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Important Aspects of Cotton Colour Measurement

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Abstract
Colour is the basic criterion of cotton classification into cotton grade according to the Universal Cotton Standards. It also reflects the quality of other non-U.S. grown cotton. For years the quality of cotton has been assessed in an organoleptic way by cotton classers. Today there are plans to replace subjective visual grading by objective instrumental measurement. The colour grade of cotton is determined by the degree of reflectance (Rd) and the yellowness (+b), which are measured instrumentally using an High Volume Instrument (HVI). Some efforts undertaken have aimed at application of a spectrophotometer for cotton color measurement. The aim of this work was to investigate some of the problems of cotton color measurement. A comparison of the classer and HVI color grading was carried out for 32 cotton samples of non-U.S. origin. HVI measurement was performed using two HVI 900 systems. Agreement between the classer and HVI grading was not high, nevertheless it was comparable with that reported in literature, between the classer and HVI grading for U.S. cotton. Next cotton color measurement was conducted by means of an HVI 900 and a Datacolor 650 spectrophotometer. The results confirmed a strong correlation between the (Rd) from the HVI and the CIE L from the spectrophotometer.*

Key words: *cotton fibres, color assessment, spectrophotometer, high volume instrument.*

Introduction

Cotton is the basic textile raw material processed worldwide. In spite of strong competition from intensively developing man-made fibres, the share of cotton in the total fibre consumption is still high – ca. 35% [1, 2]. In the global cotton trade, a very important role is played by the quality classification of cotton. Traditionally, cotton is assessed by cotton classers in an organoleptic - visual way. However. human assessment is subjective and inadequate to consumer needs, especially in the prediction of fibre behaviour in cotton processing.

Today there are plans to replace the subjective visual grade determined by the cotton classer with objective instrumental measurement. According to Shofner and Co. [3, 4], in 2020 official cotton classing can be completely based on instrumental measurements. The following quality parameters are envisaged for cotton classing in 2020:
- current: length, Micronaire, strength, color and trash,
- new: moisture content, nep content, maturity and stickiness.

The first instrument officially introduced in the USDA/ASM for cotton classing was the Micronaire [3]. Nowadays there are many methods, techniques and devices for the measurement of cotton fibres. Some of them are for the measurement of particular parameters of cotton, e.g. the Micronaire, Pressley, Stelometer, Fibrograph, Thermodetector, etc. There are also measurement systems enabling complex evaluation of cotton quality, such as an HVI (High Volume Instrument), Premier ART, AFIS (Advanced Fibre Information System), IsoTester, FibroLab, and UAK 1 [4 - 6].

These devices and systems provide cotton producers, merchants and spinners with valuable information which can be used not only for cotton classing but also for predicting fibre performance and the quality of yarns manufactured from the cotton measured [7 - 17].

Cotton colour measurement

Colour is one of the most important properties of cotton. It can be affected by many factors connected with cotton cultivation: rainfall, freezes, insects, fungi, staining through contact with soil, grass, etc., as well as by the condition of cotton storage: moisture and temperature. [18, 19]. Thus colour deterioration indicates the reduced processing efficiency of cotton and, at the same time, a lower market value. Color deterioration also affects the ability of fibres to absorb and hold dyes and finishes [20].

Colour is a basic criterion which decides on the quality classification of cotton raw materials [21 -22]. According to the standardised procedures developed by the USDA (United States Department of Agriculture), colour grade describes the colour of cotton lint. There are standards for 25 colour grades of Upland cotton and five categories of "below grade" colour. Fifteen of these grades are represented in a physical form by boxes of cotton representing the full range of each standard, while the remaining 10 grades and five below grade categories are descriptions based on physical colour grade standards. The Universal Cotton Standards are globally accepted and routinely used in many countries as the standard for U.S. and non-U.S. grown cottons. They are used by over 50 countries worldwide. Some countries have developed their own cotton classification rules [23 - 25]. Nevertheless, the Universal Cotton Standards are commonly applied in international trade for the classification of cotton of different origin.

Cotton colour assessment is usually performed by cotton classers in an organoleptic way. A specially trained expert classifies the cotton sample by visual comparison with a set of physical standards under standard illumination. The visual assessment is performed in a room with grey walls, in which samples are placed on a black desk illuminated by light of 1200 lx illuminance.

