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A Study on The Fibre Parameters of Cotton Quality and Processability Evaluation

Pamuk Lifi Parametrelerinin ve İşlenebilirliğinin Değerlendirilmesi Üzerine Bir Araştırma

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A STUDY ON THE FIBRE PARAMETERS OF COTTON QUALITY AND PROCESSABILITY EVALUATION

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ABSTRACT: Currently, the textile industry is mainly using the two basic commercial quantification methods namely, SCI and FQI to evaluate the technological values of samples of commercial DP-90 cotton genotypes. Of late, researchers were investigating that these two widely used cotton characterization tests as they seem to be insufficient to give quality and processability information about the commercial cottons. I this study a modified fiber quality index (MFQI) is formulated for the studied commercial DP-90 cotton. In the study, experiments were done to assess the importance of the association between tenacity and elongation of cotton fibres in the overall evaluation of the cotton quality and processability. The results obtained from the study demonstrated that the cotton fibre elongation property is critically important to predict the quality and processability of cotton as well. The results obtained show that the combination of HVI and CCS data allows us to predict quite accurately technological values of cotton fiber properties for commercial bales.

Key words: Quantification methods, Quality, Processabiliy, Elongation, HVI, CCS

PAMUK LİFİ PARAMETRELERİNİN VE İŞLENEBİLİRLİĞİNİN DEĞERLENDİRİLMESİ ÜZERİNE BİR ARAŞTIRMA

ÖZET: Günümüzde, tekstil endüstrisi ticari DP-90 pamuk genotiplerinin örneklerinin teknolojik değerlerini ölçmek için “SCI” ve “FQI” olmak üzere iki temel ticari nicelikleme yöntemini kullanmaktadır. Son yıllarda, araştırmacılar, ticari pamukların kalitesi ve işlenebilirliği bilgisi vermek için yetersiz göründükleri tespitiyle bu iki yaygın yöntem üzerine için araştırmalar sürdürülmektedir. Bu çalışmada, pamuk kalitesi ve işlenebilirliğinin genel değerlendirilmesinde pamuk elyafının mukavemeti ve uzaması arasındaki ilişkinin önemini belirlemek üzere deneysel bir çalışma yapılmıştır. Çalışmadan elde edilen sonuçlar pamuk lifi uzama özelliğinin pamuk kalitesini ve işlenebilirliğini öngörmek için kritik önem taşıdığını göstermiştir.

Anahtar Kelimeler: Niceleme yöntemleri, Kalite, İşlenebilirlik, Uzama, HVI, CCS

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1. INTRODUCTION

Determining the technological value of cotton fibre is an interesting field of textile research. This is because of the fact that the quality of final yarn is largely influenced (up to 80%) by the characteristics of raw cotton [1]. Nowadays, it is observed that many investors have shown interest to invest in the field of textiles in the developing countries. In recent years, the number of textile factories in Ethiopia alone is increased by more than 100%. The number of textile factories in Ethiopia in the year 2001 was 10 (Government owned). Now in 2017, the number of textile factories has gone to 29 (by the inclusion of 19 private owned textile factories officially registered and performing their production activities). Since the textile industry is labor intensive in nature, it can provide a lot of employment opportunities. So, one can easily understand the importance of this sector in settling the people in their own local places.

It is important to note and understand that the local (Ethiopian) cotton breeders have to consciously work to breed high quality of varieties of cotton (raw material) that can satisfy the existing and emerging markets of the globe. To continue through sustainable efforts with their cultivators, small scale sector farms in Africa have to clearly understand the types of cotton fibres are they going to cultivate and the ultimate benefits will they receive by such cultivation.

The current challenges of cotton breeders were already reported by Hequet, E. F. and his coworker [2]. They pointed out that our era cotton breeders are facing the challenges of predicting the processability of the raw material which is the most important task. The challenges will be tougher for the cotton breeders of developing countries (who lack modern cotton breeding technologies). It is worth to mention here that even though cotton breeders of developing countries are subjected to many challenges; they would still remain as the active players in the modification of cotton cultivators that could have a potential for predicting the technological value of cotton. Therefore, the cultivation and production of quality cotton can provide better opportunity to the small and large scale farmers in particular and to all players of cotton value chain as a whole. Even though the existing quantification methods for cotton quality are not perfectly explained or are not widely recognized as effective tools within cotton scientists/technologists/research circles, the creation of single index value by combining several fibre quality parameters works as a practical method in providing relative information to the overall quality evaluation of cotton.

