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Statistical Analysis and Instrumental Characterization of Commercial Ethiopian Cotton Varieties

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ABSTRACT

The finding of ANOVA analysis with no significant difference in length distribution will permit the spinners to classify the bales into the same categories during HVI fiber selection and laydowns arrangements. Classification of cotton bales with similar length distribution will minimize the undesirable laydown variability in critical properties such as short fibers contents which are the main sources of yarn unevenness. In this study the HVI tenacity for the studied three commercial varieties fall within the range of 26.94-28.28. According to USDA system of cotton classification this range is categorized in the descriptive designation "average" strength group. FAVIGRAPH elongation in percent fall within the range 6.41-7.01. For the studied samples Acala SJ-2 variety has a relatively better elongation property. This can be used as information for the spinners to increase the proportion by weight of Acala SJ-2 during the preparation of a cotton mix desired for relatively better yarn and greige fabric elongation. In this research work a modified fiber quality index (MFQI) is formulated to instrumentally characterize the studied commercial Ethiopian cotton varieties. The results obtained show that the combination of HVI and FAVIGRAPH data allows us to predict quite accurately fiber properties for commercial bales.

Keywords: Ethiopian cotton, tenacity, elongation, HVI, AFIS, FAVIGRAPH

Introduction

Cotton occupies a unique position in Ethiopia's agrarian economy. Ethiopia has enormous potential for the production of cotton. Ethiopia has a conducive weather and topography for the cultivation and production of cotton. Currently, cotton (Gossypium hirsutum L.) is widely grown in the irrigated low lands on large-scale farms and in warmer mid altitudes on small-scale farms under rain-fed conditions.

A recent study of the Ministry of Agriculture indicates that there is 3,000,810 Ha of land suitable for cotton production, which is equivalent to that of Pakistan, the fourth largest producer of cotton in the world. Pakistan harvests about 2.3 million MT of cotton annually from a total cotton area of 3.05 million Ha (in the year of 2014/15) Cotton Outlook (2015). Out of the total 3 million ha of land suitable for cotton production in Ethiopia, 1.9 million ha or 63.3% is found in 38 high potential cotton producing areas and the remaining 1.1 million ha or 36.7% is in 79 medium potential districts Despite this immense potential, Ethiopia recently (2015/16) produces about 40,932.2 MT of lint cotton annually from a total cotton area of 130,000 ha land which is only 4.33% of the total area favorable for cotton cultivation (Foreign Agricultural Service/USDA, 2015).

The problems associated to the quality of raw cotton represent important obstacles to the processing performance and efficiency of spinning machinery. The presence of quality-control measures and recognized standardization system could lead to improvement of the competitiveness of Ethiopian cotton, yarn and final products which is important to the players of cotton value chain.

Local textile industries buy cotton from farms in bulk to meet their three months up to one-year requirements at a time. It is vital for cotton farms as well as spinning industries to know fiber characteristics for various commercial and technical requirements. It is becoming common in most of the cotton producing countries to grade cotton based on fiber properties rather than traditional subjective methods of appearance grading and hand stapling. Availability of quick and accurate means of measurements through improved technologies has helped the cotton sector tremendously to grade the cotton. Information based on instrumentally measured data about various fiber characteristics is very important for cotton breeders, production farms and textile enterprises.

Researchers made an attempt to characterize Egyptian cotton (El Messiry and Abd-Ellatif 2013). But, unfortunately, no comprehensive documented information is available about different varieties of cotton grown in Ethiopia. Currently, in Ethiopia, cotton is identified in the industry by the name of the farm or the place of cultivation irrespective of their property. This investigation was undertaken primarily to generate required information about important commercial varieties useful for all concern in the textile production chain.

Before the invention of current fast and high-volume textile testing instrument, Manual testing instruments (e.g. Stelometer) have been utilized to correlate cotton fiber property combinations with quality, end-use requirements and mechanical processing characteristics (Meredith 1946); (Brown 1954), (Hertel and Craven 1956); (Virgin and Helmut 1956).

The relations of cotton fiber properties with end-use requirements and quality of spun yarns has been a subject of intensive research (Bogdan 1956), (Fiori et al. 1956), (Hunter 1988), (El Mogahzy 1988), (Ramey et. al 1989), (Faulkner et. al 2012). For the last two decades, US cotton breeders have used High Volume Instrument (HVI) as their primary and often sole source of fiber quality data when making plant selection (Kelly et. al 2012). The increase of production speed of textile machines (spinning preparation, spinning, weaving and knitting) requires cotton fibers with sufficient strength and elongation. Therefore, evaluation of strength and elongation becomes more and more important for the assessment of the spinnability of cotton fibers (Kugler et. al 2010). To maximize profitability, cotton (Gossypium hirsutum L.) producers must attempt to control the quality of the crop while maximizing yield.

