Prediction of some cotton fiber blends properties using regression models

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Cotton fibers exhibit differences in properties governed by region of cultivation as well as cotton seed types and variability of climate conditions under which cotton is cultivated. Cotton fiber blending is a process entailing the production of a homogenous fiber assembly, through combining different cotton fiber components, in order to obtain optimum yarn quality and cost. In this study, a research aiming to predict the blended fibers properties using the properties of individual components and blending ratios as predictors, was performed. Various types of cotton fibers were blended with different proportions. Physical and mechanical properties of blended fibers were measured on the HVI. Based on experimental results, multiple regression analyses were carried out to predict blended fibers properties. It was found that the regression models give good prediction accuracy as indicated from correlation analyses. In addition, the analysis of the test samples used to verify the extent of viability of the deduced regression models shows high correlation coefficients between actual and predicted values ranging from 0.897 to 0.954 and low mean error percents ranging from 1.56 to 3.13 % indicating that the proposed equations have a satisfactory prediction capability.

إن الأقطان المختلفة يوجد بينها اختلاف كبير فى الخواص نتيجة اختلاف مناطق الزراعة وانواع بذور القطن والاختلاف فى الظروف الجوية التى ينمو فيها النبات. لذلك فإن عملية خلط الأقطان تهدف إلى انتاج خليط متجانس من شعيرات القطن للحصول على أفضل جودة للخيط مع عدم تجاوز التكلفة المحددة. تتناول هذه الدراسة بحثا يهدف إلى التنبؤ بخواص الشعيرات المخلوطة كدالة فى الخواص المختلفة لكل مكون من مكونات الخلطة وكذلك كدالة فى نسبة الخلط. وقد تم استخدام وخلط انواع اقطان مختلفة وتم قياس الخواص الفيزيائية والميكانيكية لها عن طريق جهاز HVI. أعتماداً على النتائج المعملية تم عمل تحليلات الانحدار للتنبؤ بخواص الخليط الناتج قد وجد من نتائج تحليلات الارتباط الخطى أن المعادلات المستنتجه لها قدرة عالية على التنبؤ بخواص خلطات القطن المختلفة. بالاضافة الى ذلك فقد تم انتاج عينات اختبارية لاختبار كفاءة المعادلات المستنتجة ووجد ان معامل الأرتباط الخطى مرتفع بين كل من الخواص المقاسة والخواص المستنتجة لخليط اقطان شعيرات القطن حيث تتراوح قيمته بين 0.897 إلى 0.954 وكانت نسبة الخطأ المتوسطة لقياس الخواص تتراوح مابين 1.56% إلى 3.13% ممايدل على أن المعادلات المقترحة لها قدرة عالية على التنبؤ بخواص الخلطات المختلفة للأقطان.

Keywords: Cotton, Blending, Fiber properties, Prediction, Regression analysis

1. Introduction

Fiber blending is a process entailing the production of a homogenous fiber assembly through combining different fiber components whether of the same type or of different types. Blending of the same type of fibers is a process aiming at the production of a consistent fiber mixture where fibers of the same type but having different characteristics are distributed evenly along the length as well as the cross section of the resulting fiber assembly. Blending of different fiber types is mainly concerned with producing a fiber mixture exhibiting predetermined characteristics not available in individual fiber types [1-4].

Cotton fiber blending is considered an indispensable step in cotton manufacturing. Cotton fibers exhibit differences in properties governed by region of cultivation as well as cotton seed types and variability of climate conditions under which cotton is cultivated [5-7]. These differences in fiber characteristics should be minimized by blending in order to obtain optimum yarn quality. In addition, blending can reduce yarn cost which is achieved by implementing less expensive cotton types in the blend mixture without degrading quality or process efficiency [8-12]. Extensive research on fiber blending has been performed [13-16]. However, various aspects relating to this critical phenomenon have still to be explored.

2. Evaluation of fiber blend properties

Fiber blending is combining predetermined weight proportions of various blending components together. Traditionally, prediction of properties of blended fibers has been obtained by assuming that the fiber blend assembly has an ideal normal probability distribution where fibers have a completely random arrangement and the value of the characteristics of one component is independent from the value of the same characteristics of the other component. In this case, the mean value of any fiber property can be estimated using the following eq. (1)

$$\mu_B = \sum_{i=1}^{i=n} a_i \mu_i$$

where
μ_B is the mean value of blend property,
a_i is the blend ratio of fiber component i in the blend (proportion of fiber component i in the blend), and
μ_i is the mean value of the fiber property of component i in the blend.

