Michal Vik[1], Nayab Khan[1*], Bekir Yildirim[2], Martina Vikova[1]

Non-contact Method for Measurement of Colour Variation in a Cotton Sample

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[1] **Technical University of Liberec, Department of Material Engineering Faculty of Textile Engineering,**
Czech Republic
* E-mail: knayabrpm@yahoo.com

[2] **Erciyes University, Department of Textile Engineering, Faculty of Engineering,**
Turkey

Abstract
Colour is the visual perceptual property in the cotton grade classification of Universal Cotton Standards. We undertook an experimental study on the variation in cotton colour using the Non-contact method. Rd (degree of reflectance) and +b (yellowness) are globally recognized colour parameters of cotton, which are measured by HVI (High Volume Instrument). The Non-contact method is used for the evaluation of colour variation within cotton samples. The results obtained from the Non-contact method were compared with those of other conventional methods used globally for the color measurement of cotton fibers. Additionally image analysis is interpreted with the variation in cotton colour. Results confirmed a strong co-relation between the Non-contact method and image analysis for the colour variation of cotton.

Key words: *cotton, Rd, +b, HVI (High Volume Instrument), image analysis.*

Introduction

Cotton possesses great importance in the textile world. Its economic value is very high as compared to other natural fibers. The share of cotton fiber in the textile market is exceptionally large and is considered to be the most important raw material in textile. Cotton industries are the backbone of economic growth in both developing and non-developing countries [1]. The quality of cotton is decided on the basis of some physical properties like length, strength, micronaire, colour and the uniformity index. Colour plays an important role in cotton grading as it has a significant effect on the further end-product. The colour property of cotton fiber is affected by rainfall, insect attacks and contact with soil [2]. Colour can also be affected by an excessive moisture and temperature level during storage, both before and after ginning [3]. Hence the colour deterioration of cotton fiber results in a great loss in the economic value of cotton fiber. Also the color deterioration of cotton fiber affects its ability in dyeing and finishing process [4]. Thus the precise and accurate measurement of cotton colour is difficult as a single pound of cotton may contain 100 million or more individual fibers.

The testing of raw cotton in spinning mills before going into the process for yarn manufacturing is a very common phenomenon. Normally two or three random samples are taken from a cotton bale of 160-220 kg, which represents the properties of the whole bale of cotton. In recent years, a lot of work has been done to improve the overall colour grading system of cotton samples [5]. The method most commonly used for cotton color measurement is by means of a colorimeter, which is not capable of giving information on colour variation within the sample. As the cotton sample represents a major part of the cotton bale, it is necessary to measure the colour variation within the sample as it represents the whole bale of the cotton. The color of cotton is a combined property of individual fibers. A uniform color property is an extremely desirable quality of the processing [6].

Variation in the properties of cotton fiber should be in the narrow range. Normally cotton colour assessment is performed by instruments, but the final decision about the colour grade of cotton has been taken by the cotton classer till now due to disagreement between the instrumental measurement and visual measurement. Although the sample of cotton has its own average value of the color, variation within the cotton sample exists [1]. A colour space system which should be linear and able to give improved perception of colour is greatly needed in the cotton colour grading system, which should lead to a non-linear transformation of the CIEXYZ color space system [7]. The most recognised colour space system in the world is the CIELAB system, which is a three dimensional system and is commonly known as the L*a*b* system [8]. In this system L* represents lightness or darkness, a* – redness or greenness, and b* – the yellowness and blueness of the sample [9].

The colorimeter method, which is used for the colour measurement of cotton fiber, is very old, and it shows great disagreement when compared with the visual grading system of cotton. In recent times cotton colour has been measured with in so many different ways. Cotton colour measurement by spectrophotometer is one of those methods. Strong L*↔Rd and b*↔+b have been observed. The use of L*a*b* as a cotton grading system and relating them with the global colour parameters of cotton is a great achievement. During HVI (High Volume Instrument) measurement, the variable which has a negative impact on cotton color measurement is the glass in front of the cotton sample [10]. The use of the image processing technique for cotton color measurement was also an enhancement to measure the exact colour of trashy cotton as HVI is not capable of predicting the precise colour parameters of cotton. This research enabled to remove the effect of trash on the colour measurement of cotton fiber [11].

