IOSR Journal of Polymer and Textile Engineering (IOSR-JPTE)
e-ISSN: 2348-019X, p-ISSN: 2348-0181, Volume 10, Issue 1 (Jan. –Feb. 2023), PP 01-10
www.iosrjournals.org

RankingandFiber QualityNorms of Egyptian CottonsBased on AHP and K-means

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Abstract
This paper presents the Analytic Hierarchy Process (AHP) techniqueto determine the technological value of Egyptian cottons. Based on the high dimensional data of the Fiber Classifying System (FCS) instrument, the unique classes of cotton quality were drawn by K-means clustering.The materials used are lotsof different lint grades of Egyptian commercial cotton varieties that collected from cotton ginning mills across the country.The extra-long and fineness varieties outperform the rest of the varieties in terms of quality, and the classer gradeFG in each variety shows a great superiority over the rest of the grades.GF_{AHP} *can be used as quantitative criteria to describe the grade of Egyptian cotton more clearly than GrF, and* M_{AHP} *can also be used to expressthe technological value of the cotton lot more accurately than FQI.Because these criteria take into account the relative importance of each separate fiber property.Using K-means clustering, cotton fiber quality norms can be made to facilitate manufacturers to select the most appropriate fibers that achieve the optimal combination of several good yarn characteristics.*
Keywords: Analytic Hierarchy Process, Fiber Quality Index, Grade Factor, technological value, Egyptian cottons

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Introduction

Cotton is the most important and widely used natural fiber that possesses galore variability in its physical characteristics.The priority of breeding programs around the cotton farming world is most often given to the improvement of fiber length, strength and fineness. Cotton fibers are not homogeneous and their physical have a great diversity within the sample. Fiber characteristics are multivariate character of information, various units and lack of transformation to the utility scales the main problem with utilization of cotton fiber (Rasked, 2002). Longer fibers are generally stronger than shorter ones. The presence of excessive amount of short fibers can give rise to low production efficiencies and poor quality of textile product (Ebaido and Rokya, 2011). The cotton fiber strength and elongation directly affect yarn strength and elongation (Yang and Gordan, 2016 and Hassan and Ibrahim, 2018). Generally, yarn strength that considered being the most important of spun yarns, is largely influenced by fiber length, length uniformity, short fiber content, tenacity, elongation and fineness of the constituent raw cotton (Majumdar*et al*., 2004).

At the premises of Textile Testing Technology (TEXTECHNO Company), the Fiber Classifying System instrument (FCS) designed to measure multiple physical properties of both cotton and man-made fibers. This system consists of four modules, each one run separately, i.e., Fibrotest, Wira, Opotest and MDTA (Ebaido*et al*., 2021). Cotton classing methodology is based on both grade and instrument standards used hand-in-hand with state of the art methods and equipment to provide the cotton industry with possible information on cotton quality for marketing and processing (Chang and Chang, 2003). Cotton grades are based on the preparation of raw cotton, color and trash content. Egypt is well known as a country that is growing up cotton varieties with very special unique properties such as length, strength, fineness (Ebaido*et al*., 2017).

In the last decades, three traditional methods, namely the fiber quality index (FQI), premium discount index (PDI) and spinning consistency index (SCI), were used to determine the technological value of cotton fibers in the form of dimensions indexes. The determination of technological value and ranking cotton fibers is primarily a multi-criteria decision making (MCDM) problem. The Analytic Hierarchy Process (AHP) which introduced by Saaty (1990) is one of the most frequently discussed methods of MCDM (Majumdar*et al*., 2005 and Husseiene*t al*., 2010).The reason for AHP popularity lies in the fact that it can handle the objective as well as subjective factors, and the criteria weights and alternative scores are elicited through the formation of a pair-wise comparison matrix, which is the heart of the AHP technique (Majumdar*et al.*, 2010).For Egyptian cottons, Ahmed and Kamal (1981) and Abdel-Aziz (2009) used the grade factor (GrF= Rd*Mike/Trash) to quantify the lint cotton grades. They concluded that the grade factor is anelaborated and credible numerical means that could use satisfactorily to define and specify the grade and quality of Egyptian cotton. In this respect, Hussein and Ebaido 2011 used AHP for determining the criteria weights of fiber properties encompassed by the grade factor.

Clustering technique is a process of partitioning data objects into groups, or clusters, so that the objects within a cluster are similar to one another and dissimilar from the objects in other clusters (Han *et. al.*, 2012).