In the 1930's the USDA started developing instrumental colour measurement [26]. Two parameters were then introduced into cotton grade classification: the grayness - the degree of reflectance (Rd) and the yellowness (+b). The degree of reflectance (Rd) indicates how bright or dull a sample is, whereas the yellowness (+b) indicates the degree of colour pigmentation. Normally, colour has three dimensions: hue, lightness and chroma. However, numerous investigations have confirmed that the hue for cotton is so nearly constant that measurement of lightness and chroma is sufficient to define the colour of cotton grades [27, 28].

Cotton color grade is determined instrumentally using a two-filter colorimeter. This objective method was developed by Nickerson and Hunter in the early 1940's to check USDA cotton grade standards. The Hunter scales used in a Nickerson Hunter Cotton Colorimeter indicate the percentage reflectance (Rd) in a vertical direction, which is a measure of the lightness of a sample, and in a horizontal direction the color code is determined by locating the point at which the (Rd) and (+b) values intersect on the Nickerson-Hunter cotton colorimeter diagram for Upland cotton [22, 29].

During a colour test, photodiodes absorb filtered light from the illuminated sample, and a microprocessor expresses results in two values: the percentage reflectance Rd expressing the lightness of cotton sample and the yellowness corresponding to the (+b) value in the Nickerson-Hunter's scale. Combination of both the lightness and yellowness determines the USDA Upland colour grade.

In the 1970's colorimeter technology was integrated into the HVI [26]. The HVI utilises a dual Xenon light source to illuminate a sample window measuring 2.8 inches by 3.6 inches to give a colour sample area of 10.1 square inches. The two light sources are located at 45 ° with respect to the viewing angle in order to comply with ASTM D 1729. This is to avoid the specular reflection component that is highly related to the smoothness of the surface. In the colour measurement process, cotton is placed on the sample window and compressed to a predetermined pressure. This pressure is necessary to avoid the influence of way of sample preparation on the measurement results. Light is reflected from the surface of the cotton sample through two proprietary interference filters, which are wide band interference filters – one located in the blue region of the spectrum and the other in the green region – chosen to approximate CIE standard observer functions. The light is measured by two separate detectors. The signals from these detectors are used to calculate the sample color (Rd) and (+b) with a precision to the nearest tenth of the measurement unit.

The degree of reflectance (Rd) determined by the HVI shows the brightness of the sample, which corresponds to the reflectance (Rd) represented in the Nickerson-Hunter color chart. The yellowness (+b) according to the HVI is determined using a yellow filter, which depicts the degree of cotton pigmentation. The yellowness (+b) from the HVI corresponds to the (+b) value represented in the Nickerson-Hunter colour chart. The yellowness (+b) is used in conjunction with the reflectance (Rd) value to determine the instrument-measured colour grade of cotton.

The color of cotton can also be measured by other instruments, such as the FQT/FibroLab (Lintronics) and IsoTester (Schaffner Technologies, Inc). The FibroLab and IsoTester are implemented in industrial practice, but their usage is not widespread. At present the HVI is considered as a universal method for cotton color measurement worldwide. Furthermore, this method is recommended by the Committee of Cotton Testing Method of the ITMF (International Textile Manufacturers Federation). Ca. 2600 HVI units: ca. 2200 from Uster and ca. 400 from Premier are applied in the world cotton industry, half of which are in China [5].

There are some problems connected with colour measurement using the HVI, which uses a two-dimensional system: the (Rd) and (+ b) to assess the colour of a sample and the color grade. However, the HVI approach is insufficient in comparison with visual human perception. HVI color results are correlated with the visual grading, but an agreement between the HVI and the classer grading is unsatisfactory – ca. 70% [18]. Two reasons for low HVI-classer agreement are as follows: the so-called boundary problem and the colorimeter – classer conflict [21]. The boundary problem is caused by the arbitrary assignment of the color grade by the HVI when the point (Rd, +b) on the Nikerson-Hunter diagram is placed close to the boundary between two grades. Colorimeter-classer conflict occurs when the HVI grading is "white", whereas the visual classing is "light spotted".

Moreover, cotton consumers: spinners and fabric manufacturers need colour data for cotton grading irrespective of the cotton origin. Textile manufacturers, e.g. in Europe process cotton originating from different regions of cultivation. This cotton is very often classified according to rules specific for the country of origin. In such cases HVI color grading according to the Universal Cotton Standards and the Nickerson-Hunter color diagram is inappropriate.

The reproducibility and repeatability of results from different HVI systems is also at an unsatisfactory level. An investigation carried out in the form of Bremen Round Tests and CSITC (Commercial Standardisation of the Instrument Testing of Cotton) round trials showed differences between the results of cotton colour measurement using different HVI systems. Potential causes are the as follows:

- the age and condition of the colour tiles,
- the age and condition of the lamps (HVI 900),
- the pressure of the color hand,
- HVI malfunction,
- the sample preparation.