Hence there is always space for a new method for the colour determination of cotton fiber. The color parameters (Rd, +b) used for cotton colour grading have been in use since 1950s, but are not globally recognised for colour measurement [8]. Some previous studies have shown that variation within the sample exists as compared to that between samples [1]. The HVI colour measurement system comprises of two broad band filters for colour grading, in which one filter is responsible for the illuminance (Rd) and the second for the yellowness (+b). However, these two filters are not enough to cover the full spectrum, thus affecting the colour grading system [12].

The main focus of the research was to use a unique method known as the non-contact method to measure the colour variation in a cotton sample, in which LEDs were used for colour measurement. The digital imaging processing technique was also used for the measurement of colour variation within the sample, by which data of the cotton images scanned were also examined and the results compared with the HVI and non-contact methods to check the colour variation in the cotton sample.

Material and methods

In this research, 10 cotton samples of known Rd and +b value were used in order to investigate colour variation in cotton samples, provided by the CCRI, Multan, Pakistan. The research conducted in this study reveals a variation in color which further affects the cotton grade when it is classified. The properties of the cotton samples measured with HVI are given below ***Table 1***.

All the samples were measured at the Laboratory of Colour and Appearance Measurement of the Technical University of Liberec, Czech Republic. The laboratory conditions used for the colour measurement were (20 ± 2°C and 65 ± 2% RH).

Each sample was analysed by a non-contact colorimeter CA-210 (Minolta, Japan) from a controlled distance of 30 cm. As basic set calibration samples, grey scale samples from the X-Rite Color Checker standard were used. Such calibration allows the transformation of measured values x,y and Lv (luminance value) into CIE color space XYZ (***Table 2***) for both the light sources used and 2° observer, which was an internal setup of CA-210. Then Rd, a_{Rd} and b_{Rd} values were computed using expansion factors [13]:

Ka = 172.3; Kb = 67.2 for Illuminant D65 and Ka = 171.9; Kb = 71.6 for V-WLED (Violet Chip White LED).

$$Lv \cong Y \quad (1)$$

The resulting values were subsequently compared with one another and with those of the contact method using a correlation plot. It is also shown that the results of telescopic colour measurements represent a very strong relationship with the HVI colour measurements. The non-contact method is capable of measuring colour from different points of the sample so that measurements are more reliable, unlike averaging the colour of the measurement area, as is applied in the HVI system [14]. Therefore this method was used for colour analysis of cotton samples in this research, where the lighting cabinet in which the cotton sample is illuminated is equipped with a D65 illuminant, hence a a D65 illuminant (6500K) was used for the colour measurement of cotton in the non-contact method. It is the only daylight source that was actually measured. The other daylight sources (D75 and D50) were mathematically derived from these measurements. It accentuates blue and subdues green and red, commonly used as a primary light source in colour measurement instrumentation. It is derived from the average of

Figure 1. *AT colour light cabinet (equipped with Violet Chip White LEDs) and Konica Minolta CA-210 used for colour measurement with non-contact method.*

Table 1. *Properties of cotton samples measured with HVI.*

Cotton sample	Length, mm	Tenacity, cN/tex	Elongation, %	Mic	Rd (reflectance)	+b (yellowness)
159 CCRI	23.8	23.92	6	5.4	60.6	9.1
2013/2 CCRI	25.4	27.35	5.8	3.8	64.9	11.6
2012/3 CCRI	26.6	27.55	6.3	3.7	71.5	12.7
131 CCRI	24.9	27.65	5.4	3.8	66.1	8.4
2014/1 CCRI	24.7	26.37	6.1	4.5	68	13.6
2014/3 CCRI	26.4	28.63	5.9	3.5	74.7	8.9
117 CCRI	24.6	24.61	5.2	4.9	53	10.6
149 CCRI	25.2	25.20	5.3	4.8	68.2	8.8
156 CCRI	25.2	28.04	5.4	3.8	62.3	9.6
143 CCRI	27.3	29.31	6.3	3.9	64.4	9.6
2014/2 CCRI	26.8	26.86	6.1	3.8	76.4	12
109 CCRI	25.4	30.98	6	3.2	58.5	8.9

