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Evaluating the Polymerization Degree in Egyptian Cultivars vs. Upland Cotton and its Impact on Fiber Mechanical Characteristics

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Abstract

THIS investigation was carried out during the 2023 season of three Egyptian cotton varieties (Giza 95, Super Giza 94 long staple, Giza 96 extra-long staple With 3 cotton grades (Fully Good , Good , and (FGF), and two varieties of upland cotton: Edessa and Lima) to find out the relationship between the degree of polymerization (DP) and the fiber properties of different cultivars. The obvious results of this investigation can be summarized as follows: The differences between the studied cotton genotypes in all fiber and chemical properties were significant, except K/S. Giza 96 recorded the highest upper half mean length (mm), fiber uniformity index, fiber bundle strength (g/tex), reflectance degree (Rd %) and degree of polymerization (DP), while it gave the lowest fiber elongation. The Edessa variety gave the lowest values for most traits, such as fiber length, uniformity index, fiber maturity, fiber strength, and degree of polymerization, but it gave the maximum values of short fiber index and trash count. Also, Giza 97 recorded maximum fiber maturity. Lint grade FG gave the highest values of fiber length, uniformity, micronaire value strength, and DP, but it gave the lowest values of short fiber index, yellowness degree, trash area, and trash count. On the other hand, lint grade FGF gave the lowest values of most traits under study. Cotton variety Giza 96 × lint grade FG recorded the best fiber uniformity and degree of polymerization. The correlation between DP and both fiber strength and fiber elongation was positive and highly significant.

Keywords: cotton varieties, genotypes, degree of polymerization (DP), physical, mechanical properties.

Introduction

Cotton is one of the most important natural fibers in the textile industry due to its favorable properties, including softness, breathability, and absorbency. The quality and performance of cotton fibers significantly influence the mechanical properties of yarns and textiles produced from them. Among the various parameters affecting cotton quality, the degree of polymerization (DP) stands out as a critical factor. The (DP) of cotton refers to glucose monomer units number in a cellulose molecule. It directly impacts the fiber's intrinsic properties, including tensile strength, elasticity, and resistance to mechanical stress. Studies have shown that a higher DP correlates with improved mechanical strength and durability of cotton fibers. This relationship is crucial for applications requiring high-performance materials. Yarn and textile strength are paramount for both consumer satisfaction and industrial performance. Research indicates that cotton with a higher DP tends to produce yarns with superior tensile strength and reduced breakage rates during the spinning and weaving processes[(1)]. Consequently, the mechanical properties of the resulting textiles, such as tear resistance and abrasion resistance, are enhanced. Furthermore, the quality of cotton fibers, which includes factors like fineness, maturity, and uniformity, is intrinsically linked to the DP. High-quality cotton fibers with an optimal DP not only enhance the mechanical properties but also improve the overall appearance and feel of the textiles, contributing to better market value and consumer preference. In conclusion, understanding the degree of polymerization of cotton and its impact on fiber, yarn, and textile properties is essential for advancing textile engineering and improving product quality. Higher DP values are generally with increased fiber

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strength. Cotton fibers with higher DP exhibit improved tensile strength and abrasion resistance[1, 2].

Mechanical strength contributes to the longevity and resilience of cotton textiles, which is essential for both consumer satisfaction and industrial performance. For example, high-DP fibers produce yarns with superior breakage resistance during the spinning and weaving processes, leading to textiles that maintain their integrity under stress [3, 4].

Conversely, fibers with lower DP values tend to show improved dyeability. Shorter cellulose chains in lower DP fibers provide more accessible reactive sites for dye molecules, which enhances dye uptake and color retention. This property is particularly beneficial for achieving vibrant and uniform dyeing results, crucial for meeting aesthetic and market demands [5, 6]. Lower DP fibers also exhibit better dyeing kinetics, allowing for more efficient and consistent color application across different fabric types [7].

Furthermore, the overall quality of cotton fibers, including attributes such as fineness, maturity, and uniformity, is intrinsically linked to DP. High-quality cotton fibers with optimal DP not only improve mechanical properties but also enhance the tactile and visual qualities of textiles. This balance between strength and dye ability contributes to better market value and consumer preference [8, 9]. Recent advancements in processing techniques also allow for controlled modification of DP, leading to tailored properties that suit specific applications, such as enhanced resistance to environmental stresses while maintaining desirable dyeing characteristics [10, 11].

Understanding the degree of polymerization and its impact on cotton fiber properties is crucial for optimizing both mechanical strength and dyeing performance. This paper investigates the effects of varying degrees of polymerization on dye absorption characteristics and mechanical strength of cotton fibers. By analyzing these interactions, the study aims to provide valuable insights into the development of high-quality cotton textiles with enhanced performance and durability.