The primary objective of this research work is the creation of an index value which can provide precise and accurate practical information, which can be used to make practically important distinctions regarding cotton growing in different places of the given region, Gondar, Ethiopia. Comparison of the same genetic variety cultivated in different areas would help to assess the within-variety variability cultivated in different growing conditions and ultimately support the possibility to breed a new variety for the new cultivators that can exhibit less variability of fibre properties within-variety.

Traditionally, only few fibre parameters, namely: fibre grade, length and fineness have been used to evaluate the quality of cotton fibres by the cotton classers. Later, the fibre quality index (FQI) or its variants, proposed by Lord [3] and Ratnam et al., came to be applicable in the scenario [4]. Basically, it incorporated the major fibre properties in a multiplicative formula to determine the quality value of lint cotton. Murthy et al., provided a new formula of FQI which was based on HVI measurements [5].

$$FQI_{HVI} = \frac{FS \ x \ UHML \ x \ UI}{FF} \qquad (1)$$

FS is the fibre bundle tensile strength (cN/tex), UHML is the upper half mean length (mm), UI is uniformity index (%) and FF is fibre fineness (micronaire). The popularity of HVI comes with the wide application of the spinning consistency index (SCI) quantification method which is one of the composite indices used to determine the technological value of cotton [6]. The SCI method for classing cotton by using HVI system determines cotton fiber properties (physical attributes) that influence quality. The SCI method uses the following multiple regression analysis:

$$SCI = -414.67 + 2.9FS + 49.17UHML + 4.74UI - 9.32FF + 0.65Rd + 0.36(+b) \qquad (2)$$

Where:

FS is the fibre bundle strength (cN/tex), UHML is the upper half mean length (inch), UI is uniformity index (%), FF is fibre fineness (micronaire), Rd is light reflectance and +b is yellowness. *N.B. HVI instrument used to report the fibre tensile strength (FS) by the unit of"g/tex". In this paper it is preferred to use "cN/tex" which is equivalent to "g/tex".* It is important to note that both methods fail to report the important fibre parameter, which is elongation. Elongation is an important parameter to predict the cotton fibre spinnability as well as processability of yarn in the weaving machine. Backe et al., showed the importance of cotton fiber bundle elongation on yarn quality and weaving performances [7]. The reason why the cotton breeders simply ignore the fibre elongation property is explained by H. Benzina and his co-workers [8]. Reportedly, the individual fiber's work-to-break is extremely important to prevent fiber breakage. Stronger fibers tend to have higher elongation which results in better work-to- break which could lead to lower fiber breakage during processing [9]. It is observed that during fiber processing the stress is not applied to bundle of fibers but to individual fibers or small tufts of fibers. For example, the spikes and blades of beaters in the opening and cleaning stage machinery acts on the tufts in the order of few milligrams whereas carding machinery parts acts only in few tens of fibres. In ring frame, the fibres are drafted to individual fibres and then get twisted by the traveler to the required yarn count. In rotor spinning only 1-5 fibres come to the highly rotating section of the rotor to join and get twisted by the cranking action of the open end yarn. Therefore, it can be understood that the elongation characteristics associated with fibre tenacity are critically important at textile processes, namely: Ginning, Opening, Carding, Spinning and Weaving.

Considerable emphasis has been given to correlating cotton fiber property combinations with end-use requirements and quality [10], whereas the need for determining the combinations of fiber properties required maintaining maximum operating efficiency has been recognized only recently. The proper combination needed to meet one of these objectives may preclude attainment of the other. Fibre properties should therefore be considered as being dual functional, with contributions being made toward processing efficiency and toward product quality. Before the invention of current fast and high volume textile testing instrument, many efforts were made toward correlating the breaking strength and elongation of textile fibers with mechanical processing characteristics and with certain elements of product quality [11, 12, 13 and 14]. Nowadays because of the dynamic nature of spinning (e.g. ring and rotor spinning), whose efficiencies depend to a certain extent on the absorption of energy to maintain specified levels of operating efficiency, should mandatorily lead to a consideration of the elastic properties of fibers and yarns, which are energy absorptive in nature, and to those tensile behaviors reflecting these properties. Example: Spun yarns tensile properties. In the yarn formation zone of ring frame (See fig. 1a) (i.e., the zone between the pigtail lappet guide and the front rollers of the drafting system.), the yarn tension is termed as the spinning tension T_S, and is related to the balloon tension at the lappet guide T_O, by the following equation:

$$T_O = T_S\ e^{\phi\theta} \tag{3}$$

Where, ϕ = the yarn lappet guide coefficient of friction; θ = the angle at the entrance and exit of the lappet guide (Fig. 1a);

$$T_W = T_R\ e^{\alpha\sigma} \tag{4}$$

Where, T_W = the winding tension; α = yarn-traveler coefficient of friction; σ = the angle at the entrance and exit of the traveler (see Fig. 1b).