Table 2. *Transformation of value x, y and Lv values into CIE XYZ system.*

Sample No.	X	Y	Z	x	y	Lv
159 CCRI	56.08	59.48	50.69	0.337	0.358	176
2013/2 CCRI	56.91	61.73	49.28	0.343	0.360	177
2012/3 CCRI	58.91	68.76	47.16	0.351	0.368	183
131 CCRI	59.57	63	53.77	0.338	0.3573	187
2014/1 CCRI	57.60	64.05	45.98	0.352	0.367	178
2014/3 CCRI	64.23	67.83	57.40	0.339	0.358	201
117 CCRI	39.54	48.74	34.13	0.342	0.362	124
149 CCRI	58.15	61.42	52.47	0.338	0.357	182
156 CCRI	57.13	60.39	50.27	0.341	0.360	179
143 CCRI	53.66	56.76	47.75	0.339	0.359	168
2014/2 CCRI	66.21	69.86	55.84	0.345	0.364	207
109 CCRI	53.13	56.22	48.27	0.337	0.357	167

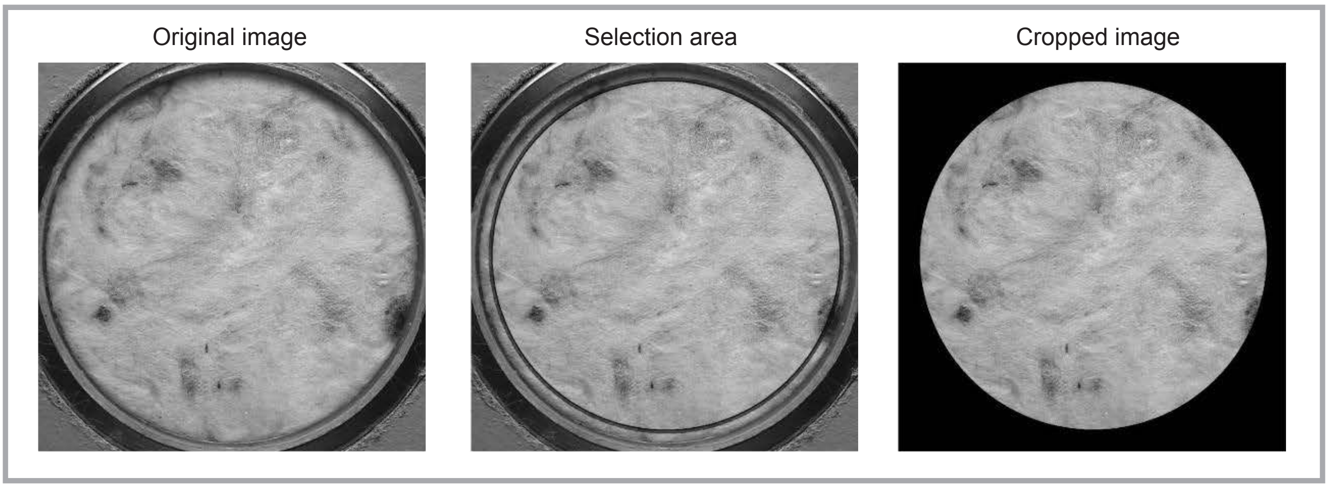

***Figure 2.** Original and cropped images of samples.*

measurements made of light coming in from a north facing window in the northern hemisphere on an overcast day at various times throughout the day at various times of the year. The cotton observer initially used daylight for cotton sorting. Morover D65 was also used in the cotton colour measurement instruments. Hence it was necessary to use same colour temperature as that already used in the cotton industry for better comparison of results with other globally recognised methods. Another part of the research was based on visual inspection in which D65 was chosen for the colour measurement of cotton.