Cotton fiber is an essential raw material in the textile field, due to its breathability, comfortable qualities and versatility. A critical attribute of cotton fiber is its degree of polymerization (DP), which signifies the average number of glucose units in the cellulose chains that constitute the fiber. The DP of cotton fiber is a key factor influencing its dye absorption properties, mechanical strength, and overall quality of the finished textile product.

The DP of cotton fiber can be affected by various factors, including the cotton variety, growth conditions, and post-harvest processing methods. Higher DP values typically correlate with increased fiber strength, which is essential for the durability and longevity of cotton fabrics. Conversely, lower DP values can enhance dye uptake, as shorter cellulose chains provide more accessible reactive sites for dye molecules [12].

Understanding the relationship between cotton fiber DP and its impact on dyeing performance and fabric strength is crucial for optimizing the quality of cotton textiles. Previous studies have shown that controlled reduction of DP can lead to improved dye ability without significantly compromising fiber strength [13]. This balance is vital for producing high-quality cotton fabrics that meet the aesthetic and functional requirements of the market.

The primary cell walls of cotton fibers contain less than 30% cellulose, noncellulosic polymers, neutral sugars, uronic acid, and various proteins [14, 15]. The cellulose in the primary cell walls has a lower molecular weight, with the degree of polymerization (DP) between 2,000 and 6,000, and their distributions are broader [16]. The secondary wall of the cotton fiber is composed of cellulose to a degree that approaches 100%. The DP of the cellulose in the secondary wall is about 14,000, and the molecular weight distribution is more uniform [17]. It is noteworthy that even fibers as young as eight days old have been found to contain the high molecular weight cellulose that is typically associated with mature cotton. In the later stage of elongation, or 10-18 days following initiation, the higher molecular weight cellulose decreases while the lower-molecular-weight cell wall components increase, possibly from hydrolysis [18]. Between the ages of 30 and 45 days, the DPs estimated from intrinsic viscosities of fibers have been shown to remain constant [19].

Among the non-cellulosic components of the cotton fibers, waxes and pectins are particularly responsible for the observed hydrophobicity or decreased water wettability of raw cotton fibers. The expiration ‘cotton waxes’ has been used to include all lipid compounds found on the surfaces of cotton fiber, containing of fats, waxes, and resins [20]. Fundamental waxes are esters, including gossypylgossypate, montanylmontanate, and gossypylcarnaubate. Alcohols, higher fatty acids, hydrocarbons, aldehydes, glycerides, sterols, acyl components, resins, cutin, and suberin, in varying quantities, have been discovered in the wax portion of the cuticle. Pectins are composed primarily of poly

(-1, 4- polygalacturonic acid) and rhamnose to make up the rhamnogalacturonan backbone [21]. A significant proportion of the polygalacturonic acid groups undergo methylation, resulting in a substance that exhibits a high degree of hydrophobicity. Although very small amount of hydroxyproline-rich proteins are present on the surface of the fibers, their primary location in the lumen. What makes it difficult to detect non-cellulosic materials in mature cotton fibers in their scarcity compared to cellulosic materials was lower extents of it. Extraction and reaction techniques are frequently utilized to separate the non-cellulosic cell wall components for subsequent characterization. However, these procedures often result in the disruption of their organization and the potential alteration of their chemical compositions [15].

During fiber elongation, there is a change in the amounts of the non-cellulosic components that move from the primary to the secondary wall, but discrepancies remain in the chemical composition and properties of this composition of cotton in the exact quantities of these changes. Some protein components (structural, regulatory or enzymatic) are regulated during the growth phase [15]. During the beginning of secondary cell wall formation, the non-cellulosic components in cotton fibers can be identified through some analytical techniques such as DSC, TGA, FTIR/ATR, and pyrolysis-GC/MS methods [22].

Among the inorganic substances, the presence of phosphorus in the form of organic and inorganic compounds is important in the scouring process used to prepare fibers for dyeing. These phosphorus compounds are soluble in hot water, but become insoluble in the presence of alkaline earth metals. The use of hard water, therefore, can precipitate alkali earth metal phosphates on the fibers instead of eliminating them [23].

The strength of cotton fibers is attributed to the rigidity of the cellulosic chains, the highly fibrillar and crystalline structure, and the extensive intermolecular and intramolecular hydrogen bonding. Varietal links to fiber strength have been well documented by bundle strength, such as that generated by the Stelometer and the high-volume instrument (HVI), in recent years. According to previous researchers, the Stelometer bundle strength increases gradually with fiber growth between 30 and 70 dpa. The youngest age, in that case, is about two weeks in, or about halfway through, the secondary cell wall development. However, bundle strength is not to be sensitive to strength variability [24].

How fiber strength is developed during growth and is related to genotypical traits has been confirmed by single fiber tensile measurements. The major challenges in single fiber measurements are the selection and the quantity of fibers to represent each specific population. Single fiber tensile measurements using a standard tensile tester and fiber sampling protocols were evaluated in an exploratory study and subsequent extensive data collection [25].