An HVI does not measure intermediate spinning products, such as web, sliver and roving. Due to this fact, changes in color during cotton processing cannot be recognised on the basis of HVI results.

The colour measurement of naturally colored cotton is a very interesting and till now unsolved problem. It cannot be done by HVI. The problem is how to sell and buy naturally colored cotton, how to define its color, and how to ensure the color repeatability of textiles made of this cotton.

In view of the increasing export of U.S. cotton and the expectation of other countries having their own cotton classification systems, an important problem is to develop a method for the application of a spectrophotometer for cotton color assessment and classification. Similar expectations are expressed by representatives of the textile industry who commonly apply spectrophotometer L*a*b* data for the color assessment of textile goods.

The application of a spectrophotometer for the color measurement of cotton has been investigated by many researchers [30, 31]. The impact of glass use on cotton color measurement and minimising the glass effect was the object of an investigation carried out by Rodgers and Co. [29]. A project was implemented for the comparative analysis of color measurement by 8 spectrophotometers: 4 bench-top and 4 portable. The relationships L* ↔ Rd and b* ↔ b as well as the impact of the instrumental and procedural variables on color results were investigated. Very good agreement between the bench-top spectrophotometers and moderate agreement between the portable units were reported for the L*, b* and ΔE (CIE color difference) for measurement without glass. For all the bench-top units, very similar linear relationships were obtained for the L* ↔ Rd and b* ↔ b. The use of glass significantly influenced the L* readings and color differences ΔE between the particular instruments [29].

It should be noted here that the objects of the investigations carried out by Shofner and Co. as well as by Rodgers and Co. were not real cotton samples. Shofner and Co. measured tails provided with the spectrophotometer and painted plaits, whereas Rogers and Co. concentrated on color tiles, AMS standard tiles and AMS standard cotton batts.

Experimental

The aims of the work were:
- a comparison of classer and HVI color grading for non-U.S. grown cottons,
- a comparative analysis of cotton color measurement by means of an HVI and spectrophotometer.

Cotton color measurement was performed using an HVI 900 from Uster and a Datacolor 650 spectrophotometer.

Comparison of Classer and HVI Color Grading

Comparison of classer and HVI color grading was undertaken for cotton of non-U.S. origin. 32 cotton samples originating from Central Asia, mostly from Uzbekistan, were assessed and classified into a color grade according to the HVI color measurement and visual classer grading based on the Universal Cotton Standards. Two HVI 900 systems were used in this part of experiment. Results of the HVI measurement and a comparison of the classer and HVI color grading are presented in ***Table 1***.

Table 1. *Comparison of classer and HVI color grading; □ - agreement between the classer and HVI, ■ - disagreement between the classer and HVI, GM - Good Middling, GMLtSp - Good Middling Light Spotted, SM - Strict Middling, SMLtSp - Strict Middling Light Spotted, M - Middling, LMLtSp - Low Middling Light Spotted.*

No.	Classer grade	HVI 900 No. 1			HVI 900 No. 2		
		Rd	+ b	CG	Rd	+ b	CG
1	GM	77.9	10.7	**12-2**	78.3	11.1	**12-1**
2	GM	78.9	10.7	**12-1**	78.7	10.6	11-3
3	GM	78.6	10.1	11-4	79.3	9.7	11-4
4	GM	79.7	10.7	11-3	79	10.7	11-3
5	GM	79.1	10.1	11-4	78.9	10.5	11-3
6	GM	77.5	9.6	**21-3**	77.6	9.3	**21-4**
7	GM	79.2	9.6	11-4	77.8	9.5	**21-3**
8	GM	76.9	10.2	**21-3**	78.5	10.1	11-4
9	GM	78.2	10.6	**12-2**	78.2	9.9	11-4
10	GM	79.0	10.7	**12-1**	79	10.6	11-3
11	GM	78.7	10.9	**12-1**	79.1	10.6	11-3
12	GM	78.7	10.3	11-4	78.1	10.3	11-4
13	GM	79.4	9.8	11-4	77.6	10.2	11-4
14	GMLtSp	79.0	10	**11-4**	78.2	10.0	**11-4**
15	GMLtSp	77.2	11.5	12-1	77.2	11.0	12-2
16	GMLtSp	76.4	11.2	12-2	76.8	11.2	12-2
17	GMLtSp	79.0	10.3	**11-3**	78.2	10.1	**11-4**
18	GMLtSp	79.4	10.5	**11-3**	77.6	10.4	12-2
19	GMLtSp	78.6	10.9	12-1	78.5	10.8	12-1
20	SM	77.9	10.2	**11-4**	76.9	9.8	21-4
21	SM	77.7	9.6	21-3	77.3	9.3	21-4
22	SM	78.7	10.1	**11-4**	76.9	9.1	**31-3**
23	SM	78.7	9.3	21-3	78	9.2	21-4
24	SM	79.0	8.3	21-2	78.9	8.0	**31-1**
25	SM	77.6	10.5	**12-2**	76.9	10.1	21-3
26	SM	76.7	9.9	21-4	78.1	9.8	21-3
27	SMLtSp	76.7	10.3	22-1	76.8	10.5	22-3
28	SMLtSp	76.7	10.4	22-1	76	10.7	22-1
29	SMLtSp	77.5	9.5	**21-4**	76.5	9.1	**31-3**
30	M	75.6	10.1	**22-2**	75.9	9.4	31-3
31	M	74.9	9.2	31-3	74.1	9.1	31-4
32	LMLtSp	67.0	9.3	52-1	67	9.0	52-1