Instrumental characterization of fiber properties should be considered as being dual functional, with contributions being made toward processing efficiency and toward product quality. Because of the dynamic nature of spinning (e.g. Ring, Rotor, Compact, Air-jet), whose efficiencies depend to a certain extent on the fiber properties and amount and properties of fibrous faults and

foreign matters constituents to maintain specified levels of operation efficiency, should mandatory lead to a consideration of the physical properties of fibers, fibrous faults as well as amount and properties of foreign matters constituents. May and Taylor reported the requirement of breeding cottons with higher tenacity to overcome the greater strain on cotton yarns introduced as a result of the increase in manufacturing speeds on the knitting and weaving machinery (May, Lloyd O. and Taylor, Robert A. 1998).
The importance of cotton fiber physical properties and influence of fibrous faults as well as foreign matters constituents in priority order in different spinning systems is documented (Hunter 2006):

i. Ring spinning system: fiber length, fiber strength, fiber fineness, neps, trash and dust content
ii. Rotor spinning system: fiber strength, fiber fineness, fiber length and length uniformity, neps, trash and dust content
iii. Compact spinning system: fiber length and length uniformity, fiber strength, fiber fineness, neps, trash and dust content
iv. Air-jet spinning system: fiber fineness, neps, trash and dust content, fiber strength, fiber length and length uniformity

All instrumental measurements currently utilized in USDA Upland cotton classification are from Uster High Volume Instrument (HVI) systems.

It has been reported that fiber quality attributes measured by High Volume Instrument (HVI) have a strong relationship with ring spun yarn tensile strength. For example, (El Mogahzy et al. 1990) showed that cottons with improved upper half mean length (UHML), tenacity, micronaire, and length uniformity can be used to produce yarns with a higher skein breaking factor (SBF). (Backe 1996), showed the importance of cotton fiber bundle elongation on yarn quality and weaving performances.
(G.B. Tesema and Hussein 2015) used the HVI fiber properties to compare the relative performance of different quantification methods to define the technological value/fiber quality of cotton varieties from Ethiopia, India and Egypt involved in the study.

Though the strength of cotton fibers has been usually measured using bundle methods (Hunter and Gee 1982); (Harig et al. 1994); (Sasser et al. 1991); (Taylor 1986), although more precise and laborious measurements of individual fiber strength also exist (e.g. FAVIGRAPH of TEXTECHNO, Germany, is a tensile tester for single fibers working according to the CRE-principle).

This test method is effectively used for research purposes because of that strength assessed by the individual fiber method characterizes fibers from the material engineering point of view, and for this reason its value is so countless.

The FAVIGRAPH combines linear-density measurements and tensile tests in one test equipment. Here the linear-density measuring head, which is based on the FAVIMAT+ technology, is situated adjacent to the tensile test section. In FAVIGRAPH the appropriate pre-tensioned fiber is manually loaded. At the start of the test the transfer clamp is positioned above the linear-density measuring head. First, the linear density of the fiber is determined. Thereafter, the transfer clamp turns to the tensile test section and places the fiber into the measuring- and draw-off clamp.

Reportedly, the individual fiber’s work-to-break is extremely important to prevent fiber breakage during processing. Stronger fibers tend to have higher elongation which results in better work-to- break which could lead to lower fiber breakage during processing (Hequet et al. 2016). 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 fibers. In ring frame, the fibers are drafted to individual fibers and then get twisted by the traveler to the required yarn count. In rotor spinning only few fibers come to the highly rotating section of the rotor to join and get twisted by the cranking action of the open-end yarn. In Dref-3 Friction Spinning System, twin opening rollers are used, to obtain a high degree of fiber separation and the drums generate false twist into the fiber ribbon while wrapping the deposited individual fibers around the fiber ribbon. A Murata Air-Jet spinning system consists of 3-over-3 high speed roller drafting unit, so that attenuate and individualize the fibers ribbon before coming out from the front roller of the drafting unit (Lawrence 2003).

Therefore, it can be reasonably explained that the elongation characteristics associated with fiber tenacity are critically important at textile processes, namely: Ginning, Opening, Carding, Spinning and Weaving.

Investigators reported that fiber quality attributes measured by laboratory testing instruments have relationship with the quality of cotton and/or cotton spun yarns (Iwona 1995).

Yarn thin and thick places, which refer to imperfections that are within the measuring sensitivity range (±50% with respect to the mean value of yarn cross-sectional size) adversely affect yarn and fabric quality (Sharieff and Vinzanekar 1983); (Meredith 2002). High quality yarns should also have a low number of thin and thick places per a given length of yarn. The number of thin and thick places in the yarn has been shown to be related to HVI micronaire and uniformity index.