Cluster analysis is an unsupervised learning method that acts as a cornerstone in intelligent data analysis processes. It is used for the exploration of interrelationships among a collection of patterns by organizing them into homogeneous clusters (Kotsiantis and Pintelas, 2004).Clustering techniques of high dimensional cotton fiber data could group items into sets of similar objects based on the given attributes.The K-means algorithm defines k centers one for each cluster and hence has k groups. The grouping is done by minimizing the sum of squares of distances between the data members and the corresponding cluster centers. (Vivekanandan and Doke, 2003).The objective of this study was for determinethe technological valueusing Analytic Hierarchy process andnorming the quality of Egyptian cotton using K-means clustering.

I. Materials and Methods

This study was carried out at Egyptian & International Cotton Classification Center (EICCC), Cotton Research Institute, Agricultural research Center,Giza,The materials used in this study were the commercial varieties of Egyptian cotton, i.e., Giza 45, Giza 93, Giza 92, Giza 96, Giza 86, Giza 94, Giza 97 and Giza 95.

According to the local classifying system, the main lint cotton grades, i.e., Fully Good (FG), Good (G), Fully Good Fair (FGF), Good Fair (GF) and Fully Fair (FF) were used for each variety. The bulk samples were brought from cotton gin mills, where each variety followed its own region for the cotton crop season 2020. Six sub-samples from each lint cotton grade were used to determine cotton fiber characteristics using Fiber Classifying System instrument (FCS) – Version 5.4 ($V_{5.4}$). The cotton fiber measurements screened on FCS were upper half mean length (UHM), mean length (ML), uniformity index (UI), short fiber content (SFC), fiber strength (FS), elongation,micronaire value (Mike), maturity ratio (MR), trash content (T), reflectance percentage (Rd) and yellowness degree (+b).

Cotton samples were conditioned prior to testing in the BINDER humidifier equipment for at least 48 hours at 65%±2% Rh and $21^{o}\pm2^{o}C$.

1- Traditional methods of cotton fiber:

- For bale; Fiber Quality Index (FQI)

FQI = $\frac{UHM\times UI\times FS}{FF}$(SITRA, 1995)

Where UHM is upper half mean length, UI is uniformity index, FS is fiber strength and FF is micronaire value.

- For grades;Grade Factor (GrF)

GrF = $\frac{Rd\times Mike}{T}$ (Ahmed and Kamal, 1981)

Where Rd% is reflectance percentage, Mike is micronaire value and T is trash content.

2- Multi-criteria decision making for cotton classification:

- For bale;$\mathbf{M_{AHP}}$= $\frac{UHM^{0.380}\times UI^{0.054}\times FS^{\ \ 0.394}}{Mike^{0.059}\times E^{0.056}\times SFC^{0.054}}$(Majumdar*et al.*,20005)

Where E is elongation and SFC is short fiber content.

- For grade; $\mathbf{GF_{AHP}}$= $\frac{Rd^{0.429}\times Mike^{0.143}}{T^{0.429}}$ (Hussein and Ebaido, 2011)

Figure 1 illustrates the flow chart of the AHP algorithm.

The K – means clustering technique was used to give numerical values for cotton grades by partitioning the dimensional data of cotton grades into groups. The centroid of each of these groups expresses the grade of cotton. Figure 2 illustrate the flow chart of the K-means algorithm.

Using Minitab 17 software (Minitab, Inc., State College, PA), the collected data were subjected to the proper analysis of descriptive statistics.

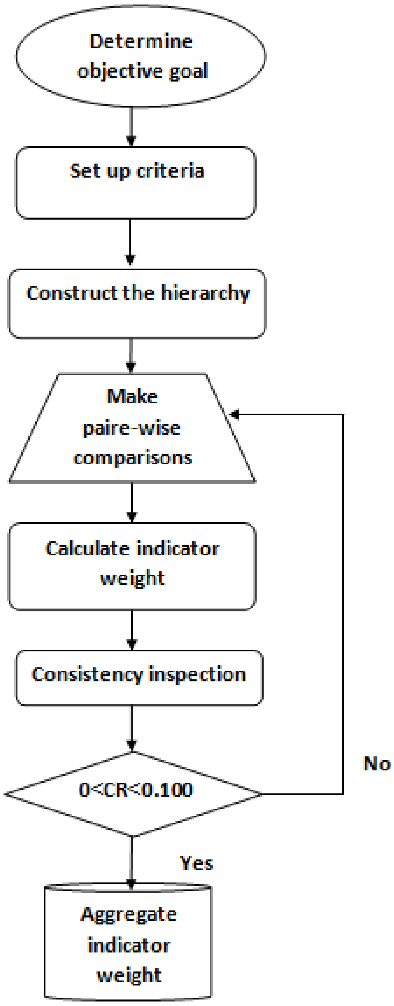

Figure 1.Flow chart of the AHP algorithm.