From a practical point of view, differences between the results from both HVI systems are not high with respect to the (Rd) and (+b) ranges for cotton on the whole and for particular cotton grades. The average difference between the (Rd) readings from HVI No. 1 and HVI No. 2 is 0.66, the highest (Rd) difference being 1.8. The average difference between the (+b) readings from both HVI systems is 0.28, the highest one being 1.0 (***Table 2***).

A strong correlation relationship was found between the results from both HVI systems. The value of correlation coefficient between the (Rd) readings from HVI No.1 and HVI No.2 is 0.934, whereas between the (+b) readings it is 0.903.

Colour grading agreement between the classer and both HVI systems was noted in 15 cases (47%), whereas agreement between both HVI systems occurred in 19 cases (60%) (***Table 1***). The number of compatible assessments between the classer and HVI was bigger for instrument No. 2 (75%) than for instrument No. 1 (53%). The majority of disagreement cases concerned cotton samples classified into neighbouring grades: GM and GM LtSp – typical *colorimeter-classer conflict* [21].

Table 2. *Differences between the results of (Rd) and (+b) measurements using two HVI devices.*

Difference	Rd	+ b
Average	0.66	0.28
Maximum	1.8	1.0
Minimum	0.0	0.0

Table 3. *Summary of colour measurement results from the HVI 900.*

Parameter	Number of specimens	Average	Min	Max
(Rd)	68	77.38	67.60	80.20
(+ b)	68	10.82	8.30	15.60

Table 4. *Summary of color measurement results from the Datacolor 650.*

Parameter	Number of specimens	Illuminant - D 65			Illuminant - A			Illuminant - F 11		
		Aver.	Min	Max	Aver.	Min	Max	Aver.	Min	Max
L*	68	89.93	85.59	91.43	90.78	86.39	92.12	90.50	86.13	91.89
a*	68	0.93	0.48	2.07	3.52	2.55	5.11	1.34	0.89	2.38
b*	68	11.12	8.10	13.68	11.75	8.51	14.65	12.53	9.13	15.50
C*	68	11.16	8.12	13.83	12.12	1.52	15.15	12.61	9.18	15.68
h	68	85.27	81.41	86.75	73.36	70.53	74.24	83.91	81.17	84.81

Table 5. *Values of the correlation coefficients between the results from the HVI and the spectrophotometer;* ***Italic****– statistically significant correlation.*

Illuminant	Colour parameter from the spectrophotometer	$R_{x, y}$	
		(Rd) from HVI	(+ b) from HVI
D 65	L *	***0.87***	***-0.31***
	a*	***-0.50***	***0.54***
	b*	-0.16	***0.53***
	C*	-0.17	***0.53***
	h	***0.57***	***-0.46***
A	L*	***0.87***	***-0.27***
	a*	***-0.38***	***0.57***
	b*	-0.18	***0.53***
	C*	-0.21	***0.49***
	h	***0,63***	***-0,33***
F 11	L*	***0.87***	***-0.28***
	a*	***-0.46***	***0.55***
	b*	-0.18	***0.53***
	C*	-0.18	***0.53***
	h	***0.59***	***-0.41***
D65	W_{CIE}	***0.55***	***-0.55***
	T_{CIE}	***0.45***	***-0.60***

The level of compatibility between the classer and HVI color grading is not high; nevertheless, it is comparable, especially in the case of HVI No. 2, with the level of agreement between the classer and HVI grading for U.S. cotton is mentioned in the papers cited [18, 22]. The results obtained can be assessed as satisfactory taking into consideration that the comparative analysis was conducted for cotton from Central Asia, which is usually classified according to the Uzbek or GOST standards. An assessment of Uzbek cotton appearance and its grading according to the U.S. standards is difficult due to the quite different preparation of Uzbek cotton in comparison to that of U.S. Upland cotton. The results also confirmed that looking for an alternative to the HVI method of cotton color measurement is justifiable and should be continued.