HVI characterization of cotton quality and uniformity is important and common practice. But since, during fiber processing the stress is not applied to bundle of fibers but to individual fibers or small tufts of fibers. Therefore, the individual fiber's work-to-break is extremely important to understand the mechanisms of fibers breakage during their processing. Since elongation at break is the main contributor to the work-to-break of cotton fibers. This implies that considering the property of individual fiber elongation, in the characterization of cotton, is very important. Unfortunately, elongation is not currently reported by HVI.

Therefore, the objective of this research work is to instrumentally characterize the three commercial cotton varieties by using the three-important cotton fiber testing instruments, namely HVI, AFIS and FAVIGRAPH.

Materials and methods

The materials used in this study composed three commercial varieties, namely: Acala (SJ-2), Arba and Deltapine (DP-90) collected from three plantation zones and 12 ginneries. The major cotton plantation zones covered are: North Ethiopia - (Tigray, Amhara & Benishangul Gumuz); North-Central Ethiopia (Upper Awash, Middle Awash & Lower Awash) and Southern Ethiopia (Oromia, Arba Minch & Gambella)[**].

Table 1. Particulars of different regions of Ethiopia used for collection of commercial samples

Regions	Farms/ Places	Irrigation/ Rain fed	Approximate Altitude
North Ethiopia	Hiwot farm in Humera Small & Large farms in Metama Zeleke farm in Benishangul	Rain Feed	700-1000 m
North-Central Ethiopia	Tendaho Agricultural Development Agency	Irrigated	300 m
	Middle Awash State Farm, Amibara Farm, Bonta Farm	Irrigated	700 m
South Ethiopia	Arba Minch State Farm Small farms in Malayata Sodo Birala Agricultural farm in Jinka	Irrigated except in Sodo	1000 m

Careful attention has been made to avoid mixing of cotton from different field lots as well as lots from different plantation areas and varieties at the time of ginning seed cotton. Therefore, the original variety and source is identified after ginning.

A subset of 32 bales from each variety of similar maturity group was selected to instrumentally characterize the commercial cotton varieties. For each bale a complete fiber quality profile was done. A cotton sample for each bale were tested with 100 number of measurements on High Volume Instrument (USTER HVI 1000). This procedure was used on 32 Bales (i.e. 1 sample x 100 tests x 32 Bales replications).
Definitions regarding sampling, sample handling and testing of cotton in the laboratory as well as the use of **S**tandardized **I**nstruments for **T**esting **C**otton, High Volume Instrument (HVI) was performed according to the internationally harmonized rules (Drieling et al. 2017).

They were also tested on the Advanced Fiber Information System (USTER AFIS PRO 2), with 15 replications of 3,000 fibers.

Single fibers were tested with the FAVIGRAPH (gauge length = 3.0 mm, pre-tension = 0.1 cN/dtex, and testing speed = 100 mm/min). The same subset of 32 bales was used to investigate the relationship between FAVIGRAPH individual fiber tenacity and HVI bundle tenacity. A total of 750 fibers (150 fibers x 5 replications) from each of the 32 bales were tested on a FAVIGRAPH tensile tester at a 3mm gauge length. FAVIGRAPH provides the force-to-break, elongation, and work-to-break of individual cotton fibers.

The HVI fiber properties along with statistical parameters of commercial cotton varieties, namely: Acala (SJ-2), Arba and Deltapine (DP-90), are shown in Table 2.

Table 2. HVI values of commercial cotton bundle fiber properties and their statistical parameters

Cotton Varieties	Fiber properties	Statistical parameters						
		Mean	S. D	Min	Max	S.E.	R	C.V (%)
Acala (SJ-2)	MIC	4.40	0.39	3.61	4.81	0.10	1.20	8.86
	UHML	28.30	0.60	27.46	29.36	0.16	1.90	2.12
	UI	82.25	2.15	77.58	85.37	0.55	7.79	2.61
	SFI	10.25	0.48	9.79	11.14	0.12	1.35	4.68
	FS	28.28	0.72	25.47	30.12	0.06	4.65	2.55
	FE	4.72	0.29	4.30	5.09	0.07	0.79	6.14
	Rd	79.85	1.36	77.42	81.67	0.35	4.25	1.70
	+b	8.77	0.55	7.57	9.44	0.14	1.87	6.27
Arba	MIC	4.14	0.06	3.99	4.23	0.22	0.24	1.45
	UHML	27.48	0.71	26.76	28.55	0.18	1.79	2.58
	UI	81.13	0.55	79.99	82.18	0.14	2.19	0.68
	SFI	12.63	1.93	10.31	15.40	0.50	5.09	15.28
	FS	27.89	0.18	27.31	28.57	0.01	1.26	0.65
	FE	4.28	0.44	3.67	5.12	0.11	1.45	10.28
	Rd	79.85	1.52	77.42	81.67	0.48	4.25	1.90
	+b	11.44	0.26	10.72	11.79	0.07	1.07	2.27
Deltapine (DP-90)	MIC	4.30	0.10	4.18	4.48	0.03	0.30	2.33
	UHML	27.26	0.60	26.42	28.32	0.16	1.90	2.20
	UI	81.13	0.55	79.99	82.18	0.14	2.19	0.68
	SFI	9.25	0.92	7.93	11.05	0.24	3.12	9.95
	FS	26.94	0.74	22.81	27.61	0.06	4.80	2.75
	FE	5.14	0.32	4.79	5.92	0.08	1.13	6.23
	Rd	71.33	4.41	61.33	74.51	1.14	13.18	6.18
	+b	8.14	0.14	7.76	8.28	0.04	0.52	1.72