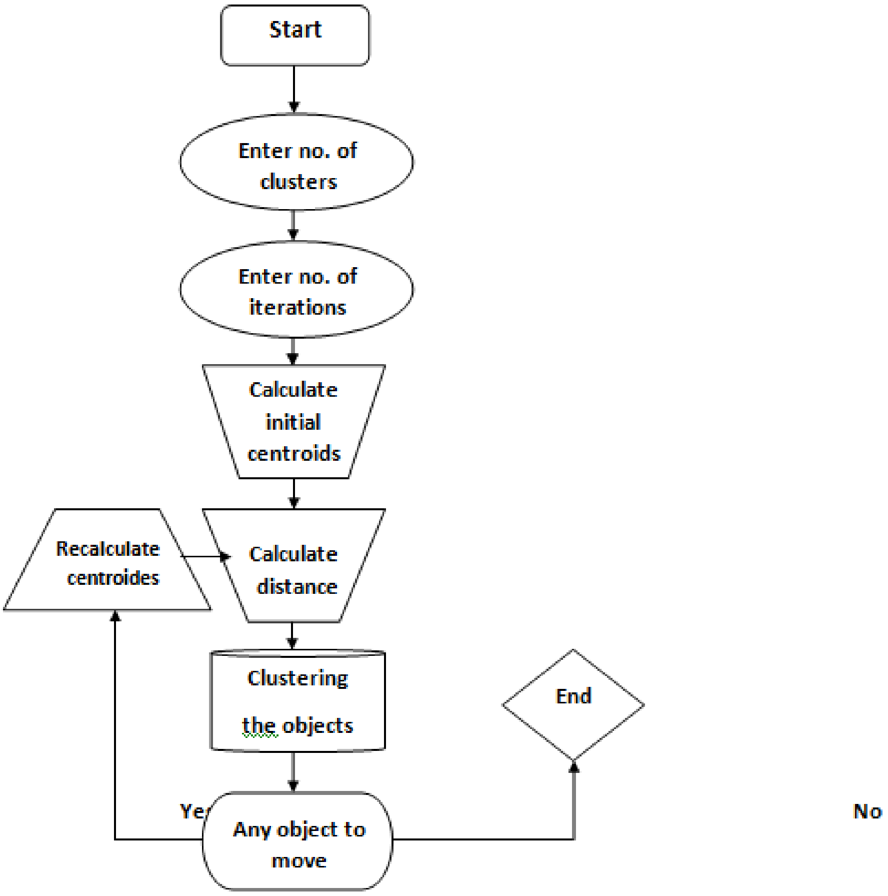

Figure 2.Flow chart of the K-means algorithm.

II. ResultsAnd Discussions

- Variation in cotton fiber properties:

Descriptive statistics for upper half mean length, mean length, uniformity index, short fiber content, fiber strength, elongation,micronaire value, maturity ratio, trash content, reflectance percentage, and yellowness degree, and also $M_{AHP,}$ GrF and $GF_{AHP}$are shown in Table 1. The descriptive statistics were most sensitive with high values of the whole of cotton fiber properties. Grade factor (GrF) and GF_{AHP}showed the highest values of % CV. This is due to the wide variation between lint cotton grades.

The slight differences of symmetry of data distribution for slight differences of fiber properties and the derived multiple criteria were exhibited, where the mean values were nearest to median values. On the other hand, the differences between mean and median values of GrF and GF_{AHP}were very high, so the symmetry was poor with high skewness. The first quartile (Q1) indicates the exactly 25%of values are less than Q1 and the third quartile indicates that exactly 75% of values are less than Q3 so almost of values (Q3) were nearer to the mean value more than the lower values (Q1). Due to the wide variation between cotton varieties and grades, the high differences between Min and Max values exhibited the wide range of FQI, M_{AHP}, GrF and GF_{AHP}.