Comparative Color Measurement using HVI and a Spectrophotometer

Color measurement was performed by means of an HVI 900 and Datacolor 650 spectrophotometer. Datacolor spectrophotometers are relatively often used in the Polish and European textile industries for the color measurement of yarns and fabrics as well as for dyestuff preparation. The measurement was done without glass in order to eliminate the "glass effect". The fact that traditional visual classer assessment is done without glass was also an important factor in the choice of this method.

Spectrophotometer measurement was performed under different illuminants: D 65, A and F 11, which are standard CIE illuminants. The D 65 illuminant represents natural daylight with a correlated color temperature of 6500 K; illuminant A is equivalent to a blackbody radiator with a color temperature of 2856 K, and the F 11 illuminant represents fluorescent light with a correlated color temperature of 4000 K. Different illuminants were used in order to check under which illuminant the correlation between the results from the HVI and the spectrophotometer is the strongest.

The following color parameters were assessed:
- the lightness - L*,
- the chromaticity coordinates:
- a* – green/red,
- b* – blue/yellow,
- C* – chroma,
- h – hue angle.

68 white cotton samples of different origin were measured: 32 Uzbek cotton samples measured using the method described in the previous part of the investigation, and 36 additional samples of different origin: from Chad, Turkey, Benin, Mali, Sudan, Yemen, the U.S. and Greece. An enlargement of the sample number allowed to perform statistical analysis of the results. Thanks to the addition of cotton samples of different origin, the results and relationships between the HVI and spectrophotometer readings obtained can be considered as independent of the cotton origin. A summary of the results from the HVI are presented in ***Table 3***, and those from the Datacolor - in ***Table 4***.

The range of b* values from the spectrophotometer is similar to that of the yellowness (+b) from the HVI, whereas the range of lightness L* from the spectrophotometer shifted in the direction of higher values in comparison to the range of reflectance (Rd) from the HVI.

A correlation analysis showed a correlation relationship between the values of the degree of reflectance (Rd) from the HVI and the color parameters L*, a* and h from the spectrophotometer (***Table 5***). A strong correlation was found between the degree reflectance (Rd) from the HVI and the lightness L* from the spectrophotometer. The correlation between the (+b) from the HVI and the CIE b* from the spectrophotometer is weak. The statistical analysis confirmed that the correlation relationships between the (Rd) and the L* as well as between the (+b) and the b* are statistically significant.

Figures 1 - 6 (the lines present not function but tendency of changes) show

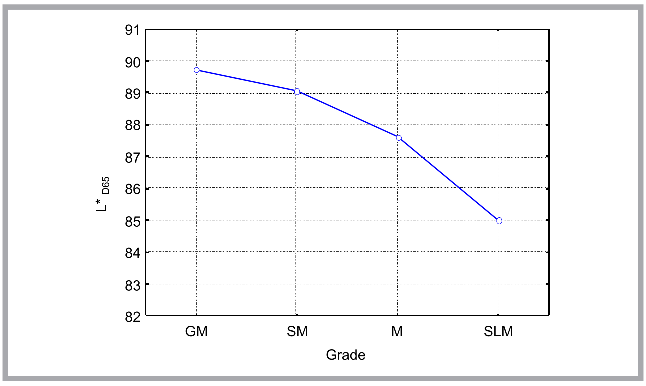

Figure 1. Lightness L from the spectrophotometer as a factor of the color category.*

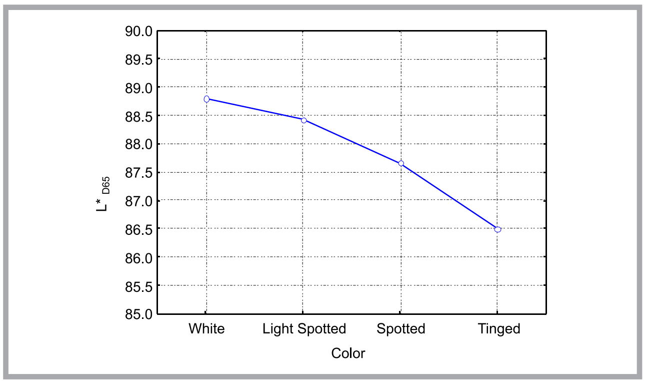

Figure 2. Lightness L from the spectrophotometer as a factor of the cotton grade.*