Table 3. AFIS fiber properties and statistical parameters of Acala SJ-2 commercial variety

Cotton variety	Fiber properties	Statistical parameters						
		Mean	S. D	Min	Max	S. E	R	CV (%)
Acala (SJ-2)	Fineness, mtex	164	9.16	149	184	2.36	35	5.58
	Maturity ratio	0.85	0.02	0.81	0.91	0.01	0.10	2.80
	Length by weight, mm	23.7	0.83	21.9	25.2	0.22	3.3	3.51
	Length by weight CV, %	33.6	1.08	32.4	36.0	0.28	3.6	3.21
	Short fiber content by weight, %	8.2	1.17	6.4	10.9	0.30	4.5	14.26
	Upper quartile length by weight, mm	28.8	1.02	26.7	30.6	0.26	3.9	3.56

	Length by number, mm	19.2	0.75	17.8	20.5	0.19	2.7	3.89
	Length by number CV, %	48.5	2.19	44.7	52.7	0.57	8.0	4.52
	Short fiber content by number, %	24.5	2.66	19.7	30.3	0.69	10.6	10.84
	Immature fiber content, %	8.7	0.90	7.2	10.8	0.23	3.6	10.42
	Total neps, count/g	188	36.71	132	248	9.48	116	19.48
	Total neps mean size, mm	692	49.22	623	784	12.71	161	7.12
	Fiber neps, count/g	173	34.90	118	234	9.01	116	20.17
	Fiber neps mean size, mm	652	26.90	608	723	6.95	115	4.13
	Seed coat neps, count/g	15	12.78	4	44	3.30	40	83.32
	Seed coat neps mean size, mm	1179	315.33	742	1725	81.42	983	26.75
	Visible foreign matter, %	1.35	0.52	0.13	2.12	0.15	1.99	38.66

M (Mean), S.E (standard error), C.V % (coefficient of variation), S.D (standard deviation), R (range)

Table 4. AFIS fiber properties and statistical parameters of Arba commercial variety

Cotton variety	Fiber properties	Statistical parameters						
		Mean	S. D	Min	Max	S. E	R	CV (%)
Arba	Fineness, mtex	156	11.04	136	170	2.85	34	7.09
	Maturity ratio	0.84	0.04	0.77	0.91	0.01	0.14	5.16
	Length by weight, mm	23.1	1.20	20.3	24.9	0.31	4.6	5.18
	Length by weight CV, %	34.7	3.44	29.2	41.0	0.89	11.8	9.91
	Short fiber content by weight, %	9.2	3.53	4.4	17.3	0.91	12.9	38.37
	Upper quartile length by weight, mm	28.1	0.91	25.5	29.1	0.24	3.6	3.24
	Length by number, mm	18.7	1.82	14.8	21.6	0.47	6.8	9.75
	Length by number CV, %	49.0	6.66	39.2	66.4	1.72	27.2	13.60
	Short fiber content by number, %	25.7	7.97	14.4	45.6	2.06	31.2	30.98
	Immature fiber content, %	8.7	2.36	5.6	14.1	0.61	8.5	27.11
	Total neps, count/g	213	46.95	122	280	12.12	158	22.08
	Total neps mean size, mm	729	59.85	657	867	15.45	210	8.21
	Fiber neps, count/g	186	52.93	92	270	13.67	178	28.50
	Fiber neps mean size, mm	654	25.28	616	693	6.53	77	3.87
	Seed coat neps, count/g	27	18.56	8	76	4.79	68	68.91
	Seed coat neps mean size, mm	1175	108.24	964	1305	27.95	341	9.21
	Visible foreign matter, %	2.71	1.52	0.50	5.66	0.39	5.16	56.28

M (Mean), S.E (standard error), C.V % (coefficient of variation), S.D (standard deviation), R (range)

Table 5. AFIS fiber properties and statistical parameters of DP-90 commercial variety