***Table 3.** Summary of descriptive statistics of values measured using digital camera.*

	Cotton samples	159 CCRI	2013/2 CCRI	2012/3 CCRI	131 CCRI	2014/1 CCRI
L*	Min	0.36	2.18	13.66	0.99	18.04
	Max	98.96	99.12	98.49	99.07	98.66
	Mean	73.73	74.92	74.80	74.41	75.54
	Median	75.45	76.13	75.36	76.05	76.09
	Std.Dev.	8.78	7.38	5.39	8.06	4.87
a*	Min	-16.77	-12.18	-12.45	-13.21	-12.13
	Max	12.93	13.10	6.76	10.25	6.24
	Mean	-4.89	-4.17	-4.38	-4.87	-4.46
	Median	-4.92	-4.20	-4.32	-4.84	-4.37
	Std.Dev.	2.02	1.85	1.70	1.88	1.66
b*	Min	-7.92	-2.92	-3.46	-1.84	-0.74
	Max	31.60	31.03	27.72	36.94	27.14
	Mean	2.44	8.18	7.50	7.62	10.00
	Median	2.21	7.85	7.39	7.44	9.88
	Std.Dev.	3.11	3.43	3.15	3.04	2.78

***Table 4.** Summary of descriptive statistics of values measured using digital camera for cotton samples.*

	Cotton Samples	2014/3 CCRI	117 CCRI	149 CCRI	156 CCRI	143 CCRI
L*	Min	3.94	0.72	3.18	1.78	10.94
	Max	98.67	99.34	98.85	99.07	98.58
	Mean	76.51	73.90	75.93	74.99	76.83
	Median	77.36	75.39	77.07	76.36	77.16
	Std.Dev.	6.14	9.46	7.03	8.29	4.85
a*	Min	-12.56	-14.29	-13.47	-14.59	-12.46
	Max	10.06	12.40	12.29	12.54	6.77
	Mean	-4.77	-5.32	-5.03	-5.20	-5.00
	Median	-4.77	-5.34	-5.06	-5.22	-4.98
	Std.Dev.	1.92	2.10	1.84	2.01	1.73
b*	Min	-5.60	-1.78	-1.59	-2.14	-2.68
	Max	25.51	44.55	31.66	31.47	24.74
	Mean	3.17	9.15	7.90	8.09	7.08
	Median	2.89	8.95	7.81	8.10	6.94
	Std.Dev.	2.98	3.70	2.84	3.19	3.06

Telescopic color measurement method

Three samples, which are shown in the figure, were measured 10 times using the non-contact method. The instrument settings were the same as those used with the incandescent light source (with a correlated colour temperature of (6500K), which is known as an illuminant "D65" and 2° observer condition. A light cabinet (Atelier Technik, Czech Republic) was used for measurement, in which a D65 illuminant was used, shown in ***Figure 1***. LEDs were used for this light source and to see the effect on the samples.

Digital image processing for colour measurement

All the cotton samples were placed in a light cabinet and images acquired under the same illumination conditions with a digital camera – "Panasonic SDR-H280". The auto white balance and other auto coloor correction functions of the camera were switched off so that the image colours obtained were not altered significantly. The colour values of images might deviate from the real colorimetric measurements due to the lack of calibration and characterisation of the digital camera. However, as previously mentioned, the images were acquired under same conditions without colour corrections, and thus relative comparisons of colour measurements between samples were meaningful.

The original images (72 dpi resolution) are shown in ***Figure 2***. The images are cropped in order to include a 700x700 pixel area, as shown in the cropped image.

All images were captured in an RGB space. Images were converted from the RGB space into a CIE L*a*b* space, in which the a* axis corresponds to red–green opponent hues, with distances along the positive a* axis corresponding to a measure of redness. Colour images in the RGB space can be converted into a CIE L*a*b* space with the help of the following conversion equations.

$$L^* = 116 f(Y/Y_n) - 16 \quad (2)$$

$$a^* = 500[f(X/X_n) - f(Y/Y_n)] \quad (3)$$

$$b^* = 200[f(Y/Y_n) - f(Z/Z_n)] \quad (4)$$

Where $f(t) = t^{1/3}$ if t > 0.008 856, else $f(t) = 7.787t + 16/116$

(X_n, Y_n, Z_n) are (X, Y, Z) values for the reference (neutral) white point. The transformation from RGB to CIE L*a*b* requires an intermediate step called XYZ:

$$X = 0.412453R + 0.357580G + 0.180423B \quad (5)$$

$$Y = 0.212671R + 0.715160G + 0.072169B \quad (6)$$

$$Z = 0.019334R + 0.119193G + 0.950227B \quad (7)$$

Results and discussion

This research investigated variation in the cotton color standard with a new method (non-contact method) using LEDs as a light source. Standard samples obtained from the AMS department with known Rd and +b values wer used for experiments [15]. The results obtained from this new method were compared with other image analysis as well as HVI results. Moreover the spectral data obtained for these samples with the help of a miniscan hunterlab was also used to compare the results with those of the spectrophotometer.