$$T_O = T_R + mR^2\omega^2 \tag{5}$$

Where, T_R = the tension of yarn at the ring and traveler; m = mass per unit length; R = radius of curvature; ω= angular velocity of the yarn. We have,

$$T_S\ e^{\phi\theta} = T_R + mR^2\omega^2 \tag{6}$$

During winding as the traveler is pulled around the ring, the centrifugal force, C, on the traveler will lead to the friction drag, F, where

$$F = \mu C \tag{7}$$

$$C = MR_r\omega^2 \tag{8}$$

Where, M = traveler mass; R_r = radius of the ring; ω angular velocity of the traveler

($\omega = 2\pi N_t$), where, N_t = traveler r.p.m. We have,

$$C = 4\pi^2\ N_t^{\ 2} MR_r \tag{9}$$

Therefore, with ring spinning, the spinning tension increases as a quadratic function of the spindle (traveler) speed. If the spindle speed, for example is greater than 20,000rpm (when processing 100 % cotton), the possibility of traveler burning or complete failure would be considered due to lack of resistance to the generated thermal heat. From the above equation (9), it can be observed that the mass of the traveler is also one of the parameters that determine the degree of friction of the traveler on the ring and thus the yarn tension. The mass of the traveler must therefore be adjusted exactly to the yarn count and tenacity-elongation properties and to the spindle speed.

In rotor spinning, the tension in the yarn is largely the result of centrifugal force and it is therefore proportional to the square of the product of the rotor speed and diameter. Reportedly a rotor speed and rotor diameter of 70,000 rpm and 40 mm, respectively, give optimal yarn tension with minimal ends down [15]. To maintain optimal yarn tension with increased rotor speed, the following relationship may be used:

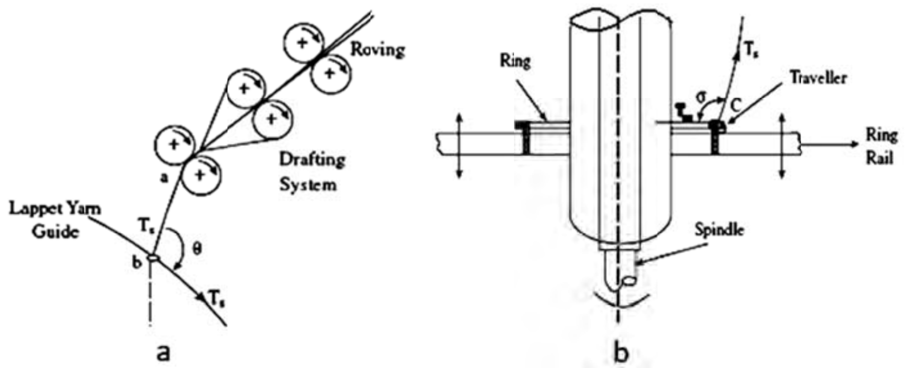

Figure 1. Yarn tensions at the lappet guide and ring-traveler

n = 3.2 x 106/D (10)

Where, n = rotor speed; D = diameter of the rotor

If the rotor speed is increased beyond the optimal level, the decrease in breaking elongation of the yarn will be resulted because of the increase in spinning tension. This in turn would cause a permanent strain in the yarn which could be resulted in multiple breakages in the weaving shed. The amount of "stretch" required in yarns is referred as the per cent take-up or contraction in the weaving and finishing operations, and "sewability" of threads. These imply functional use of yarn elasticity, in addition to strength, as evaluating media, even though the latter property is in the majority of cases the only one measured and considered [16]. Reportedly, breeders are advised to give attention to both strength and elongation [17].

In this work, in addition to HVI, the Cotton Classifying System (CCS of TEXTECHNO, Germany) was also used. CCS, in addition to the usual relative testing method of HVI, uses the actual (absolute) strength-elongation testing method. It is important to note that CCS applies the principles of actual/absolute measurement of bundle tensile-elongation properties [18].