		Statistical parameters						
		Mean	S. D	Min	Max	S. E	R	CV (%)
Deltapine (DP-90)	Fineness, mtex	160	7.43	149	174	1.92	25	4.65
	Maturity ratio	0.85	0.03	0.82	0.91	0.01	0.09	3.06
	Length by weight, mm	23.1	0.61	21.8	24.4	0.16	2.6	2.63
	Length by weight CV, %	34.1	1.48	30.9	36.4	0.38	5.5	4.33
	Short fiber content by weight, %	8.6	1.40	5.6	10.4	0.36	4.8	16.15
	Upper quartile length by weight, mm	28.1	0.60	26.9	29.0	0.16	2.1	2.14
	Length by number, mm	18.8	0.76	17.4	20.5	0.20	3.1	4.04
	Length by number CV, %	47.9	2.39	42.9	50.9	0.62	8.0	4.98
	Short fiber content by number, %	24.6	3.04	18.0	28.4	0.78	10.4	12.35
	Immature fiber content, %	8.1	0.94	6.4	9.7	0.24	3.3	11.59
	Total neps, count/g	202	26.62	156	238	6.87	82	13.20
	Total neps mean size, mm	711	20.61	670	738	5.32	68	2.90
	Fiber neps, count/g	186	26.59	138	218	6.87	80	14.33
	Fiber neps mean size, mm	669	21.08	635	708	5.44	73	3.15
	Seed coat neps, count/g	16	4.47	6	22	1.15	16	27.95
	Seed coat neps mean size, mm	1189	155.08	992	1500	40.04	508	13.04
	Visible foreign matter, %	1.62	0.79	0.29	3.03	0.20	2.74	48.90

M (Mean), S.E (standard error), C.V % (coefficient of variation), S.D (standard deviation), R (range)

Table 6. ANOVA for AFIS length (L_n) distribution evaluation (Between commercial cotton varieties)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.982	2	.991	.668	.518
Within Groups	62.303	42	1.483		
Total	64.284	44			

Table 7. Values of FAVIGRAPH single fiber properties and their statistical parameters

Cotton Varieties	Fiber properties	Statistical parameters						
		Mean	S. D	Min	Max	S.E.	R	CV (%)
Acala (SJ-2)	Linear Density, dtex	1.60	0.10	1.25	1.75	0.01	0.50	6.54
	Tenacity, cN/Tex	23.28	0.17	22.35	23.82	0.01	1.47	0.71
	Elongation, %	7.01	0.98	4.80	9.42	0.08	4.62	14.00
Arba	Linear Density, dtex	1.62	0.12	1.25	1.78	0.01	0.53	7.34
	Tenacity, cN/Tex	22.67	0.20	22.17	24.23	0.02	2.06	0.90
	Elongation, %	6.63	0.88	4.11	8.24	0.07	4.13	13.28
Deltapine (DP-90)	Linear Density, dtex	1.64	0.11	1.27	1.77	0.01	0.50	6.86
	Tenacity, cN/Tex	21.41	0.19	20.69	21.71	0.02	1.02	0.87
	Elongation, %	6.41	0.78	0.93	7.94	0.06	7.01	12.24

Results and discussion

Instrumental characterization of the three Commercial Ethiopian Cotton

Among twelve different Ethiopian cotton varieties, widely used three different commercial cotton varieties namely, Acala SJ-2, Arba and Deltapine (DP-90) were selected for instrumental characterization of Ethiopian cotton. The test results obtained from HVI, AFIS and FAVIGRAPH instruments are presented in Tables 2-7.

(i) Fiber Length and Length Distribution:

AFIS test results on fiber length distributions are presented in tables 3-5 for varieties used in the study. From the ANOVA table 6 we can observe that no significant difference in the fiber length distribution is observed (i.e., p value > 0.05) between the varieties. Acala SJ-2 (Ln = 19.2, SFCn = 24.5); Arba (Ln = 18.7, SFCn = 25.7); DP 90 (Ln = 18.8, SFCn = 24.6). The result of ANOVA analysis with no significant difference in the fiber length distribution permits the spinners to classify the bales into the same categories during HVI fiber selection and laydowns arrangements.

(ii) Fiber Tenacity and Elongation

This work, in addition to HVI bundle tenacity, uses the FAVIGRAPH single fiber tenacity/elongation results (FAVIGRAPH of TEXTECHNO, Germany). The relationships between average FAVIGRAPH Single fiber tensile properties and HVI bundle properties are all linear with a positive slope and a rather good coefficient of determination (R^2 = 0.792).

The elongation characteristics associated with fiber tenacity are of critical important at textile processes, namely: Ginning, Opening, Carding, Spinning and Weaving. Stronger fibers tend to have higher elongation which results in better work-to-break. This could lead to lower fiber breakage during processing. FAVIGRAPH elongation and work-to-break relationships are also all positive with a positive slope and good coefficient of determination (R^2 = 0.793).