Table 1. Descriptive statistics for cotton fiber properties and FQI, $M_{AHP,}$ GrF and GF_{AHP}

	Mean	Median	Min	Max	CV	SD	Q 1	Q 2
Mike	3.62	3.64	2.39	4.72	18.04	0.654	3.085	4.18
MR	0.805	0.82	0.61	0.0.98	14.81	0.120	0.700	0.91
UHM	31.71	31.58	26.12	36.31	7.81	2.48	30.07	33.53
ML	25.41	25.37	17.87	31.92	15.21	3.86	22.43	28.57
UI	79.69	81.1	68.4	88.2	8.04	6.4	74	84.93
SFC	11.56	11.47	4.37	19.04	40.35	4.67	7.11	15.93
FS	38.61	39.4	21.5	48.8	17.08	0.595	33.75	44.3
E	6.9	6.85	6.1	8.6	9.74	0.676	6.3	7.4
T	6.72	5.71	0.479	17.83	81.84	5.5	1.83	10.37
Rd	67.86	68.5	51.2	78.5	10.10	6.86	62.33	73.1
+ b	9.4	8.8	8.1	12.2	14.86	1.40	8.4	10.8
FQI	285	272	104.7	506.4	34.36	97.84	272	341.4
M_{AHP}	21.87	19.22	10.10	44.07	40.71	8.9	19.22	28.6
GrF	145.5	45	7.7	602	127.8	186.4	45	165.3
GF_{AHP}	52.46	18.20	7.36	203.2	117.3	61.78	18.2	56.1

Table 2 exhibited the mean values for fiber properties of Egyptian cotton varieties and lint grades. Giza 93 and Giza 45 were the most fine and long staple cotton varieties. Approximately all cotton varieties showed somewhat similar value of each offiber elongation and trash content. There is no impact of cotton color with the quality of cotton fibers, since the creamy cotton variety G 93 showed superior values of fiber quality. Within each variety, the differences between lint cotton grades were very high, especially the differences between the FG grade and other lower grades. The strongest cotton fiber varieties were G45, G93, G96 and G92, respectively. Accordingly, the high values of FQI and $\mathbf{M_{AHP}}$ were of G 45, G 93, G 92 and G 96.It is worth to mention that the variety G 92 exhibited values of FQI and $\mathbf{M_{AHP}}$higher thanG 96as a result of the lower micronaire value of G 92 than G 96. It was clear that the extra-long and the finest varieties; G 45, G 93, G 92 and G 96, outperformed the super Giza varieties G 86 and G 94, then the cotton varieties G 97 and G 95 in the characteristics of fiberlength, fineness and strength.

Table 2. Mean values for fiber properties and FQI, $\mathbf{M_{AHP}}$, GrF and $\mathbf{GF_{AHP}}$ of Egyptian cotton varieties and lint grades