Y values of sample 159 CCRI measured by the non-contact method vary between 56.02 and 61.42, sample 2013/2 CCRI between 53.62 and 59.87, sample 2012/3 CCRI between 57.16 and 64.71, sample 131 CCRI between 60.92 and 69.38, sample 2014/1 CCRI between 56.79 and 60.27, sample 2014/3 CCRI between 62.21 and 71.86, Sample 117 CCRI between 41.5 and 53.8, sample 149 CCRI between 57.6 and 66.87, sample 156 CCRI between 56.62 and 66.87, sample 143 CCRI between 49.63 and

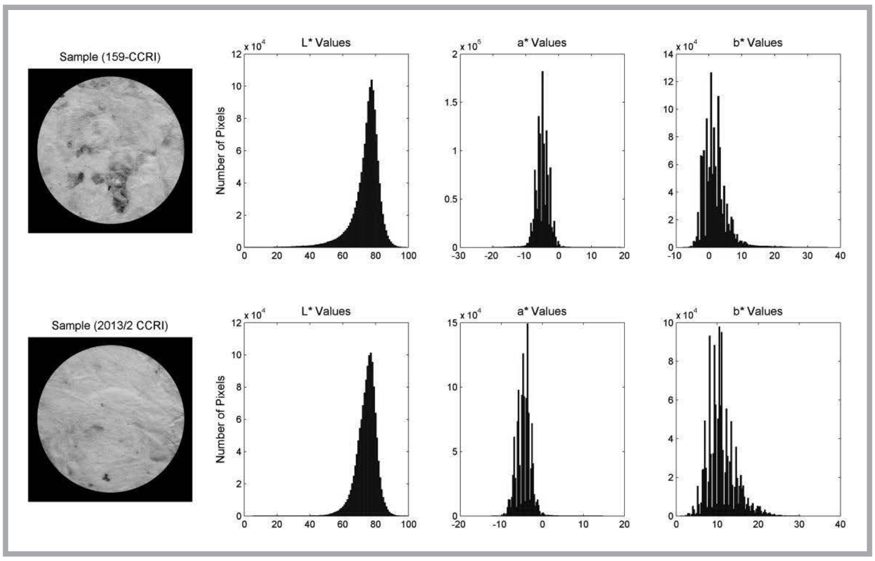

Figure 3. *Histograms of L*a*b* values for cotton samples (159 CCRI) and (2013/2 CCRI).*

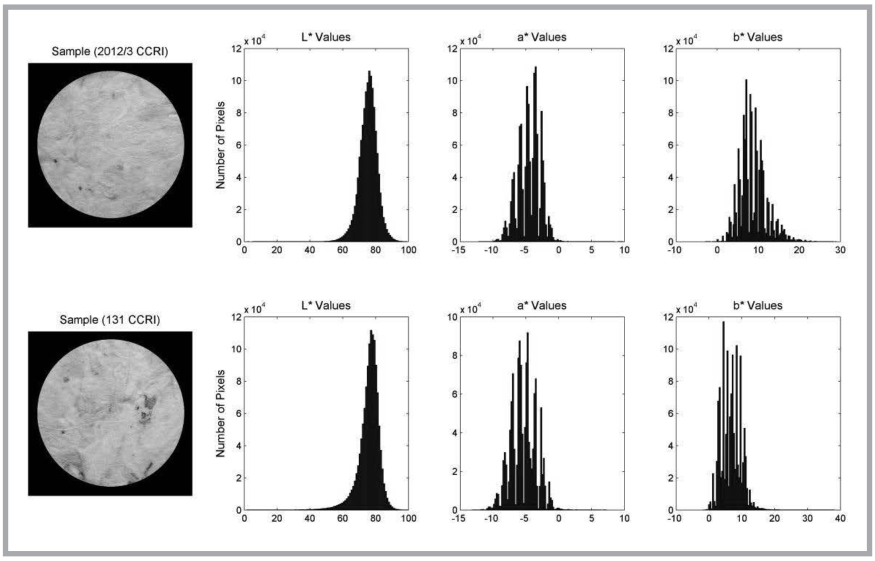

Figure 4. *Histograms of L*a*b* values for cotton samples (2012/3 CCRI) and (131 CCRI).*