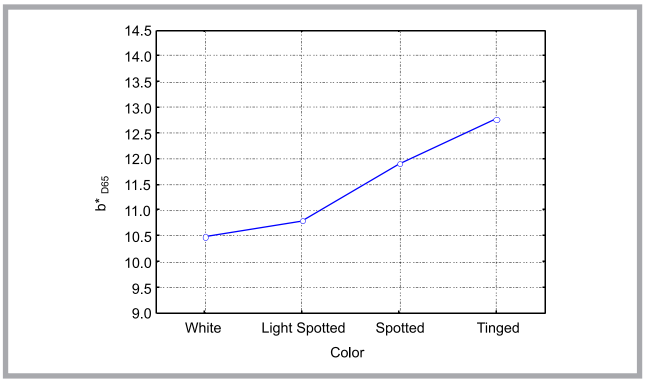

Figure 3. Color parameter b from the spectrophotometer as a factor of the color category.*

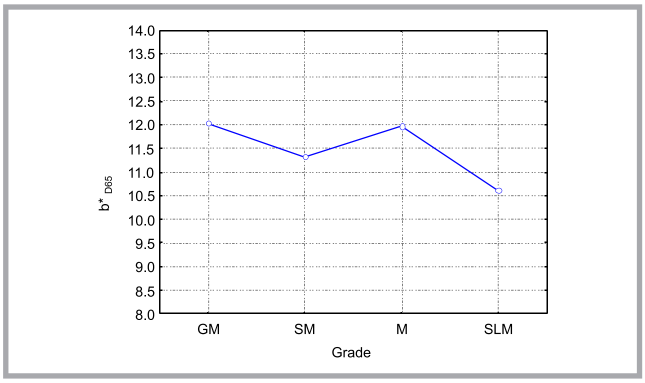

Figure 4. Color parameter b from the spectrophotometer as a factor of the cotton grade.*

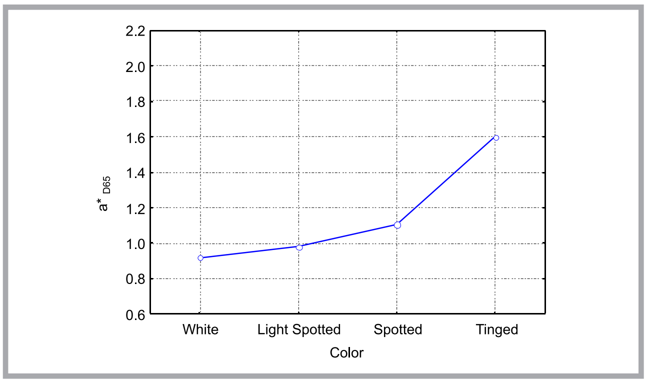

Figure 5. Color coordinate a from the spectrophotometer as a factor of the color category.*

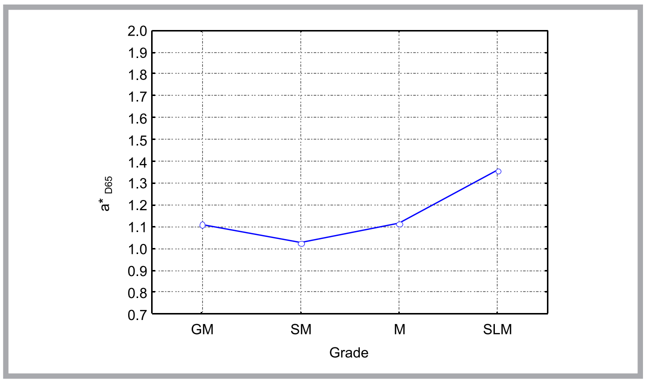

Figure 6. Color parameter a from the spectrophotometer as a factor of the cotton grade.*