In order to compare cotton of the same variety cultivated in different areas, work of rupture should be evaluated so that it is possible to take account of the various elongation properties of the same variety. Hence, specific work of rupture, which is the amount of energy needed to break a sample of unit mass, should be used.

The currently used fiber quality index is based mainly on HVI measurements and doesn't consider the elongation property which is the main contributor to the work-to-break of cotton fibres. Thus, in this research work the modified fibre quality index (MFQI) which considers the CCS work of rupture (cN × cm), is formulated.

2. MATERIALS and METHODS

In the study, the first experiment is done for comparing the technological values of the cotton obtained from the three cultivation areas of Gondar region, Ethiopia. The second experiment of the study was done to assess the influence of tenacity and elongation properties of the commercial cotton samples collected from the whole cultivation areas of Gondar, Ethiopia. For all experiments samples were tested by both HVI and CCS laboratory testing instruments.

Experiment 1: Sixty samples from commercial DP-90 cotton genotypes in the Gondar region of Almahal, Kokyt and Abderafe were selected for comparison of their technological values by the commercially used quantification methods. Tables 1-3, shows the fiber properties values of the cotton along with statistical parameters from the three cultivation regions in Gondar. Table 4 shows their technological values as determined by the quantification methods, ranked (R) in ascending order. Table 5 shows their technological values as measured by the modified quantification method.

Table 1. Values of the Abderafe region fiber properties and their statistical parameters

Cotton Cultivating Area	Fibre Properties	Statistical Parameters						
		M	S. D	Min.	Max.	S.E.	R	C.V%
Abderafe	MIC	4.10	0.37	3.51	4.57	0.12	1.06	9.02
	UHML	29.56	0.74	28.31	30.51	0.23	2.20	2.50
	UI	86.02	0.77	84.80	87.50	0.24	2.70	0.90
	SFI	6.47	0.54	5.80	7.30	0.17	1.50	8.35
	FS	30.26	1.24	28.10	32.10	0.39	4.00	4.10
	FE	6.53	0.34	6.00	7.00	0.11	1.00	5.21
	Rd	84.75	1.27	83.00	87.00	0.40	4.00	1.50
	+b	9.69	0.59	8.40	10.50	0.19	2.10	6.09

MIC (Micronaire reading), UHML (Upper Half Mean length), UI (Uniformity Index), SFI (Short Fiber Index), FS (Fiber Strength), FE (Fiber Elongation), Rd% (Reflectance), +b (yellowness), M (Mean), S.D (Standard Deviation), Min. (Minimum), Max. (Maximum), S.E (standard Error), R (Range), C.V% (Coefficient of Variation)

Table 2. Values of the Almaehal region fiber properties and their statistical parameters

Cotton Cultivating Area	Fibre Properties	Statistical Parameters						
		M	S. D	Min.	Max.	S.E.	R	C.V%
Almaehal	MIC	3.88	0.06	3.77	3.97	0.02	0.20	1.55
	UHML	27.24	0.68	26.39	28.08	0.22	1.69	2.50
	UI	81.99	1.68	79.30	84.30	0.53	5.00	2.05
	SFI	10.73	2.09	7.30	14.10	0.66	6.80	19.48
	FS	26.79	1.68	24.10	29.10	0.53	5.00	6.27
	FE	5.75	0.50	5.00	6.70	0.16	1.70	8.70
	Rd	78.07	1.59	75.30	79.50	0.50	4.20	2.04
	+b	12.28	0.31	11.60	12.80	0.10	1.20	2.52

Table 3. Values of the Kokyt region fiber properties and their statistical parameters

Cotton Cultivating Area	Fibre Properties	Statistical Parameters						
		M	S. D	Min.	Max.	S.E.	R	C.V%
Kokyt	MIC	4.27	0.20	4.05	4.55	0.06	0.50	4.68
	UHML	29.25	0.63	28.06	30.46	0.20	2.20	2.15
	UI	83.70	2.73	78.30	86.60	0.86	8.30	3.26
	SFI	7.55	0.73	6.70	9.10	0.23	2.40	9.67
	FS	27.46	0.81	26.30	28.80	0.26	2.50	2.95
	FE	6.67	0.49	6.20	7.80	0.16	1.60	7.35
	Rd	83.19	4.94	73.80	87.00	1.56	13.20	5.94
	+b	9.44	0.16	9.10	9.60	0.05	0.50	1.69

Table 4. The technological values of studied cotton fibre properties determined by commercial quantification methods, ranked (R) in ascending order.