Tensile measurements of both hydrated (as early as 15 dpa) and dried fibers were made using either an Instron tensile tester (1122 TM) equipped with standard pneumatic and rubber-faced grips or a Mantis single-fiber tester. A 3.2 mm gauge length was used with both methods. A 50-mm/min strain rate was employed on the Instron, whereas the strain rate on the Mantis was 60 mm/min. All measurements were performed at a constant temperature of 70°F and 65% relative humidity. The much higher rate of measurement on the Mantis instrument has enabled collections of a much larger number of single fiber strength data [25, 26, 27, 28, 29, 30, and 31]. As a Mantis single fiber tensile instrument is not readily available but is employed in most work cited in the following sections, it is worth mentioning the difference from the Instron measurements. The breaking forces measured by the Mantis instrument appear to be slightly higher than those by the Instron, whereas the opposite is observed with the breaking elongation values [26]. On the Mantis, fibers are positioned manually. The instrument automatically straightens, clamps down, and exerts a preload on individual fibers. Single fiber measurements conducted on the Instron tensile instrument required extensive handling to prepare each fiber in a paper holder [25]. The extra fiber handling on the Instron is believed to be the cause of the lower strength. The absence of preload when preparing fibers for measurement using the Instron explains the higher breaking elongation values. A standardized fiber selection and sampling approach has been established for cotton development. It starts with tagging the flowers on the day of flowering (anthesis). Green bolls aged 14 days post-anthesis (dpa) to 50 dpa and opened bolls can be sampled from the first position (closest to the main stem) between the fourth and the twelfth fruiting branches. There is a positive relationship confirmed about (53% to 69%) between bundle strength by the Stelometer and crystallinity from eight Egyptian cottons [32]. However, the relationships between strength and crystallinity may not be easily compared among studies. One reason is that the extent of crystallinity of matured cotton ranges from 50% to nearly 100% depending on the measurement techniques. The differences resulting from the methods of crystallinity determination are further complicated by the inevitable variations among cotton fibers due to a combination of varietal and environmental factors.

In this paper, we investigate the effects of varying degrees of polymerization on the dye absorption characteristics and mechanical properties of cotton fibers. By analyzing the interactions between DP, dye uptake, and tensile properties, we aim to provide insights that can guide the development of superior cotton textiles with enhanced performance and find out the relationship between the DP and the tensile properties of different cultivars G95, G94, G96 with 3 cotton grades FG, G, and FGF, Edessa, and Lima. Cellulose DP reduction is a necessary process to enable fiber extrusion. A reduction in DP means a reduction in the fiber properties.

Materials and Methods

This study was carried out at the Cotton Research Institute, Agricultural Research Center, Giza, Egypt, during the 2023 season to investigate the effect of three Egyptian cotton varieties (Giza 95 and super Giza 94 long staple, Giza96 extra-long staple, and two varieties of upland cotton: Edessa and Lima) and take three lint grades: FG, G, and FGF. The aim of this study was to find out the relationship between the DP and the tensile properties of different cultivars. As well as correlation coefficients among traits. A randomized design was used to conduct the experiment with four replications. The materials of Egyptian cotton varieties were obtained from the Cotton Research Institute, Agricultural Research Center, Egypt. All fiber and yarn technological properties were tested under controlled atmospheric conditions of (20°C ± 2°C) temperature and (65 % ± 5 %) relative humidity at the fiber and chemical laboratories, Cotton Research Institute, Agricultural Research Center, Giza, Egypt.

Evaluation Tests

a) Fiber technological properties

1. Upper half mean length (mm).
2. Fiber uniformity index (%).
3. Short fiber index (%).
4. Micronaire value.
5. Fiber maturity.
6. Fiber bundle strength (g/tex).
7. Fiber elongation percentage (%).
8. Fiber brightness degree (%).
9. Fiber yellowness degree.
10. Trash count
11. Trash area

b) All fiber tests were determined by High Volume Instrument (HVI 1000) according to ASTM 4605-1986, which was used to measure all fiber properties.

c) Fiber chemical properties

12. K/S
13. DP

All fiber tests were determined by Viscosimeter (BSL Engineering LTD.PARVALUX WOLVER HA PARVALUX, England) for DP evaluation test.

K/S and D/P chemical fiber maturity.