V	G	Mike	MR	UHM	ML	UI	SFC	FS	E	Trash	Rd	+b	FQI	M_{AHP}	GrF	GF_{AHP}
G 45	FG	3.16	0.94	36.10	31.7	87.8	4.57	47.5	6.1	0.49	75.9	8.5	447	42.98	493	200
	G	3.07	.897	35.36	30.4	85.9	6.77	45.2	6.2	1.64	73.3	8.6	448	33.2	138	58.8
	FGF	2.83	0.82	33.64	28.1	83.4	10.5	42	6.3	4.98	71.3	8.6	416	23.77	41.2	20.6
	GF	2.63	0.73	31.82	25.9	81.3	14	39.9	6.4	10.2	69.1	8.7	392	18.41	17.8	11.19
	FF	2.46	0.68	30.29	23.2	76.6	16	36	6.6	14.6	65.9	9	340	15.53	11.1	8.77
	M	2.83	0.81	33.44	27.8	83	10.4	42.1	6.3	6.38	71.1	8.7	415	26.78	140	60
G 93	FG	3.06	0.95	36.21	31.9	88	4.75	47.9	6.1	0.55	67.8	11.4	49	42.73	381	161.6
	G	2.88	0.90	35.18	29.8	84.7	6.77	45.1	6.2	1.94	65.5	11.5	467	33.48	97.2	44.6
	FGF	2.78	0.82	32.75	26.7	81.6	10.4	41.3	6.3	5.44	62.5	11.6	397	23.28	32	16.8
	GF	2.62	0.72	31.39	23.6	75.3	14.6	37.4	6.3	10.1	59.2	11.7	337	16.71	15.4	10.17
	FF	2.40	0.66	29.81	21.2	71.1	17.4	32.4	6.5	15.3	51.7	11.8	286	13.60	8.2	8.54
	M	2.75	0.81	33.07	26.6	80.1	10.8	40.8	6.34	6.67	61.4	11.6	397	25.96	107	48.5
G 96	FG	4.04	0.96	35.87	31.5	87.8	5.53	48.4	6.2	0.58	74.7	8.1	`378	35.10	519	175.6
	G	3.82	0.91	33.97	28.7	84.4	8.00	44.6	6.3	1.82	72.8	8.2	335	26.89	153	55.3
	FGF	3.64	.823	32.48	26.6	81.8	11.2	41.8	6.4	5.70	69	8.3	305	20.51	45.5	18.9
	GF	3.38	0.72	31.51	23.7	75.4	14.8	37.3	6.4	10.2	65.7	8.4	262	15.56	21.9	11.3
	FF	3.05	0.63	28.76	20.2	70.1	17.7	31.4	6.5	15.3	59.8	8.9	207	12.35	12	8.37
	M	3.59	0.80	32.52	26.1	79.9	11.5	40.7	6.4	6.7	68.4	8.4	297	22.08	150	63.9
G 92	FG	3.78	0.94	34.67	30.5	88.1	5.67	48.5	6.1	0.64	77.6	8.2	392	35	461	163.2
	G	3.62	0.88	33.20	27.3	84.1	7.6	44.4	6.2	1.90	74.5	8.2	342	28	142	53.20
	FGF	3.44	0.80	32.10	25.1	78.2	11.7	40.5	6.3	5.79	71.8	8.3	295	19.5	43.3	18.68
	GF	3.28	0.70	31.18	22.9	73.5	15.2	36.1	6.3	10.1	67.7	8.4	252	15	22	11.50
	FF	2.83	0.62	28.78	20.2	70.1	18.2	30.3	6.6	15	61.5	8.8	216	12.2	11.6	8.49
	M	3.39	0.79	31.99	25.3	78.8	11.7	39.9	6.3	6.68	70.6	8.4	300	21.92	136	51
G 86	FG	4.68	0.97	33.60	29.4	87.5	6	45.9	7	0.67	78.1	8.3	288	30.6	550	166.6
	G	4.57	0.91	32.43	27.3	84.1	7.88	42.7	7.1	1.90	75.8	8.4	255	24.8	188	58.9
	FGF	4.25	0.84	31.35	25.3	80.8	12.1	39.6	7.2	5.14	72.4	8.5	236	18.1	62.7	22.41
	GF	4.04	0.70	30.20	22.4	74	15.6	33.2	7.3	10.2	68.5	8.6	184	13.8	27.2	12
	FF	3.61	0.63	28.23	19.7	69.6	18.3	27.6	7.5	15.7	59.9	8.9	150	11.3	13.7	8.47
	M	4.23	0.81	31.16	24.8	79.2	12	37.8	7.2	6.71	70.9	8.5	223	19.7	169	53.7
G 94	FG	4.39	0.96	34.32	30.1	87.8	6.1	44.4	7.1	0.65	78.2	8.2	305	31.14	535	169
	G	4.22	0.90	33.13	28.1	84.9	8.2	42.5	7.2	1.92	75.6	8.3	283	25.19	166	55.34
	FGF	3.96	0.83	31.40	25.4	80.8	12.1	39	7.3	5.81	72.6	8.5	250	18.39	49.6	19.15
	GF	3.61	0.70	30.30	22.6	74.7	16.2	35.1	7.4	10.3	67.5	8.6	220	13.96	23.6	11.5
	FF	3.14	0.62	27.80	19.3	69.4	18.7	28.2	7.6	14.9	59.7	9	174	11.40	12.6	8.49
	M	3.87	0.80	31.39	25.1	79.5	12.3	37.8	7.3	6.73	70.7	8.5	246	20	157	52.7
G 97	FG	4.58	0.96	33.54	29.4	87.6	5.51	45	7.3	0.63	75.4	8.9	289	32.11	546	168.4
	G	4.39	0.90	32.31	27.1	84	8.16	42.3	7.4	1.95	72.3	9	261	24.58	163	53.29
	FGF	4.14	0.83	31.22	24.8	79.3	11.2	39.1	7.4	5.62	69.6	9.1	234	19.04	52.1	19.51

	GF	3.83	0.71	30.16	22.2	73.7	16.1	35.3	7.4	10.2	68.1	9.2	205	14.39	25.6	11.81
	FF	3.66	0.62	27.86	19.4	69.7	18.2	28.1	7.5	15.3	59.6	9.3	149	11.3	14.3	8.59
	M	4.12	0.80	31.02	24.6	78.8	11.6	38	7.4	6.73	69	9.1	228	20.3	160	52.3
G 95	FG	4.64	0.95	31.47	27.1	86.2	5.99	39.2	8	0.61	66.8	11.7	229	28.83	506	157.9
	G	4.44	0.90	30.18	25.1	83.2	8.18	36.1	8.1	2.04	64.2	11.8	204	23.11	140	46.39
	FGF	4.23	0.82	29.11	23	78.9	12.8	32.8	8.2	6.02	62.1	11.8	178	16.21	43.7	16.83
	GF	4.04	0.71	28.30	20.8	73.6	16.3	28.2	8.2	10.5	58.5	11.9	145	12.56	22.6	10.67
	FF	3.76	0.61	26.43	18.1	68.5	18.7	21.8	8.5	16.7	52.2	12.1	105	10.29	11.8	7.78
	M	4.22	0.80	29.1	22.8	78.1	12.4	31.6	8.2	7.17	60.8	11.9	172	18.2	145	47.9