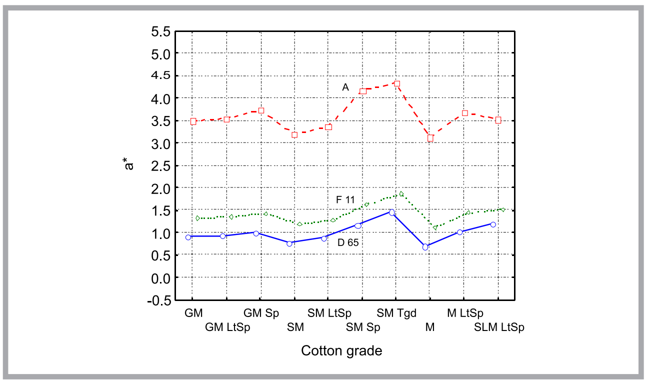

Figure 7. CIE a color parameter from the spectrophotometer as a factor of the cotton grade and the illuminant.*

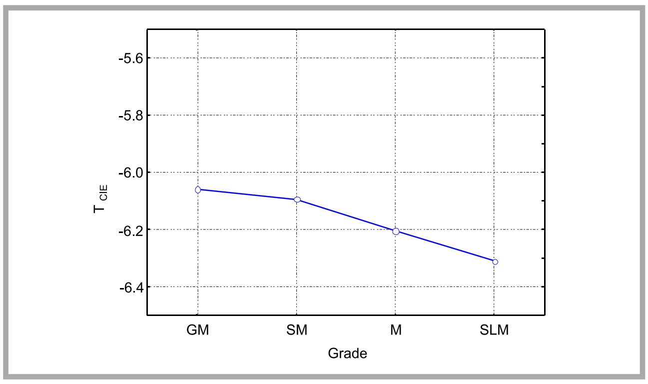

Figure 8. Parameter calculated according to the T_{CIE} formula as a factor of the cotton grade.

average values of the CIE L*a* b* parameters from the spectrophotometer for cotton samples representing particular colour categories (white, light spotted, spotted and tinged) and cotton grades (Good Middling, Strict Middling, Middling, and Strict Low Middling). It can be seen that the lightness L* decreases in the direction from white to tinged and from GM to SLM. The parameters b* and a* increase from white to tinged, whereas their changes with the cotton grade do not show any clear tendency. The statistical analysis (ANOVA) confirmed the statistically significant influence of both the color category and the cotton grade on the lightness L* from the spectrophotometer as well as the statistically significant influence of the color category on parameters a* and b*.

The analysis also confirmed the statistically significant influence of the kind of illuminant on CIE L*a*b* readings, especially on CIE a* values (***Figure 7,*** see page 21), which should be taken into consideration when developing a method of cotton color measurement using a spectrophotometer.

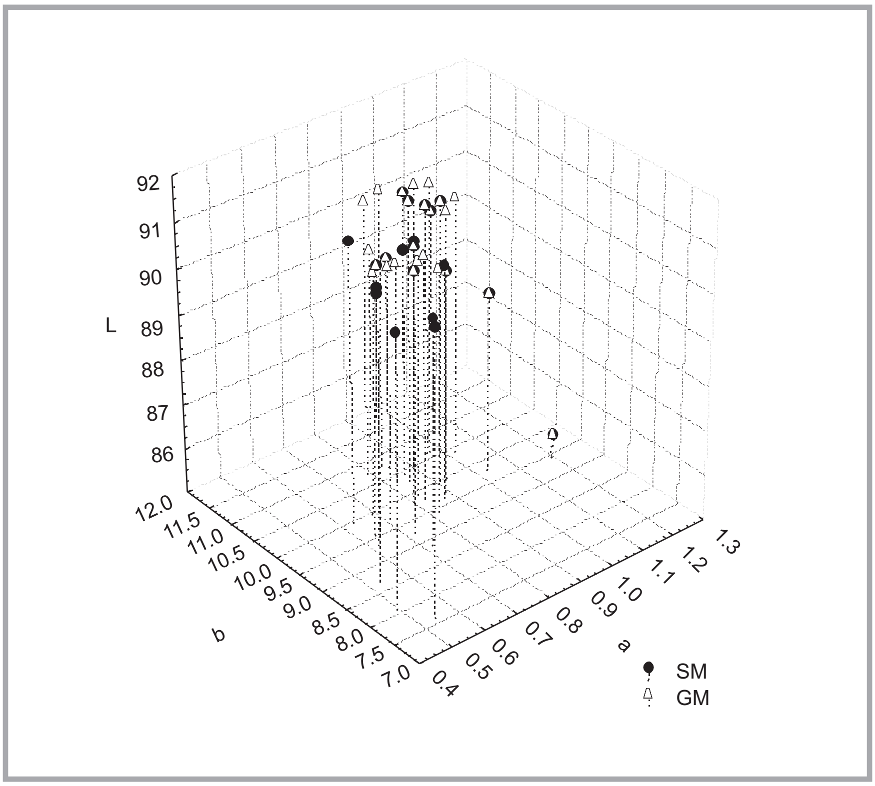

Figure 8. *Comparison of CIE L*a*b* readings from the spectrophotometer for cotton samples classified acc. to the classer grading into the following grades: Good Middling (GM) and Strict Middling (SM).*