This equation is probably the most widely used method to estimate the blend properties. The main reason of its popularity may be attributed to its simplicity. However, in practice the assumption that fiber properties are normally distributed is not accurate. Investigations of the cotton fiber length distribution on a wide range of bale cotton fibers revealed that the fiber length distribution does not conform to a normal distribution and its shape is dependent on the fiber mechanical handling, ginning and its propensity to break [17-19]. In addition, a previous study of the frequency distribution of fiber length and fineness associated with cotton blends for different types of cotton found that the actual distribution of fiber length and fineness for blends deviate considerably from the ideal normal distribution [20].

In the current work, in order to predict cotton blend properties, regression analyses were used to formulate the relations between the properties of blended fibers and both the properties of individual fiber components and the blending ratios. Several types of cotton fibers of significantly different properties were implemented. This allows the deduced equations to be applied for the prediction of blend properties of various cotton types (e.g. long cotton, short cotton, etc.).

3. Material and methods

In the present work, several types of cotton fibers were blended together. Blending was performed by either using two fiber components or using three fiber components in the blend.

In two-component blending, different types of cottons were utilized. The properties of these fibers are shown in table 1.

Table 1
Properties of cotton fibers used in two-component blends

Cotton type	Fiber properties				
	UHML (mm)	Micronaire (μg/in)	Strength (g/tex)	Rd	+b
Giza 70	35.63	3.53	45.3	75.4	9.5
Giza 88	34.7	3.82	47.2	68.5	12.8
Giza 86	32.69	4.43	42.1	77.7	9.1
Giza 89	31.51	3.76	38.5	76.4	8.1
Giza 83	31.12	3.85	35.8	65.7	12.8
Giza 85	31.43	3.62	36.2	78.5	9.3
Giza 80	30.17	3.15	35.6	65.6	13.3
Akala	30.18	3.25	34.1	66.2	13.9
Barakat	33.69	3.58	36.9	68.3	13
Greek	30.75	3.91	33.3	74.7	8.6

The blending ratios employed in two-component blending were varied in step of 10% starting by 0/100% blend ratio up to a blend ratio 100/0% for each blend. The various types of cotton fibers blended together are shown in table 2.

In a subsequent step of the research, three-component blends were performed. Table 3 shows the properties of the cotton fibers used in the three-component blends.

Blending ratios implemented in three-component blend were (33.33/33.33/33.33%) as well as (50/25/25%) that was applied in rotation to each fiber component. Table 4 shows the different types of cotton blended together.

Several researchers investigated the properties of cotton fibers during processing. It was found that cotton fiber properties such as fiber length, short fiber percentage, fiber fineness, maturity, strength and Rd are altered during processing due to the mechanical actions and stresses acting on the fibers during processing and due to fiber propensity. It was also found that the fiber properties are mildly changed after the drawing process unless a combing process is added to the production line [16, 19, 21, 22]. Therefore, in the current study, the individual fiber components were blended by processing blended fibers up to the drawing frame. Physical and mechanical properties of the different blending ratios for various types of blends were then measured on the HVI.

Table 2
Two-component blends

Blend	Blending components		Blend	Blending components	
1	Giza 70	Giza 86	9	Giza 89	Giza 80
2	Giza 88	Giza 89	10	Giza 89	Giza 85
3	Giza 70	Giza 89	11	Giza 80	Akala
4	Giza 88	Giza 86	12	Giza 80	Barakat
5	Giza 86	Giza 83	13	Giza 80	Greek
6	Giza 86	Giza 80	14	Giza 85	Akala
7	Giza 86	Giza 85	15	Giza 85	Barakat
8	Giza 89	Giza 83	16	Giza 85	Greek

Table 3
Properties of cotton fibers used in three-component blends

Cotton type	Fiber properties				
	UHML (mm)	Micronaire (μg/in)	Strength (g/tex)	Rd	+b
Giza 88	36.36	4.24	45	67.3	10.7
Giza 87	35.05	3.22	44.9	72.8	9
Giza 86	33.84	4.5	44.2	77.5	8.6
Giza 80	30.43	4.07	38.7	64	12.4
Giza 90	30.24	3.71	35.5	67.7	11.8
Giza 85	29.63	3.88	36	75.4	8.1

Table 4
Three-component blends

Blend	Blending components		
1	Giza 88	Giza 87	Giza 86
2	Giza 88	Giza 86	Giza 80
3	Giza 86	Giza 80	Giza 90
4	Giza 88	Giza 86	Giza 85
5	Giza 87	Giza 85	Giza 90
6	Giza 85	Giza 86	Giza 90
7	Giza 86	Giza 85	Giza 80
8	Giza 85	Giza 80	Giza 90

Subsequently, in order to predict the fiber blend properties, multiple regression analyses were applied to formulate equations estimating the most important fiber blending characteristics (length, fineness, strength, and color) as a function of the corresponding characteristic of the individual blend components and the blending ratios. Correlation analyses were performed to justify the accuracy of the deduced equations.