Chemicals and auxiliaries:
All analytical grade chemicals used were purchased from local suppliers: NaOH sodium hydroxide, H_2O_2 hydrogen peroxide solution (30%), sodium silicate, Triton X100 as a non-ionic detergent and wetting agent (Hostapal CV, Clariant), cuprammonium hydroxide solution (SHIRLEY’S), mercury (metal) Hg, and reactive dye Reactive Green KE-4B. The chemical structure is represented in Fig.1

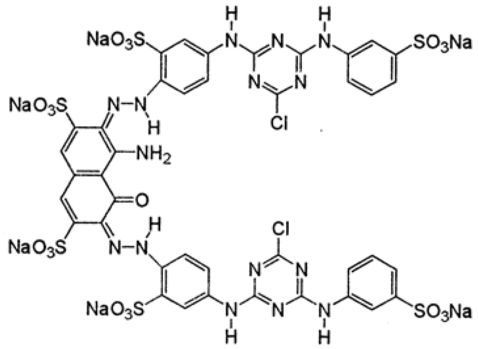

Figure (1): Chemical structure of Reactive green dye

Methods

Pretreatments

Scouring:
All cotton fiber samples were scoured using sodium hydroxide (4.0 %) and Triton X-100 as wetting agents. The work was done with a solution ratio (1:50 w/v), boiled for 90 minutes, then rinsed with hot and cold water, and at last air-dried at room temperature [33].

Bleaching:
The scoured cotton samples were chemically bleached using 0.4 g/l sodium silicate, 1.5 g/l sodium hydroxide, 0.2 g/l magnesium sulphate, 0.2 g/l sodium carbonate, and 25 ml/l 35% hydrogen peroxide. The liquor ratio was 1:50 and boiled for 90 minutes. At last, the samples were rinsed with hot and cold water and air-dried [33].

Dyeing
All pre-treated samples were dyed using 6% reactive green dye [33], using the conventional exhaustion method.

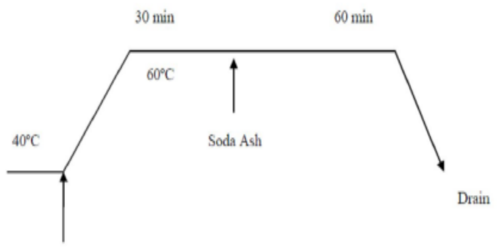

Figure (2): Dyeing chart of cotton using conventional dyeing techniques

Degree of polymerization (DP):

The relative viscosity of cellulose is measured by the equation:

Relative viscosity = time of sample/time of blank.

Time of sample: time of the flooding of the sample (sec.).

Time of blank: time of the flooding of copper ammonium hydroxide solution (sec.).

The degree of polymerization (DP) of cellulose is determined by the following equation:

DP = 2160 [(log ŋr + 1) – 0.267], where, ŋr is the relative viscosity [33].

2160 and 0.267: correct content.

Fiber technological Analysis

All fiber tests were determined by High Volume Instrument (HVI 1000) according to ASTM 4605-1986, which was used to measure all fiber properties: upper half mean length (mm), short fiber index, fiber uniformity index, fiber maturity, micronaire value, fiber elongation percentage, fiber bundle strength (g/tex), fiber yellowness degree, fiber brightness degree, trash area and trash count.

Color measurement

The reference spectra of dyed samples were observed by using a Perkin Elmer spectrophotometer Color strength (K/S) values were determined for each cotton sample. That was assessed in triplicate and calculated using the Kubelka–Munk equation:

$$K/S = (1 - R)\ 2/2R$$

Where K is the sorption coefficient, R is the reflectance of the dyed fabric and S is the scattering coefficient of the dyed samples.

Statistical analysis:

This study was conducted as a completely randomized block design with four replications and analyzed as a factorial experiment according to the method described **by Gomez and Gomez (1984).** The data was carried out using the SPSS 20.0 program.

Results and Discussion

The extent to which fiber quality characteristics and waste content are affect by Egyptian cotton varieties:

Results in Table (1) showed that there were significant differences among the five cotton varieties on all fiber quality properties under study except K/s. Giza 96 recorded the greatest means of upper half mean length (34.91mm), uniformity index (86.97%), fiber strength (43.96), reflectance degree (73.24), and degree of polymerization (DP) (3830.85). On the other hand, it gave the lowest means of fiber elongation, trash count, and trash area. Giza 95 gave the highest means of micronaire value (4.06), fiber elongation (6.97), fiber yellowness (11.57), and trash area (1.41). But it gave the lowest means of reflectance degree (61.65). Giza 97 gave the best fiber maturity (0.90). While the cotton variety Edessa showed the highest mean of short fiber index (11.61) and trash count (132.22), it gave the lowest mean of upper half mean length (27.58 mm), uniformity index (80.69%), fiber maturity (0.78), fiber strength (27.66), and degree of polymerization DP (1385.03).

The relation between DP and the strength of the fibers is rather obvious, i.e., the higher the DP, the higher the tensile strength, but researchers have different views regarding the relationship.

The differences between the studied cotton varieties in fiber quality properties could be due to the genetic differences between these varieties, while the differences in their trash content could be referred mainly to the handling and care during crop management, especially during harvesting and ginning. According to fiber elongation %, this is a genetic trait of the variety, but it is affected by the maturity levels, such as the fiber strength and fiber length.