HVI tenacity values: Acala SJ-2 (28.28 cN/tex), Arba (27.89 cN/Tex), DP-90 (26.94 cN/Tex) is quite narrow for the three commercial varieties. FAVIGRAPH single fiber tenacity and elongation is also presented in table 6 with the value: Acala SJ-2 (Tenacity = 23.28 cN/Tex, Elongation = 7.01 %), Arba (Tenacity = 22.67 cN/Tex, Elongation = 6.63 %), DP-90 (Tenacity = 21.41 cN/Tex, Elongation = 6.41 %).

HVI Tenacity in cN/tex of the three commercial varieties fall in the range 26.94-28.28. This HVI tenacity data of the representative samples for the studied three commercial varieties will be useful to the spinner while blending cotton with other varieties of cotton or manmade fibers and to the weaver and finisher for identifying suitable varieties which can stand sizing and chemical finishing treatments better.

Fiber elongation at break or the breaking elongation is an important cotton fiber property that directly affects yarn elongation and work-to-break values. It is reported that even though, Fiber bundle elongation can be measured by HVI systems, but, due to a lack of calibration standards, the results are not comparable between systems (Benzina et. al). In the studied samples the FAVIGRAPH elongation in percent for the three commercial varieties fall in the range 6.41-7.01. According to literatures a level above 7% being desirable. Based on this information to prepare a cotton mix for relatively better yarn and greige fabric elongation the spinner has to increase the proportion of by weight of the Acala SJ-2 variety.

(iii) Fiber Fineness and Maturity

Typically, fiber fineness is reported by micronaire value. However, variation in micronaire value for any one variety usually indicates change in maturity rather than change in fineness because, micronaire value calculated by normal airflow instruments is influenced by fiber maturity. Therefore, the Advanced Fiber Information System (USTER AFIS PRO 2) were used to measure fineness in addition to HVI micronaire.

Micronaire values: Acala SJ-2 (4.40), Arba (4.14), DP-90 (4.30) is quite narrow for the three commercial varieties. This range is considered good for spinning. Differences in AFIS fineness between the three commercial varieties: Acala SJ-2 (164 mtex), Arba (156 mtex), DP-90 (160 mtex) is also very small.

Average Maturity Ratio range of the three commercial cotton varieties grown at different places/farms is Acala SJ-2 (0.85), Arba (0.84), DP-90 (0.85), which is considered satisfactory. Cotton fiber maturity greatly affects nep formation, dye uptake and dyed appearance. Variations in maturity within a yarn batch or fabric can lead to streakiness and barré due to differences in dyed appearance. The spinner has to understand, however, not only the average maturity which is important but also the distribution of maturity. A small percentage of immature or “dead” fibers may not significantly affect the average maturity but could affect the yarn and fabric appearance, notably in terms of nippiness and white flecks which can comprise only about 0.5% (by weight) of fibers.

(iv) Neps

Number of neps per gm of fibers and also nep size are influencing factors in quality of yarn, particularly of finer count. AFIS is considered one of the most reliable process control instruments used to measure neps at different stages in processing. The AFIS measurements of neps in cotton samples are provided in tables 3-5. Since nep count is commonly used in spinning industry, we have: Acala SJ-2 (Neps = 188 Count/g); Arba (Neps = 213 Count/g); DP-90 (Neps = 202 Count/g). It is expected that neps are created at first place during ginning and nep count is influenced by fiber maturity which mostly varies from place to place and time to time within the same variety. Thus, nep count is likely to be influenced by ginning practices and sources of fibers. Therefore, further study is required for comparative analysis of nep counts between places/ginneries and also before and after machine ginning.

A modified cotton fiber quality index

It is documented that various studies associated with HVI systems may be divided into three categories: (a) evaluation of the precision and repeatability of HVI measurements, (b) engineered fiber selection and cotton bale management using HVI parameters, and (c) development of prediction equations of yarn quality and processing performance (EL Mogahzy et al. 1990).

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.

The currently used fiber quality index is based mainly on HVI measurements:

$$FQI_{HVI} = \frac{FS \times UHML \times UI}{FF} \quad \ldots\ldots \quad (1)$$

FS is the fiber bundle tensile strength (cN/tex), UHML is the upper half mean length (mm), UI is uniformity index (%) and FF is fiber fineness (micronaire) Murthy and Samanta (2000).

The FQI_{HVI} equation doesn't consider the elongation property which is the main contributor to the work-to-break of cotton fibers.