Cotton Cultivating Area	Fibre Properties Cultivated in the Three Areas								The calculated Technological values by Quantification Methods			
	MIC	UHML	UI	SFI	FS	FE	Rd	+b	SCI	R	FQI	R
Abderafe	4.10	29.56	86.02	6.47	30.26	6.53	84.75	9.69	158.2	3	187.7	3
Almehal	3.88	27.24	81.99	10.73	26.79	5.75	78.07	12.28	123.3	1	154.2	1
Kokyt	4.27	29.25	83.70	7.55	27.46	6.67	83.19	9.44	135.9	2	157.4	2
								Mean	139.1		166.4	

Experiment 2: It is done to assess the influence of association between tenacity and elongation, 75 samples from commercial DP-90 cotton genotypes in the Gondar region were selected for comparison. The samples were tested on HVI-1000 and Version 5 of CCS instruments, with 50 replications. The figures 2 and 3 show tenacity-elongation relationships of HVI and CCS, respectively, as measured by the relative method of testing. Figure 4 shows the tenacity-elongation relationship as measured by the absolute/actual method of testing.

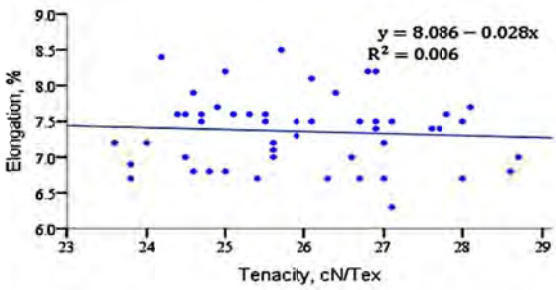

Figure 2. Elongation vs. HVI tenacity. DP-90 commercial varieties

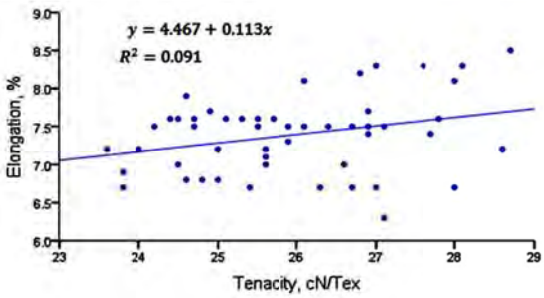

Figure 3. Elongation vs. CCS relative HVI mode DP-90

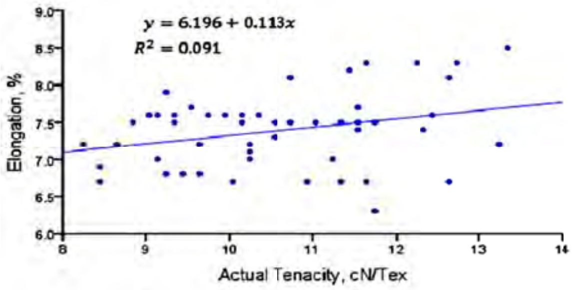

Figure 4. Elongation vs. Actual Tenacity DP-90

3. RESULTS and DISCUSSIONS

A Modified Cotton Fiber Quality Index

Fiber Quality Index (FQI) is one of the ad hoe curvilinear equations, in which the cotton fiber properties are combined into one integrated index. It was introduced on the basis of the following considerations: (i) the fiber properties used in the index should be selected from the theoretical considerations or from prior knowledge of their impact on yarn strength, or from a combination of both; (ii) the minimum number of properties should be used; (iii) the properties should be the usually measured ones, so as to ensure the applicability of this index in practice; (iv) the error of measurement of the fiber properties should be low; and (v) the form of the function and any parameters used in constructing the index should be invariant over different spinning conditions.

It has shown that (Fig. 2-4) the positive contributors in both SCI and FQI and also in other quantification methods which are not mentioned in this paper are the main influential parameters to evaluate the technological performance of cotton [19]. But, emphasis has not given to the elongation parameter which has to be considered during the speed and striking action optimization of spinning machinery parts. Reportedly, the between-bale variance of HVI bundle breaking elongations within a lay-down is quite useful as a criterion for bale selection and yarn and fabric strength maximization [20].