Table (1): Effect of cotton varieties on fiber and chemicals properties:

Fiber properties	Varieties					LSD at 5%
	Giza 95	Giza 96	Giza 97	Lima	Edessa	
UHML	29.62	34.91	32.62	27.76	27.58	0.385
UI%	83.66	86.97	85.28	81.93	80.69	0.729
SFI%	10.31	7.45	6.88	10.99	11.61	0.449
MIC	4.06	3.65	3.82	3.41	3.38	0.114
MR%	0.88	0.89	0.9	0.82	0.78	0.030
SF	35.03	43.96	41.88	28.04	27.66	0.580
Elong	6.97	5.84	6.3	6.11	6.4	0.232
Rd	61.65	73.24	68.78	72.13	69.39	1.339
+b	11.57	9.16	8.97	8.94	9.49	0.324
TRCNT/(gr)	126.44	50.67	68.44	127.44	132.22	17.15
TR/Ara	1.41	0.82	1.33	1.4	1.29	0.206
K/S	10.45	10.6	10.54	7.15	7.09	NS
DP	3553.09	3830.85	3667.52	1732.85	1385.03	20

Effect of lint grade on fiber properties:

Results in Table (2) indicated that these traits were significantly affected by lint grade. Most studied traits increased with increased lint grade. The maximum values for these traits were obtained from fully good (FG) upper half mean length (31.87), length uniformity index (85.59%) ,micronaire reading (4.22), maturity ratio (0.92), fiber strength (38.25), fiber elongation (7.17), reflectance degree (73.31) and degree of polymerization (2959.26) while gave the lowest values of short fiber content (8.17), yellowness degree(8.87), trash area (0.473) and trash count (30.4) while the minimum values were obtained from fully good fair (FGF) upper half mean length (28.72), length uniformity index (81.44 %), micronaire reading (2.82), maturity ratio (0.76), fiber strength (31.78), fiber elongation (5.49), reflectance degree (62.73) and degree of polymerization (2681.49), while gave the highest values of short fiber content (10.91), yellowness degree(10.58) , trash area (2.163) and trash count (204.33). The differences in lint grade could be attributed to lint grade combining the three factors, i.e., color, trash content, and appearance of lint, consequently. There are significant associations between lint cotton grade and fiber quality. On the other hand, these results confirm that the initial preparation processes improve the properties of the fibers, especially the scouring process, which is carried out in a high alkaline concentration ranging from 10% to 30%. This results in the removal of impurities and waxes, which leads to an increase in fiber hydrophilicity [34, 35].

Tab (2): Effect of cotton varieties of lint grade on fiber and chemicals properties

Fiber properties	Lint grades			LSD at 5%
	FG	G	FGF	
UHML	31.87	30.91	28.72	0.298
UI%	85.59	84.09	81.44	0.565
SFI%	8.17	9.27	10.91	0.348
MIC	4.22	3.95	2.82	0.088
MR%	0.92	0.88	0.76	0.024
SF	38.25	35.91	31.78	0.449
Elong	7.17	6.31	5.49	0.179
Rd	73.31	71.08	62.73	1.037
+b	8.87	9.43	10.58	0.251
TRCNT/(gr)	30.4	68.4	204.33	13.28
TR/Ara	0.473	1.112	2.163	0.159
K/S	9.2	9.14	9.16	NS
DP	2959.26	2860.86	2681.49	15.49

Impact of the interaction between cotton varieties and lint grades on fiber and chemicals properties:

Significant effect of the interaction between five varieties and lint cotton grade (FG, G, and FGF), except upper half mean length, short fiber index, micronaire reading, maturity ratio, fiber strength, reflectance degree, and K/S as shown in Table (3). Results demonstrated that the highest mean values of length uniformity index (89.50) and degree of polymerization (3947.12) were obtained from FG lint grade in Giza 96. On the other hand, it gave the lowest values of trash count (3.67) and trash area (0.17). Edessa variety × FGF lint grade recorded the lowest values of uniformity index (78.03%) and degree of polymerization (1312.56). Conversely, it gave the highest value of trash count (276.33). (5.20%) is the lowest mean average elongation value was obtained from the Lima variety × FGF, while (8.07) was the lowest yellowness degree value obtained from the Lima variety × FG. In contrast, the highest mean value of yellowness degree (12.28) was obtained from Giza95 × FGF. It concluded that Giza 96 gave the highest fiber strength due to it having the highest degree of polymerization. Fiber strength increased with increasing degree of polymerization.