It is documented that HVI bundle clamping units use a gauge length of 1/8 inch (3.175 mm) for tensile testing. The system of pre-tensioning as well as height of pre-tensioning are not known for these units. The speed of breaking according to literature is: 100…140 mm/min for the USTER HVI 1000. A comparison was made between US upland cotton measured by FAVIMAT and the three commercial upland varieties measured by FAVIGRAPH.

Single fibers were tested with similar testing conditions for both FAVIGRAPH and FAVIMAT; gauge length = 3.0 mm, pre-tension = 0.1 cN/dtex, and testing speed = 100 mm/min).
Providing similar calibration system for both the Favigraph and Favimat laboratory testing instruments, the following force-at-break correlation is found for the cotton sample used with the above mentioned linear density [Fig. 1]:

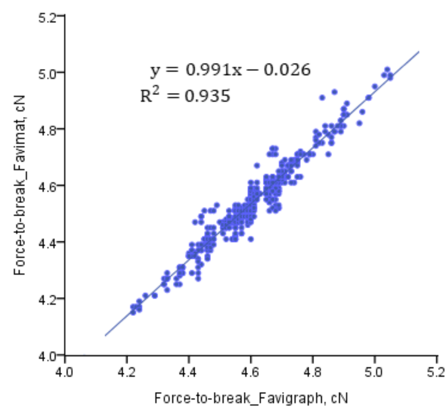

Figure 1. FAVIGRAPH force-to-break Vs. FAVIMAT force-to-break

In arriving the choice of an appropriate modified fiber quality index equation for the three commercial cottons the following correlation between FAVIGRAPH single fiber and HVI bundle tenacities is produced.

$$ST_G = 0.926BT_H - 3.420$$

Where: ST_G is the Favigraph single fiber tenacity in cN/tex, BT_H is the HVI bundle tenacity in cN/tex (fig. 2).

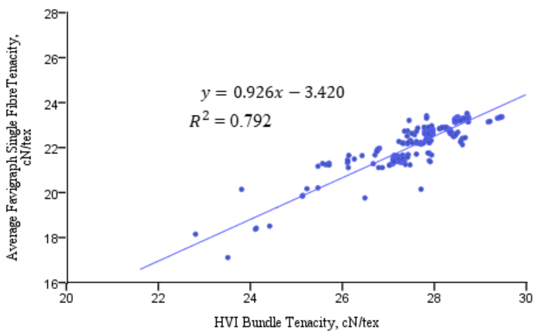

Figure 2. HVI bundle tenacity Vs. average Favigraph single fiber tenacity

The FAVIGRAPH single fiber test results are compared with the US upland cotton measured by FAVIMAT.

For the US Upland cotton, using Favimat researchers (Hequet et al. 2016) evaluated the relationship between HVI bundle tenacity and Favimat average single fiber tenacity (fig. 3)

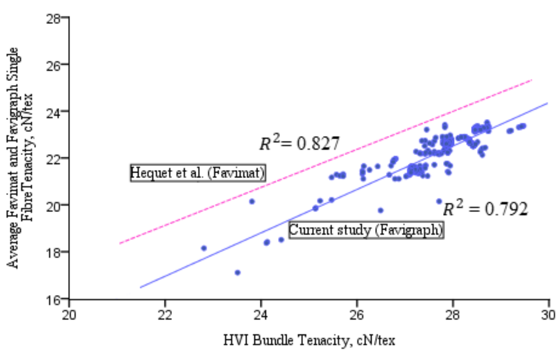

Figure 3. HVI bundle tenacity Vs. average Favimat single fiber tenacity

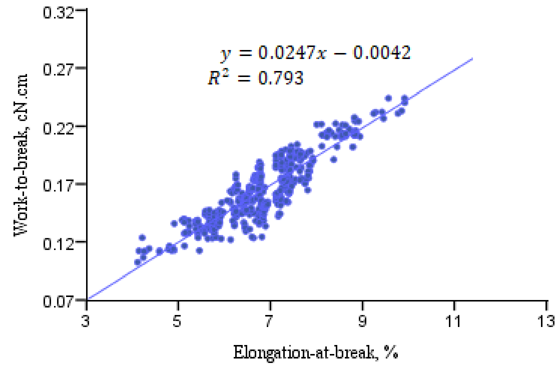

Figure 4. Favigraph elongation-at-break Vs. work-to-break

Using Favimat researchers (Hequet et al. 2016) also evaluated the relationship between elongation-at-break and work-to break on the US upland cotton and the result of their studies is presented in the following figure:

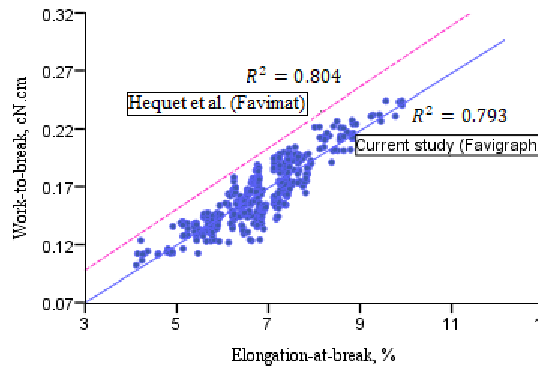

Figure 5. Favimat and Favigraph elongation-at-break Vs. work-to-break

In order to compare different cottons, work of rupture should be evaluated so that it is possible to take account of the various masses of different varieties. Hence, specific work of rupture, which is the amount of energy needed to break a sample of unit mass, should be used.