The values of grade factor (GrF) and $GF_{AHP}$for the highest grade FG increased by a very large difference from the rest lint cotton grades. The reason for this is that the value of trash which are in the denominator in the equation for calculating GrF and $GF_{AHP}$are very small and almost non-existent in FG grade. Figure 3 and Figure 4 show the great superiority of grade factor and $GF_{AHP}$of FG cotton grade for each variety over the next grade G, then FGF, GF and FF grades. It is noted that the values of GrF and GF_{AHP} differ in the same lint cotton grade from one cotton variety to another. As a result, the estimatorsGrF and GF_{AHP}can not to be use to compare between all cotton varieties, but should be confined to compare grades within each cotton variety (Abdel-Aziz, 2009).

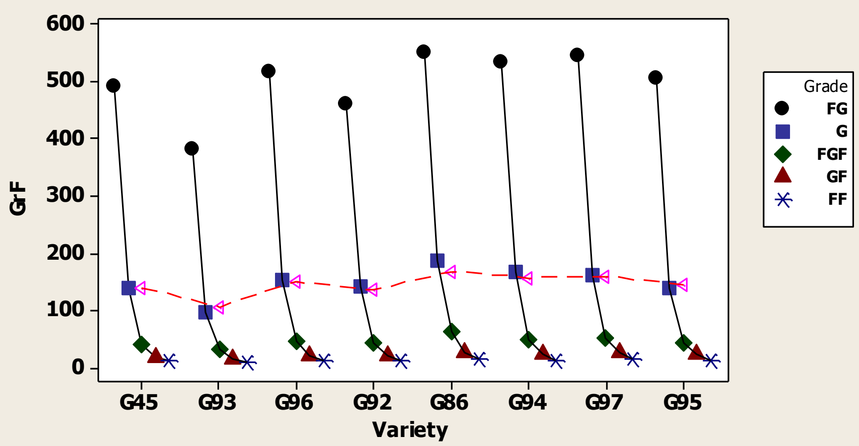

Figure 3. Multi-Vari Chart for GrF by cotton Grade - Variety

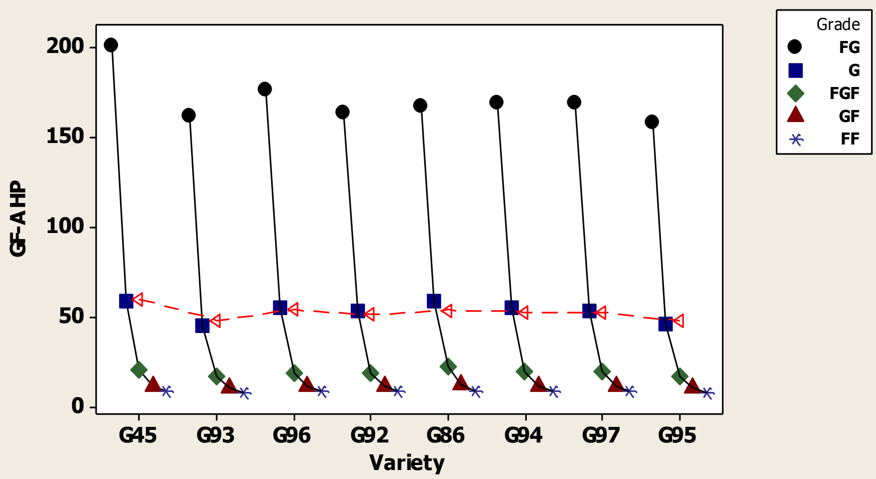

Figure 4. Multi-Vari Chart for GF-AHP by cotton Grade - Variety

Figure 5 and Figure 6 illustrate the clear superiority of extra-long, fine and strongest cotton varieties in FQI and $\mathbf{M_{AHP}}$ over the rest of the long staple varieties. It is also noted that the low grades of the extra-long varieties had higher values of FQI and $\mathbf{M_{AHP}}$than the higher grades of long staple varieties. Also, since these quantitative criteria do not include the characteristics affecting the cotton grade, therefore it is not permissible to rely on them in the classification of cotton grades.