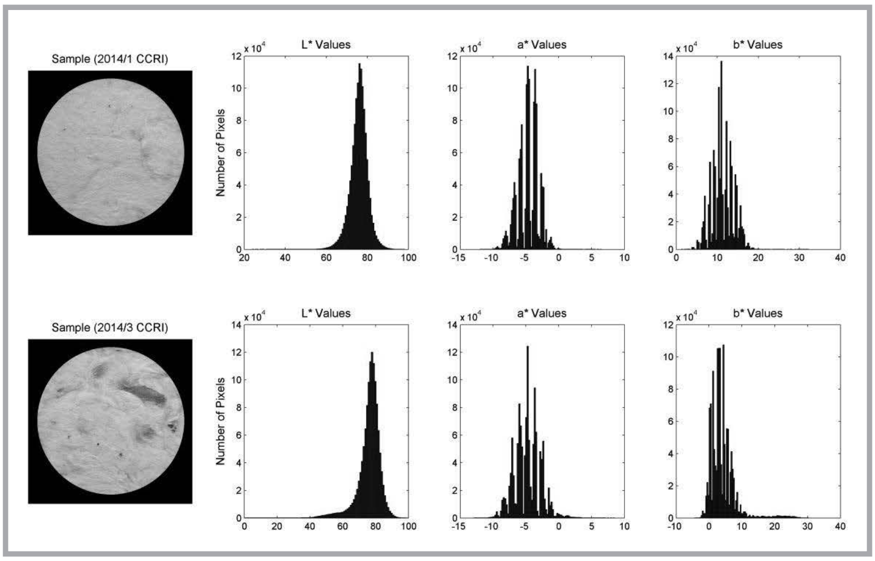

Figure 5. *Histograms of L*a*b* values for cotton samples (2014/1 CCRI) and (2014/3 CCRI).*

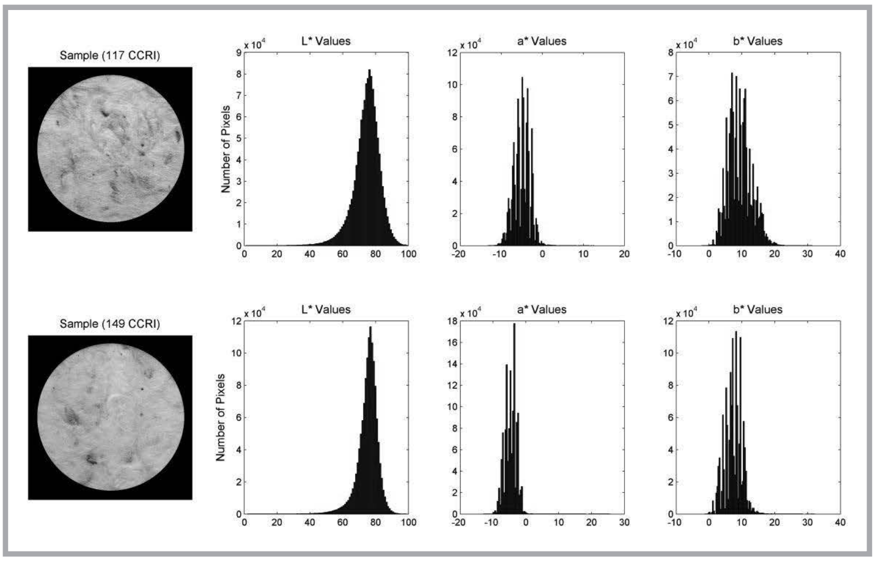

*Figure 6. Histograms of L*a*b* values for cotton samples (117 CCRI) and (149 CCRI).*