To verify the extent of viability of the proposed regression equations, a model test was carried out, in which several types of cotton fibers were blended together to form two and three component blends abiding to the above mentioned blending method and ratios. The properties of the utilized cotton fibers are previously shown in table 3. Table 5 shows the test blends performed. Correlation analyses between the actual and predicted values were performed. The mean error % (the mean of absolute difference between calculated and actual value of fiber property as a percentage of actual fiber property value) for different fiber blend properties was also estimated.

4. Results and discussions

By analyzing the results of blended cotton samples properties at various blending ratios, regression models were developed to allow the prediction of blend properties. Table 6 shows the deduced regression equations and their correlation coefficients for different fiber blend properties.

Where

α_i is the blending ratio of the fiber component i in the blend (proportion of fiber component i in the blend),

$UHML_B$ is the upper half mean length of the blend (mm),

$UHML_i$ is the upper half mean length of the fiber component i in the blend (mm),

Mic_B is the micronaire of the blend (μg/in),

Mic_i is the micronaire of the fiber component i in the blend (μg/in),

S_B is the strength of the blend (g/tex),

S_i is the strength of the fiber component i in the blend (g/tex),

Rd_B is the reflectance degree of the blend,

Rd_i is the reflectance degree of the fiber component i in the blend,

Table 5
Different types of blends utilized to test regression equations

Blend	Type of blending	Blending components		
1	Two-component	Giza 90		Giza 85
2	Two-component	Giza 86		Giza 80
3	Three-component	Giza 88	Giza 87	Giza 80
4	Three-component	Giza 87	Giza 80	Giza 90

Table 6
Regression equations for predicting blend properties

Blend fiber properties	Regression equation	Correlation coefficient
Upper half mean length (mm)	$UHML_B = 0.89 + 0.96 \sum_{i=1}^{i=n} \alpha_i UHML_i$	0.867
Micronaire (μg/in)	$Mic_B = 0.48 + 0.86 \sum_{i=1}^{i=n} \alpha_i Mic_i$	0.885
Strength (g/tex)	$S_B = 3.71 + 0.91 \sum_{i=1}^{i=n} \alpha_i S_i$	0.886
Reflectance degree	$Rd_B = 13.2 + 0.84 \sum_{i=1}^{i=n} \alpha_i Rd_i$	0.868
yellowness	$+b_B = 1.66 + 0.92 \sum_{i=1}^{i=n} \alpha_i (+b_i)$	0.867

$+b_B$ is the predicted yellowness of the blend, and

$+b_i$ is the yellowness of the fiber component i in the blend.

From the statistical analyses used to judge the accuracy of the regression equations, it was found that the deduced equations give high correlation coefficients ranging from 0.867 to 0.886.

Figs. 1 to 5 show the correlation analyses of the model test samples utilized to further verify the extent of viability of the deduced equations. It can be observed that the deduced equations give relatively high coefficients of correlation between actual and predicted values of blend properties ranging from 0.897 to 0.954 and low mean error % ranging from 1.56 to 3.13% which indicates a good consistency between the two values. Thus, it can be proved that the established regression equations have a satisfactory capability for the prediction of blended fiber properties.

5. Conclusions

Some of the most important properties of cotton fiber blends, which are fiber length, fineness, strength and color are predicted by means of regression equations taking the properties of the individual fiber components and the different blending ratios as predictors. The correlation coefficients of the proposed equations range from 0.867 to 0.886. In addition, the analysis of model test samples used to verify the extent of viability of the deduced equations for the prediction of characteristics of blended fibers shows a relatively high coefficient of correlation between the actual and the predicted values of the blends properties ranging from 0.897 to 0.954 as well as a relatively low mean error % ranging from 1.56 to 3.13%.

Therefore, it can be concluded that the proposed equations have a satisfactory prediction capability as indicated from statistical analyses and can effectively predict blend fiber properties. The deduced equations can thus be regarded as a useful tool for an optimum selection of suitable blending components giving predetermined blend properties.