Table (3): Effect of the interaction between cotton varieties and lint grades on fiber and chemicals properties:

Fiber properties	Lint grade	Varieties					LSD 0.05
		Giza 95	Giza 96	Giza 97	Lima	Edessa	
UHML	FG	30.97	36.37	33.90	29.47	28.63	NS
	G	30.03	35.17	33.07	28.30	27.97	
	FGF	27.87	33.20	30.88	25.50	26.13	
UI%	FG	84.23	89.50	88.40	83.30	82.50	1.263
	G	84.37	86.70	85.27	82.57	81.53	
	FGF	82.37	84.70	82.17	79.93	78.03	
SFI%	FG	9.00	6.05	5.11	9.88	10.80	NS
	G	10.18	7.46	6.64	10.91	11.17	
	FGF	11.74	8.83	8.89	12.20	12.87	
MIC	FG	4.70	4.15	4.43	3.90	3.93	NS
	G	4.37	3.97	4.01	3.73	3.67	
	FGF	3.10	2.83	3.02	2.59	2.55	
MR%	FG	0.95	0.95	0.95	0.89	0.84	NS
	G	0.91	0.91	0.92	0.85	0.81	
	FGF	0.77	0.80	0.83	0.71	0.70	
SF	FG	37.80	46.63	45.47	30.67	30.70	NS
	G	35.87	44.83	42.23	28.37	28.23	
	FGF	31.43	40.40	37.93	25.10	24.03	
Elong	FG	7.70	6.37	7.60	7.03	7.17	0.402
	G	7.00	5.97	6.10	6.10	6.40	
	FGF	6.20	5.20	5.20	5.20	5.63	
RD	FG	66.57	78.13	71.87	76.00	74.00	NS
	G	64.67	74.57	70.30	74.53	71.33	
	FGF	53.71	67.03	64.18	65.87	62.83	
+b	FG	11.03	8.65	8.17	8.07	8.43	0.560
	G	11.40	9.04	9.07	8.67	8.97	
	FGF	12.28	9.78	9.66	10.10	11.07	
TRCNT/(gr)	FG	48.33	3.67	9.33	44.00	46.67	29.70
	G	73.67	32.33	77.67	84.67	73.67	
	FGF	257.33	116.00	118.33	253.67	276.33	
TR/Ara	FG	0.73	0.17	0.30	0.64	0.53	0.358
	G	1.03	0.90	1.56	1.03	1.03	
	FGF	2.46	1.39	2.12	2.52	2.33	
K/S	FG	10.49	10.64	10.55	7.22	7.07	NS
	G	10.43	10.59	10.53	7.13	7.00	
	FGF	10.42	10.56	10.52	7.11	7.21	
DP	FG	3675.63	3947.12	3862.93	1843.59	1467.00	34.65

Furthermore, the quality of cotton fibers, which includes factors like fineness, maturity, and uniformity, is intrinsically linked to the DP. High-quality cotton fibers with an optimal DP not only enhance the mechanical properties but also improve the overall appearance and feel of the textiles, contributing to better market value and consumer preference. In conclusion, understanding the degree of polymerization of cotton and its impact on fiber, yarn, and textile properties is essential for advancing textile engineering and improving product quality [36]. This research paper aims to delve into the specifics of how DP influences cotton fiber strength, yarn durability, and textile quality, providing a comprehensive review of current findings and technological advancements in this field.

The simple correlation between DP, and fiber properties for Cotton varieties:

Data in Appendix Table (1-A, 1-B, 1-C) showed that the simple correlation coefficients between almost all fiber properties, trash count/gr, neps count/gr, and degree of polymerization (DP) for G95, Super Giza 97, Extra Giza 96, Edessa, and Lima were significant during the 2023 season. There were positive correlation coefficients between upper half mean length (mm), fiber uniformity index %, micronaire value, fiber maturity %, fiber bundle strength (gr/tex), fiber elongation %, fiber brightness degree, and degree of polymerization (DP).