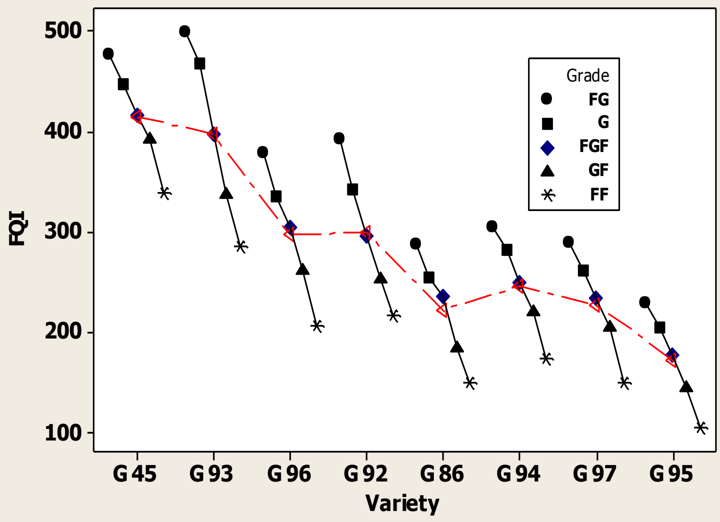

Figure 5. Multi-Vari Chart for FQI by Grade - Variety

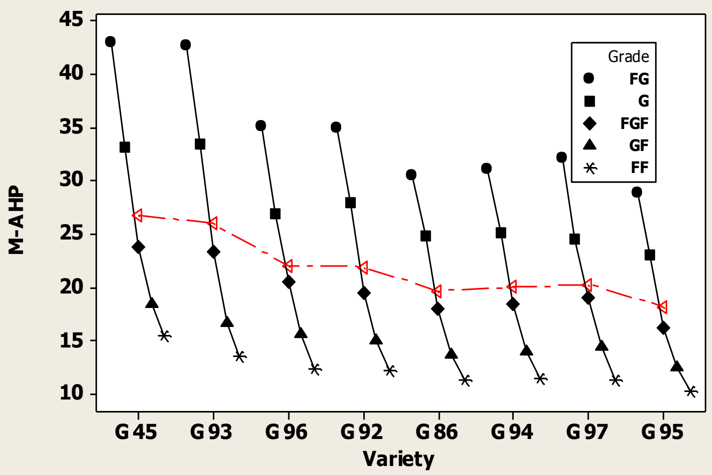

Figure 6. Multi-Vari Chart for V-AHP by Grade - Variety

- Ranking Egyptian cotton varieties and lint grades:

Despite the validity confirmed from the previous results, FQI and $\mathbf{M_{AHP}}$are not apparently indicative of the divergence among lint cotton grades. The rank of Egyptian cotton varieties according FQI and $\mathbf{M_{AHP}}$is shown in Table 3. The values of each of FQI and $\mathbf{M_{AHP}}$differed from one variety to another.

It is remarkable that the ranking of Egyptian cottons in technological value on the basis of FQI and $\mathbf{M_{AHP}}$does not follow the same trend to some extent. The extra-fine varieties G 45 and G 93 are the highest in the ranking by FQI criteria, while inconsistency appears for the rest varieties. And the two varieties G 86 followed by G 95 are the last in the order. Here it can be emphasized that the characteristics that cause this effect a lot arethe micronaire value that is in the denominator of the derived equation of FQI. Therefore, the superiority of the two extra-fine varieties is evident. Also a variety may have a higher value of FQI (G 92), although it is less in length and strength than another variety (G 96), but it is finer. Unlike the case of FQI, in the $\mathbf{M_{AHP}}$, the variety G 92 although it is finer than G 96, has a lower value of $\mathbf{M_{AHP}}$, because it is longer and almost the same as the strength of G 92. The same trend is evident in the ranking of G 94 and G 97 varieties. Since the values of elongation and the short fiber content did not differ clearly from one variety to another, they do not have a significant effect like micronaire value.

This can be explained mathematically by the fact that the attributes included in the calculation of $\mathbf{M_{AHP}}$equation are weighedby a power, while the attributes included in the calculated FQI equation are not raised to a power. So the effect of interrelationships among these characteristics on the value of $\mathbf{M_{AHP}}$ fades away compared to FQI. Based on what was mentioned, and in addition to the fact that $\mathbf{M_{AHP}}$includes more characteristics in its formation than FQI, it can be recommended to use it in rating cotton quality in a satisfactory manner.