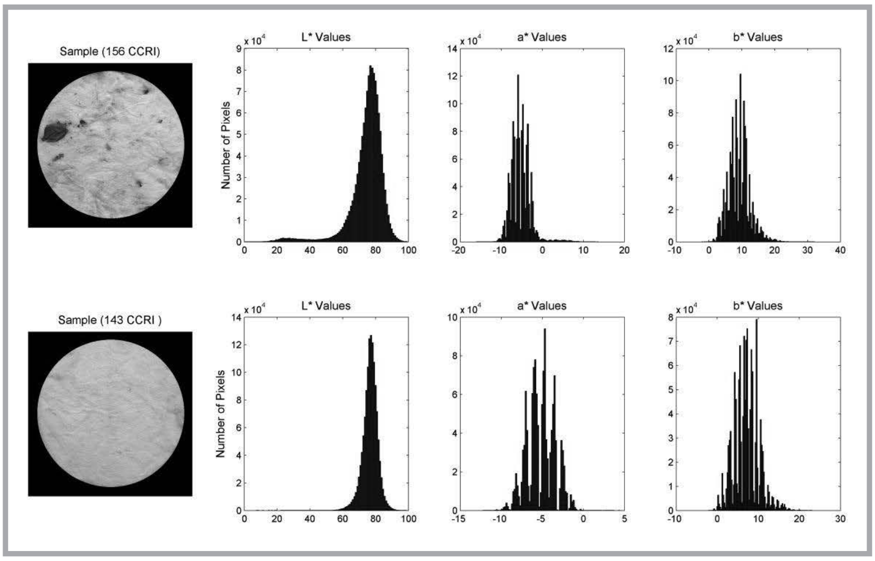

*Figure 7. Histograms of L*a*b* values for cotton samples (156 CCRI) and (143 CCRI).*

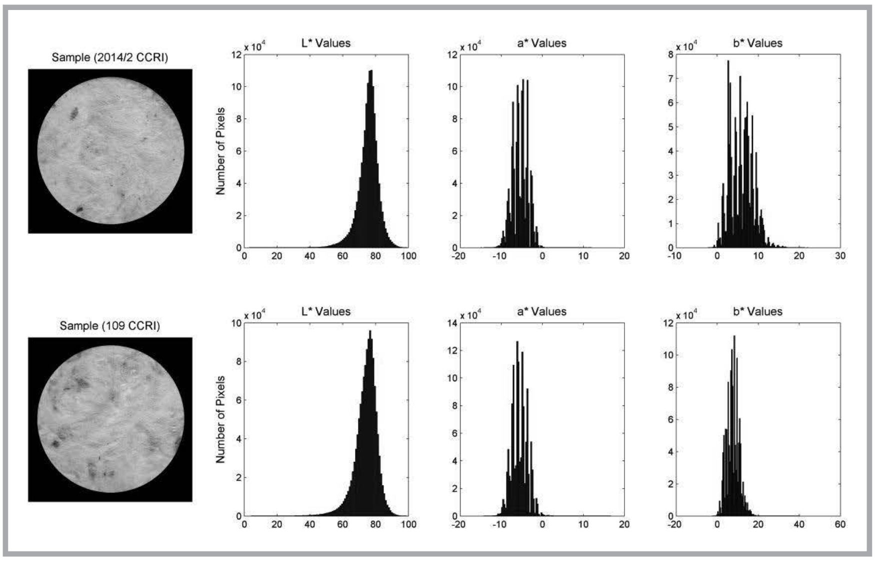

*Figure 8. Histograms of L*a*b* values for cotton samples (2014/2 CCRI) and (109 CCRI).*

58.17, sample 2014/2 CCRI between 53.4 and 59.9, and sample 109 CCRI between 51.62 and 59.94, while the means of samples calculated are shown in ***Table 6***, respectively.

Similarly +b values of sample 159 CCRI measured by the non-contact method vary between 6.08 and 8.4, sample 2013/2 CCRI between 9.10 and 14.76, sample 2012/3 CCRI between 9.16 and 11.21, sample 131 CCRI between 6.92 and 9.32, sample 2014/1 CCRI between 11.97 and 14.41, sample 2014/3 CCRI between 6.21 and 9.86, sample 117 CCRI between 8.5 and 9.8, sample 149 CCRI between 7.6 and 10.57, sample 156 CCRI between 6.21 and 10.75, sample 143 CCRI between 7.6 and 11.17, sample 2014/2 CCRI between 9.4 and 13.9, sample 109 CCRI between 5.61 and 9.49, while the means of samples calculated are shown in ***Table 7***, respectively.