Upper half mean length (mm) was positive and highly significantly correlated with uniformity index %, micronaire value, maturity ratio, fiber bundle strength (gr/tex), fiber elongation %, fiber brightness degree, and degree of polymerization (DP) in all varieties under study. In contrast, it was negative and highly significantly correlated with short fiber content, trash count/gr, and trash area in all varieties except for Giza 95, which was negatively and significantly correlated. Also, the uniformity index % was positive and highly significantly correlated with the micronaire value, maturity ratio, fiber bundle strength (gr/tex), and fiber brightness degree; on the other hand, it was negatively and significantly correlated with the trash count/gr and trash area in Giza 95, but Giza 97 and Giza 96 were negatively and highly correlated. while the short fiber index is positive and highly significant correlated with the yellowness degree (b+), trash count/gr, and trash area, except for Giza 95, which is positive and correlated with the yellowness degree (b+) and trash count/gr, on the other side it was negative and highly correlated with the micronaire value, maturity ratio, fiber bundle strength (gr/tex), fiber elongation %, fiber brightness degree, and degree of polymerization (DP), all varieties expected for DP in G95 are significantly correlated. Likewise, the micronaire reading was positive and highly significant, correlated with the maturity ratio, fiber bundle strength (gr/tex), fiber elongation, fiber brightness degree, and degree of polymerization (DP), but it was giving negative and highly correlated with the yellowness degree (b+), trash count/gr, and trash area expected for the yellowness degree (b+) in G 95. As for the maturity ratio, it is positively and highly significantly correlated with fiber bundle strength (gr/tex), fiber elongation, and fiber brightness degree. In contrast, it was negative highly significantly correlated with the yellowness degree (b+), trash count/gr, and trash area expected for the yellowness degree (b+) in G 95. Also, fiber bundle strength (gr/tex) was positively and highly significantly correlated with fiber elongation, fiber brightness degree, and degree of polymerization (DP); on the other hand, it was negatively and highly significantly correlated with yellowness degree (b+), trash count/gr, and trash area. While fiber elongation% was positive and highly significantly correlated with fiber brightness degree and degree of polymerization (DP), it was negatively and highly significantly correlated with yellowness degree (b+), trash count/gr, and trash area. Likewise, fiber brightness degree was positive and highly significantly correlated with degree of polymerization (DP); on the other side, it was negatively highly significantly correlated with yellowness degree (b+), trash count/gr, and trash area. Also, the yellowness degree (b+) is positive and highly significantly correlated with trash count/gr and trash area; in contrast, it was negatively highly significantly correlated with the degree of polymerization (DP) expected for G 95. Finely trash count/gr positive and highly significant correlated with trash area; on the other hand, it was negatively highly significant correlated with degree of polymerization (DP), while trash area was negatively highly significant correlated with degree of polymerization.

A simple correlation between the degree of polymerization, trash count, trash area, and fiber properties for Lima and Edessa cotton varieties was shown in Appendix Table (2-A, 2-B).

Conclusion

In this paper, we investigate the effects of varying degrees of polymerization on the dye absorption characteristics and mechanical strength of cotton fibers. By analyzing the interactions between DP, physical, and mechanical properties, we aim to provide insights that can guide the development of superior cotton textiles with enhanced performance and quality. A reduction in DP is an essential process for the facilitation of fiber extrusion. A reduction in DP means a reduction in the tensile properties of the fiber produced. The higher the DP, the higher he tensile strength, which indicates a clear relationship between DP and fiber strength. Giza 96 recorded the greatest means of DP and fiber strength, and Edessa verity was given the lowest values of DP. The degree of polymerization is positive and highly significant, correlated with fiber strength, micronaire reading, UHML, and fiber elongation, which are all positive and highly correlated in all varieties under this study.

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Conflicts of interest

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Appendix 1-A; Simple correlation between Degree of polymerization, trash count, trash area and fiber properties for G 95 cotton variety:

	UHML	UI	SFI	MIC	MR%	FS	Elong	RD	+b	TRCNT/ (gr	TR/Ara	DP
UHML	1	.771*	-.768-*	.974**	.871**	.929**	.799**	.950**	-.725-*	-.961-**	-.941-**	.930**
UI	.771*	1	-.512-	.771*	.702*	.682*	0.443	.682*	-.422-	-.700-*	-.708-*	0.606
SFI	-.768-*	-.512-	1	-.821-**	-.914-**	-.840-**	-.878-**	-.774-*	.696*	.740*	.847**	-.751-*
MIC	.974**	.771*	-.821-**	1	.946**	.973**	.828**	.969**	-.726-*	-.968-**	-.979-**	.888**
MR%	.871**	.702*	-.914-**	.946**	1	.934**	.871**	.894**	-.731-*	-.866-**	-.951-**	.774*
FS	.929**	.682*	-.840-**	.973**	.934**	1	.866**	.962**	-.773-*	-.939-**	-.931-**	.896**
Elong	.799**	0.443	-.878-**	.828**	.871**	.866**	1	.816**	-.794-*	-.792-*	-.813-**	.823**
RD	.950**	.682*	-.774-*	.969**	.894**	.962**	.816**	1	-.822-**	-.985-**	-.932-**	.849**
+b	-.725-*	-.422-	.696*	-.726-*	-.731-*	-.773-*	-.794-*	-.822-**	1	.734*	0.652	-.637-
TRCNT/	-.961-**	-.700-*	.740*	-.968-**	-.866-**	-.939-**	-.792-*	-.985-**	.734*	1	.942**	-.865-**
TR/Ara	-.941-**	-.708-*	.847**	-.979-**	-.951-**	-.931-**	-.813-**	-.932-**	0.652	.942**	1	-.846-**
DP	.930**	0.606	-.751-*	.888**	.774*	.896**	.823**	.849**	-.637-	-.865-**	-.846-**	1

Upper half mean length (UHML), Uniformity index (UI), Short fiber index (SFI) , Micronaire (MIC), MR% (Maturity ratio), fiber strength (FS), Elongation (Elong), Reflectance degree (Rd), Yellowness (+b), Trash /gram (TRCNT/(gr)), trash Area (TR/Ara), and degree of polymerization (DP).