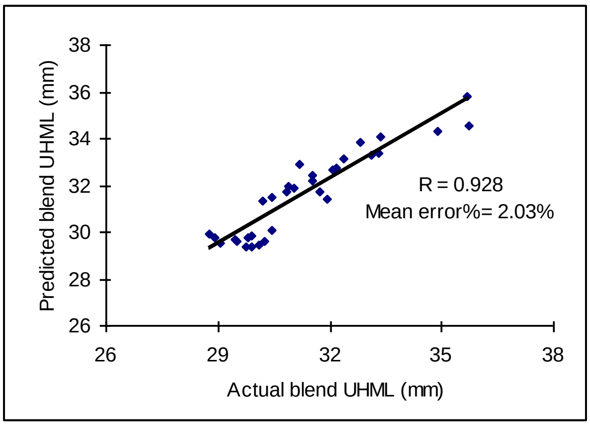

Fig. 1. Correlation between actual and predicted UHML of blend.

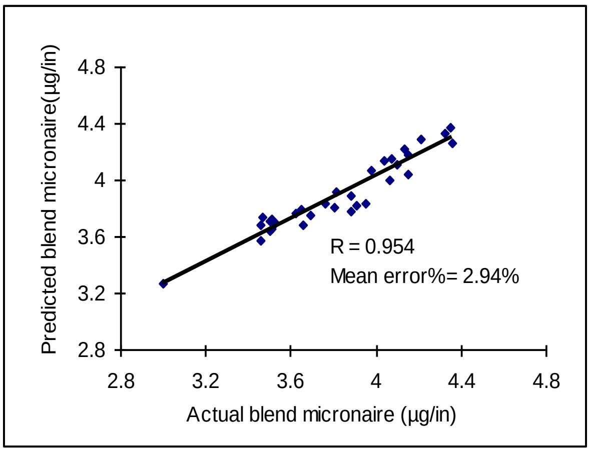

Fig. 2. Correlation between actual and predicted micronaire of blend.

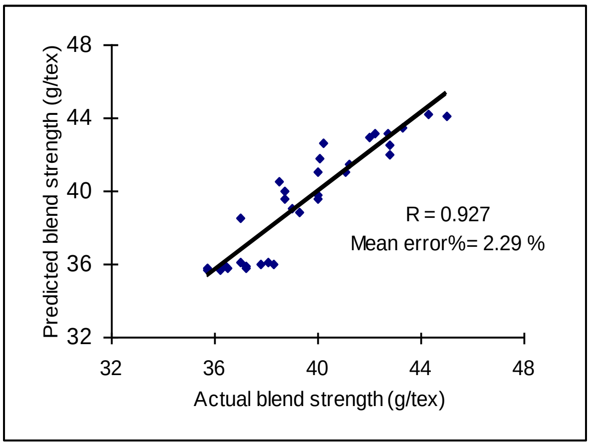

Fig. 3. Correlation between actual and predicted strength of blend.

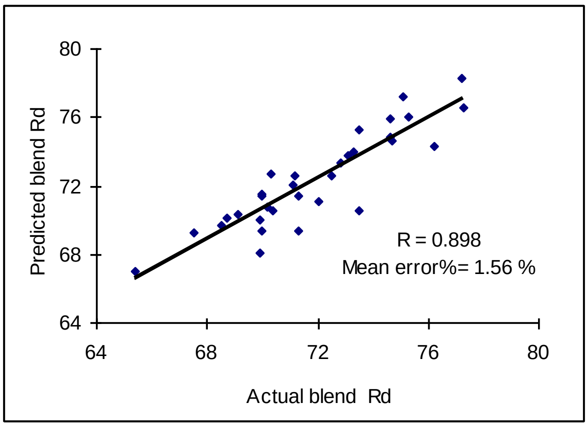

Fig. 4. Correlation between actual and predicted reflectance degree of blend.

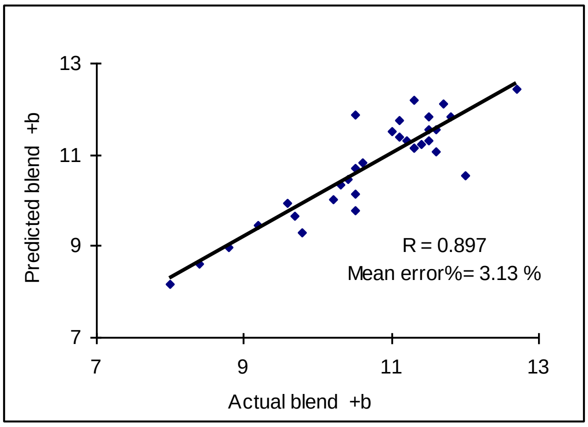

Fig. 5. Correlation between actual and predicted yellowness of blend.

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Received March 6, 2008
Accepted March 13, 2008