Thus, the MFQI which considers both the single fiber tenacity and elongation is more consistent for the comparison between different cotton varieties. Accordingly, considering both the HVI and FAVIGRAPH main fiber properties and assuming the linear geometric properties, a modified fiber quality index formula is presented as follow:

$$MFQI = \frac{[UHML_H \times UI_H \times (1 - SFI_H) \times SFS_G \times (1 + EL_G)]}{MIC_H}$$

$UHML_H$ 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), SFS_G is Favigraph single fiber tenacity (cN/Tex), EL_G Favigraph single fiber elongation (%).

Table 7. Quality Index values for the three commercial cotton varieties

Cotton Varieties	Cotton Fiber Quality Indexes		
	FQI	SCI	MFQI
Acala (SJ-2)	149.6	126.0	130.9
Arba	150.2	121.4	113.7
DP-90	138.6	110.0	106.3

Table 8. 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	549.5
US UPLAND	170.2	134.3	145.4
Giza 87	472.2	228.0	516.9

Conclusions

In conclusion, the result of ANOVA analysis with no significant difference in distribution permits the spinners to classify the bales into the same categories during HVI fiber selection and laydowns arrangements. Classification of cotton bales with similar length distribution will minimize the undesirable laydown variability in critical properties such as short fibers contents which are the main sources of yarn unevenness.

In this study the HVI tenacity for the studied three commercial varieties fall within the range of 26.94-28.28. According to USDA system of cotton classification this range is categorized in the descriptive designation “average” strength group. In the studied samples the FAVIGRAPH elongation in percent for the three commercial varieties fall within the range 6.41-7.01. According to literatures a level above 7% being desirable. During preparation of a cotton mix desired for relatively better yarn and greige fabric elongation the spinner may increase the proportion by weight of the Acala SJ-2 variety.
Micronaire values: Acala SJ-2 (4.40), Arba (4.14), DP-90 (4.30) is quite narrow for the three commercial varieties. This range is considered good for spinning. Differences in

AFIS fineness between the three commercial varieties: Acala SJ-2 (164 mtex), Arba (156 mtex), DP-90 (160 mtex) is also very small. And their average Maturity Ratio range grown at different places/farms is Acala SJ-2 (0.85), Arba (0.84), DP-90 (0.85). The similarity in maturity ratio can be taken as an indication for the accuracy of micronaire readings.

Although neps are related to maturity, including maturity distribution and "dead" fibers, harvesting, ginning and mechanical treatment (processing) conditions in the spinning mill. The measured nep level of lint (ginned) cotton for the studied varieties, Acala SJ-2 (Neps = 188 Count/g); Arba (Neps = 213 Count/g); DP-90 (Neps = 202 Count/g) can be taken as an information for spinner to optimize the speed of beating rollers in the blow room. Optimizing a carding machine is particularly challenging since the card's ability to remove objectionable faults (neps, trash and seed coat fragments) and the degree of fiber damage are diametrically opposed.

Ranges of the three commercial fiber properties fall within a narrow range. Ethiopian textile factories are equipped with both ring as well as rotor spinning facilities and some of the factories have combing machines. However, spinners need much wider range of fibers to utilize fully and economically their plants. In order to compete in the international market for export as well as to cater to the needs of domestic markets and also to run the plants at the optimum capacities, wider range of products is essential. Cotton breeders and cultivators in Ethiopia should strive to cultivate long and strong fibers with a better elongation property.

In this research work a modified fiber quality index (MFQI) is formulated for the commercial Ethiopian cotton varieties and the results are given in Table 7. The values obtained are compared with the values of the usually used fiber quality index and spinning consistency index formulas which do not consider the fiber elongation property. For example, the performance of Acala SJ-2 is known to be better than that of Arba during the back-trace history spinning processes. This is clearly shown by the value of MFQI where both FQI the SCI failed to predict it.
The results obtained show that the combination of HVI and FAVIGRAPH data allows us to predict quite accurately fiber properties for commercial bales.

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** The clustering of Regions in the North, North-Central and South Ethiopia is used only for the purpose of categorizing cotton cultivation areas where samples are collected in this research.