Histograms of b* and L* values obtained from digital images in the CIE LAB space are shown in ***Figures 3-8***, respectively. The b values correspond to the colour attribute of the sample and are more uniform, whereas L values are highly affected by the sample preparation and the lighting angle due to the fact that these effects cause shadows and that the light shines. The digital image analysis method can be used for investigation of the variation within a cotton colour sample [1].

Tables 3-7 summarise a comparison of values obtained by the non-contact method, image analysis method and standard HVI values derived for Rd and +b values. It can be clearly seen from the tables that all values show similar tendencies. Although further analysis of the noncontact method and image processing method reveals that colour variations exist even in the standard cotton samples prepared for calibration and must be as homogenous as possible. Cotton is a natural fiber and the color of such cannot be controlled fully like for manmade fibers. Therefore color variation must be an expected property, but it must be taken into account while classifying cotton grades [1].

There is a strong relationship observed between the HVI and non-contact method results. The value for the non-contact methods is the average value and should not be considered representative for the whole sample.

Conclusions

As colour is a collaborative property of individual fibers, it is difficult to predict the colour property of a cotton bale on the basis of the sample. Moreover the sample itself possesses colour variation within its area of measurement. We used the non-contact method for the measurement of colour variation within sample. In this method,the measurement is taken from a different area of the sample because the probe of the non-contact method is very small in size. Then these values are used to compute the Rd and +b values, which help to see colour variation within the cotton sample. The image analysis method was also used for the measurement of colour variation and its results are compared with those of the non-contact method. Thus the non-contact method can be effectively used to determine the colour variation in a cotton sample. Moreover the samples used in this method did not contain any trash particles on the surface of the sample, which can affect the colour measurement process. In this method, contact with the sample is not used as it may cause unevenness or roughness of the sample surface. The result shows that colour variation in the cotton samples exists even without the presence of trash particles and dark spots. It can also be concluded some further investigation is needed to enhance the precision of the cotton color measurement.

The non-contact method can also be effectively used for the measurement of cotton colour distribution and variation.

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Table 5. *Summary of descriptive statistics of values measured using digital camera.*

	Cotton samples	2014/2 CCRI	109 CCRI
L*	Min	4.20	1.56
	Max	98.93	99.14
	Mean	75.61	75.59
	Median	76.25	76.96
	Std.Dev.	6.09	7.98
a*	Min	-15.13	-14.27
	Max	9.57	12.56
	Mean	-5.46	-5.09
	Median	-5.51	-5.15
	Std.Dev.	1.83	1.94
b*	Min	-2.60	-3.91
	Max	30.84	32.31
	Mean	5.85	6.10
	Median	5.69	5.98
	Std.Dev.	2.72	3.09

Table 6. *Comparison of Rd values using different methods.*

Cotton sample	HVI	Non-contact method	Spectrophotometer
159 CCRI	60.6	59.5	55.5
2013/2 CCRI	64.9	61.7	58.8
2012/3 CCRI	71.5	68.8	60.8
131 CCRI	66.1	63.0	60.7
2014/1 CCRI	68.0	64.1	60.4
2014/3 CCRI	74.7	67.8	64.6
117 CCRI	53.0	48.7	50.6
149 CCRI	68.2	61.4	63.1
156 CCRI	62.3	60.4	60.3
143 CCRI	64.4	56.8	59.7
2014/2 CCRI	76.4	69.9	66.4
109 CCRI	58.5	56.2	57.7

Table 7. *Comparison of +b values using different methods.*

Cotton sample	HVI	Non-contact method	Spectrophotometer
159 CCRI	9.1	7.5	7.7
2013/2 CCRI	11.6	11.0	9.1
2012/3 CCRI	12.7	11.2	10.5
131 CCRI	8.4	7.7	6.9
2014/1 CCRI	13.6	13.0	11.2
2014/3 CCRI	8.9	7.3	7.2
117 CCRI	10.6	9.0	8.2
149 CCRI	8.8	7.6	7.1
156 CCRI	9.6	8.6	8.9
143 CCRI	9.6	8.4	7.7
2014/2 CCRI	12.0	10.0	10.8
109 CCRI	8.9	7.1	7.4