It was also found that the cotton samples classified into the same color grade according to the HVI results differed from each other in the range of coordinates L*, a* and b* from the spectrophotometer. For example, 23 samples classified into the Good Middling Light Spotted grade were characterised by the color parameters from the spectrophotometer in the following ranges:

- L* - 89.02 - 91.25,
- a* - 0.72 - 1.31,
- b* - 9.73 - 12.93.

Similarly, the cotton samples classified into the same color grade according to the classer grading were characterised by a wide range of color coordinates from the spectrophotometer. Moreover, it was noted that the results from the spectrophotometer do not separate neighbouring color grades properly (***Figure 8***).

On the basis of the results from the spectrophotometer for each cotton sample, 2 additional color parameters were calculated: the Whiteness and Tint indexes, which were calculated according to CIE formulas as follow:

$$W_{CIE} = Y + 800\,(x_o - x) + 1700\,(y_o - y) \quad (1)$$

$$T_{CIE} = 900\,(x_o - x) - 650\,(y_o - y) \quad (2)$$

where (x_o, y_o) are the coordinates of the achromatic point for the given illuminant. Whiteness is an attribute by which an object is judged to approach the preferred white. The meaning of the Tint index is as follows:

- $T_{CIE} > 0$ - the white has a greenish shade,
- $T_{CIE} < 0$ - the white has a reddish shade.

In all cases the value of T_{CIE} was < 0, which means that the cotton samples measured have a reddish shade. For all samples the absolute values of the index calculated according to equation (2) are higher than 3, thus it cannot be called a Tint index. Nevertheless, in comparison to the rest of the color parameters from the spectrophotometer, this index shows the strongest correlation ($R_{x,y}$ = - 0.60) with the yellowness (+b) from the HVI (***Table 5***). Moreover, contrary to the coordinates CIE b* and CIE a* from the spectrophotometer, the index calculated according to the T_{CIE} formula (2) is significantly influenced by the cotton grade (***Figure 9*** see page 21), whose value decreases in the direction from GM (Good Middling) to SLM (Strict Low Middling). This implies that maybe this index should be taken into consideration together with the lightness CIE L* in further investigation of spectrophotometer application in cotton color measurement and grading.

Conclusions

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

- the compatibility between the classer and HVI grading for cotton not. originated in the U.S is not high, ca. 50 - 75%,
- the insufficient agreement between the classer and HVI grading confirmed the necessity of looking for an another method of cotton color measurement as an alternative to HVI,
- cotton color assessment in the globally recognised CIE L*a*b* color system is important for cotton consumers, especially spinners and textile manufacturers, in order to ensure proper quality and the color uniformity of textile products,
- the correlation between the reflectance (Rd) from the HVI and the lightness L* from the spectrophotometer is strong and statistically significant,
- the correlation between the (+b) from the HVI and the CIE b* from the spec-

trophotometer is weak but statistically significant,

- the results obtained confirmed the statistically significant influence of both the color category and cotton grade on the lightness L* from the spectrophotometer as well as the influence of the color category on parameters a* and b*.
- the changes in b* and a* from the spectrophotometer with respect to the cotton grade (GM, SM, M, SLM) do not show any clear tendency,
- the kind of illuminant influences CIE L*a*b* readings from the spectrophotometer, especially the CIE a* values. This should be taken into consideration when developing a method of cotton color measurement using a spectrophotometer.
- the cotton samples classified into the same color grade according to the HVI results differ from each other in the range of parameters L*, a* and b* from the spectrophotometer. It is possible to determine the ranges of the color parameters according to the spectrophotometer for particular color grades of cotton according to the Universal Cotton Standards. The application of a spectrophotometer for cotton classification requires further investigation based on a much bigger number of cotton samples representing the whole range of color grades,
- the parameter calculated according to the T_{CIE} formula on the basis of the results from the spectrophotometer shows the highest correlation with the yellowness (+b) from the HVI in comparison to the rest of the color coordinates from the spectrophotometer. This is also significantly influenced by the color category and cotton grade, which implies that the parameter based on the T_{CIE} formula and lightness CIE L* should be taken into consideration in further investigation of spectrophotometer application in cotton grading.

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