GB3	805	341	664	141	2.65	1.19	279	98.56	1.30	0.09	0.05
GB4	1224	345	976	248	3.86	1.15	274	96.21	3.54	0.15	0.09
TB	1342	231	1243	99	2.48	1.97	441	97.66	2.21	0.08	0.05
TLBS	466	259	404	61	1.1	0.57	192	98.60	1.31	0.05	0.04
TLBL	1228	248	1126	102	2.61	1.30	336	97.06	2.78	0.08	0.07
TG	4361	250	3921	440	9.02	6.41	715	94.01	5.79	0.14	0.06

Naturally colored cottons are characterized by the very high content of dust. The highest dust content was stated for Turkish green cotton (Dust Cnt/g = 3921).

The relationships between the results of cotton contamination assessment by different measurement methods were verified using the *Sperman's correlation* test (table 7). The *Sperman's correlation* test indicated *rank correlation* between the results of Total Cnt/g and Dust Cnt/g from AFIS and results from HVI: Area and Cnt. There is also correlation between the dust percentage according to MDTA and trash content and VFM from AFIS.

Table 7. The Sperman's correlation indexes

Parameter	Area HVI	Cnt HVI	Trash % MDTA	Dust % MDTA
Total Cnt/g AFIS	0.93	0.90	0.53	0.68
Trash Cnt/g AFIS	0.60	0.63	0.60	0.90
Dust Cnt/g AFIS	0.93	0.90	0.53	0.66
VFM AFIS	0.60	0.53	0.30	0.90
Area HVI	-	-	0.30	0.60
Cnt HVI	-	-	0.26	0.41

Summing up

On the basis of the carried out investigation it was stated, that:

- there is the rank correlation between the results of maturity measurement by means AFIS and microscopic method using polarized light,
- color of the naturally colored cotton can not be measured by means of HVI,
- measurement by spectrophotometer showed that there are significant differences between color of brown cotton of different origin,
- tenacity of the naturally colored cotton measured by means of HVI is at the same level that fiber tenacity determined by means of the tensile tester DSzU,
- contamination of the naturally colored cotton is much more higher than the contamination of middle stapled white Uzbek cotton taken for comparison,
- there is the rank correlation between the results of cotton contamination measurement by means of AFIS and HVI.

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