Table 3.Ranking Egyptian cotton varieties by FQI and $\mathbf{M_{AHP}}$

Variety	FQI	Rank	Variety	M_{AHP}	Rank
G 45	*414.6*	*1*	G 45	*26.78*	*1*
G 93	*397.3*	*2*	G 93	*25.96*	*2*
G 92	*299.6*	*3*	G 96	*22.08*	*3*
G 96	*297.4*	*4*	G 92	*21.92*	*4*
G 94	*246.3*	*5*	G 97	*20.28*	*5*
G 97	*227.8*	*6*	G 94	*20.01*	*6*
G 86	*222.5*	*7*	G 86	*19.7*	*7*
G 95	*172.4*	*8*	G 95	*18.2*	*8*

- Fiber quality norms of Egyptian cotton:

For this purpose, the clustering K-means algorithm was used according to the steps of the flow chart shown in figure 2. The high dimensional CCS data of cotton fiber attributes was partitioned using K-means clustering technique. Each character divided into clusters that reflect its nominal criteria, where the value of K is the number of the desired clusters. The algorithm organizes vectors into a cluster similar to each other than other vectors belonging to different clusters. The quality norms of each cotton fiber property and the multi-criteriaGrF,GF_{AHP},FQI and $M_{AHP}$are presented in Tables4 through 10. These norms can be used by manufactures for tracking the behavior of fibers in manufacturing and selecting the most appropriate standards for their requirements.It should be noted that the classer grades Extra and Fairthat appeared in Table 9 do not exist in practice. Whereas, the grade Extra is supposed to be completely free of impurities and does not contain any insect infestations, while the grade Fair is very bad,so its fibers are difficult to manufacture. However, it is customary in the Egyptian system to name these two grades within the classer grades of Egyptian cotton.

Table 4. Norms of micronaire value (Mike) for Egyptian cottons

Mike	Class
Less than 3.0	Very fine
3.0 - 3.6	Fine
3.7 – 4.2	Average
4.3 – 4.8	Coarse
More than 4.8	Very coarse

Table 5. Norms of maturity ratio (MR) for Egyptian cottons

MR (Ratio)	Class
More than 0.94	High mature
0.86 – 0.94	Good mature
0.72 – 0.85	Average
0.60 – 0.71	Immature
Less than 0.60	Very immature

Table 6. Norms of fiber length (UHM) for Egyptian cottons

UHM (mm)	Class
More than 39.9	Extra-long
31.9 – 33.9	long
29.7 – 31.8	Medium
27.9 – 29.6	Short
Less than 27.9	Very Short

Table 7. Norms of length uniformity index (UI) for Egyptian cottons

UI (%)	Class
More than 86.6	Very good
83.5 – 86.6	Good
77.4 – 83.4	Average
73.2 – 77.3	Fair
Less than 73.2	Poor

Table 8. Norms of fiber strength (FS) for Egyptian cottons

FS (g/tex)	Class
More than 47.8	Very strong
42.7 – 47.8	Strong
35.6 – 42.6	Average
30.4 – 35.5	Weak
Less than 30.4	Very weak

Table 9 . Norming Egyptian cotton grades by Grade Factor (GrF) and GF_{AHP}

Cotton Grade	Grade Factor	GF_{AHP}
Extra	*Above 549*	*Above 200*
FG	*549*	*200*
G	*158.4*	*56.2*
FGF	*49.7*	*21.1*
GF	*23.6*	*13.3*
FF	*11.8*	*8.1*
Fair	*Less than11.8*	*Less than 8.1*

Table 10. Norms of technological value (FQI &M_{AHP}) for Egyptian cottons

Class	FQI	M_{AHP}
Superior	Above 430	Above 42.5
Very good	379 - 430	32.7 – 42.5
Good	311 - 378	27.4 – 32.6
Medium	239 - 310	21.5 – 27.3
Fair	156 - 238	12.5 – 21.4
Poor	Less than 156	Less than 12.5

III. Conclusion

Varieties of Egyptian cotton, as well as grades within each variety, differ in the technological value depending on the difference in quality characteristics.The recently proposed quantitative criteria can be used in the classification and pricing of Egyptian cotton as an alternative to relying on the price of the variety and the classer grade. GF_{AHP} can be used to express better than GrF for classer grade, and it is preferable to use $M_{\mathbf{AHP}}$ than FQI in classifying cotton quality. This is due to the fact that AHP algorithm takes into account the relative importance of each characteristic in the equation by raising the value to the power. This method can also be modified to suit the decision-maker in tracking cotton in the supply chain.

Acknowledgement

The authorextends his sincere and greetings to all colleagues for their technical support.Great gratitude to *Science, Technology&Innovation Funding Authority*(STDF), Egypt for continued support.

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