Thus, the modified fibre quality index (MFQI) which considers the CCS work of rupture (cN*cm), is presented below:

$$MFQI = \frac{[UHML_H \times UI_H \times WR_C]}{MIC_H \times SFI_H} \quad (11)$$

$UHML_H$ is the HVI upper half mean length (mm), UI_H is the HVI uniformity index (%), SFI_H is the HVI short fiber index (%), MIC_H is the HVI fiber fineness (micronaire), WR_C is CCS work-to-break (cN × cm).

Accordingly, the technological values of cotton from the three areas studied are presented (Table 5 and 6) and compared with the standard US UPLAND and PIMA cottons as well as the Egyptian Giza 87.

Table 5. Quality Index values for the cotton in the three regions

Cultivating Areas	Cotton Fiber Quality Indexes		
	FQI	SCI	MFQI
Abderafe	187.7	158.2	97.2
Almehal	154.2	123.3	39.4
Kokyt	157.4	135.9	66.3

Table 6. Quality Index values for the US Upland, Pima & Egypt Giza 87

Cotton Varieties	Cotton Fiber Quality Indexes		
	FQI	SCI	MFQI
US PIMA	479.9	230.4	287.8
Giza 87	472.2	228.0	282.3
US UPLAND	170.2	134.3	81.4

Even then, due attention and emphasis was not given for cultivating cotton with the best "Elongation"? It is because of the lack of interest to breed the cotton with better elongation property due to its negative correlation with the HVI bundle tenacity. It is interesting to observe the result of this research work which showed that, from Fig. 2, there is a weak negative relationship between HVI bundle tenacity and elongation-at-break (r^2 = 0.006) for the commercial variety DP-90. But, it is found that there is a positive but also weak relationship between CCS bundle tenacity and elongation-at-break. This can be inferred from Fig. 3 (relationship between CCS bundle tenacity and elongation-at-break (HVI/relative mode), (r^2 = 0.091)) and Fig. 4 (relationship between CCS bundle tenacity and elongation-at-break (direct/absolute mode), (r^2 = 0.091)) for the same commercial variety DP-90.

The total work-to-break of the bundle is a function of both the load required to break and the elongation before rupture. This relationship for any bundle is represented by a unique stress-strain curve. While the stress-strain curve is unavailable from HVI, the total work-to-break should be proportional to the product tenacity * elongation. Figure 5 shows that there is good correlation (R^2 = 0.890) between the HVI product tenacity * elongation and CCS work-to-break. Therefore, improving both elongation and tenacity should result in an improvement in the total work(energy) required to break the fibres in the bundle.

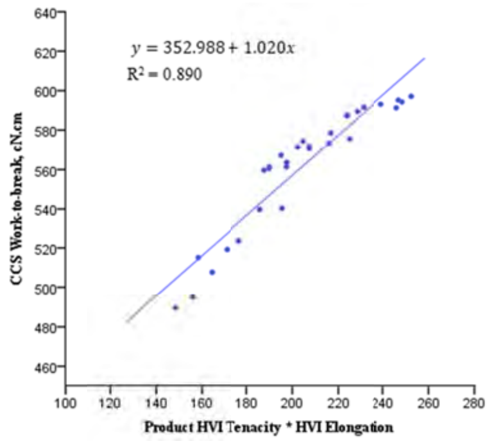

Figure 5. CCS Work-to-break vs. product HVI Tenacity * HVI Elongation for commercial DP-90

4. CONCLUSIONS

According to all quantification methods used (including our modified fibre quality index), the cotton from the Abderafe has the highest technological value followed by Kokyt and Almehal.The results obtained show that the combination of HVI and CCS data allows us to predict quite accurately technological values of cotton fiber properties for commercial bales.

The weak negative (HVI) or weak positive relation (CCS) between bundle tenacity and elongation-at- break should not lead to the practices of ignoring for cultivating the cotton with better fibre elongation property. Reportedly, ignoring of cultivating cotton with improved fibre elongation property could lead to lower work-to-break with more fibre breakage with increased short fibre content [9]. Short fibres are also the sources of draft irregularity (due to floating fibres in the drafting zone of the draw frame) which affects the quality of final textile products by leaving more thin and thick places in the yarn body. Therefore, it can reasonably be concluded that the fibre parameter of elongation is to be considered while arriving at the formula for the evaluation of cotton fibre quality and processability.

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