Appendix 1-B; Simple correlation between Degree of polymerization, trash count, trash area and fiber properties for G 97 cotton variety:

	UHML	UI	SFI	MIC	MR%	FS	Elong	RD	+b	TRCNT/(gr	TR/Ara	DP
UHML	1	.872**	-.958-**	.959**	.920**	.949**	.898**	.851**	-.855-**	-.860-**	-.846-**	.949**
UI	.872**	1	-.955-**	.951**	.956**	.954**	.963**	.919**	-.956-**	-.945-**	-.948-**	.927**
SFI	-.958-**	-.955-**	1	-.975-**	-.966-**	-.948-**	-.952-**	-.892-**	.924**	.947**	.934**	-.958-**
MIC	.959**	.951**	-.975-**	1	.979**	.965**	.927**	.958**	-.903-**	-.894-**	-.888-**	.990**
MR%	.920**	.956**	-.966-**	.979**	1	.935**	.898**	.953**	-.877-**	-.880-**	-.859-**	.982**
FS	.949**	.954**	-.948-**	.965**	.935**	1	.957**	.892**	-.944-**	-.916-**	-.916-**	.942**
Elong	.898**	.963**	-.952-**	.927**	.898**	.957**	1	.837**	-.951-**	-.957-**	-.976-**	.874**
RD	.851**	.919**	-.892-**	.958**	.953**	.892**	.837**	1	-.834-**	-.793-*	-.800-**	.961**
+b	-.855-**	-.956-**	.924**	-.903-**	-.877-**	-.944-**	-.951-**	-.834-**	1	.976**	.979**	-.871-**
TRCNT/	-.860-**	-.945-**	.947**	-.894-**	-.880-**	-.916-**	-.957-**	-.793-*	.976**	1	.984**	-.859-**
TR/Ara	-.846-**	-.948-**	.934**	-.888-**	-.859-**	-.916-**	-.976-**	-.800-**	.979**	.984**	1	-.836-**
DP	.949**	.927**	-.958-**	.990**	.982**	.942**	.874**	.961**	-.871-**	-.859-**	-.836-**	1

Upper half mean length (UHML), Uniformity index (UI), Short fiber index (SFI), Micronaire (MIC), MR% (Maturity ratio), fiber strength (FS), Elongation (Elong) Reflectance degree (Rd), Yellowness (+b), Trash /gram (TRCNT/(gr)), trash Area (TR/Ara), and degree of polymerization (DP).

Appendix 1-C; Simple correlation between Degree of polymerization, trash count, trash area and fiber properties for G 96 cotton variety.

	UHML	UI	SFI	MIC	MR%	FS	Elong	RD	+b	TRCNT/(gr	TR/Ara	DP
UHML	1	.954**	-.957-**	.919**	.939**	-.929-**	-.937-**	-.951-**	.918**	.855**	.969**	.885**
UI	.954**	1	-.986-**	.854**	.887**	-.977-**	-.905-**	-.930-**	.890**	.879**	.923**	.867**
SFI	-.957-**	-.986-**	1	-.886-**	-.918-**	.959**	.941**	.955**	-.883-**	-.904-**	-.948-**	-.862**
MIC	.919**	.854**	-.886-**	1	.984**	-.860-**	-.942-**	-.926-**	.943**	.947**	.960**	.926**
MR%	.885**	.867**	-.862-**	.926**	.884**	-.846-**	-.843-**	-.817-**	.903**	.921**	.890**	1
FS	.969**	.923**	-.948-**	.960**	.979**	-.907-**	-.978-**	-.976-**	.912**	.903**	1	.890**
Elong	.855**	.879**	-.904-**	.947**	.927**	-.896-**	-.888-**	-.879-**	.911**	1	.903**	.921**
RD	.918**	.890**	-.883-**	.943**	.951**	-.932-**	-.903-**	-.906-**	1	.911**	.912**	.903**
+b	-.951-**	-.930-**	.955**	-.926-**	-.973-**	.922**	.991**	1	-.906-**	-.879-**	-.976-**	-.817-**
TRCNT/(gr	-.937-**	-.905-**	.941**	-.942-**	-.981-**	.890**	1	.991**	-.903-**	-.888-**	-.978-**	-.843-**
TR/Ara	-.929-**	-.977-**	.959**	-.860-**	-.896-**	1	.890**	.922**	-.932-**	-.896-**	-.907-**	-.846-**
DP	.939**	.887**	-.918-**	.984**	1	-.896-**	-.981-**	-.973-**	.951**	.927**	.979**	.884**

Upper half mean length (UHML), Uniformity index (UI), Short fiber index (SFI), , Micronaire (MIC), MR% (Maturity ratio), fiber strength (FS), Elongation (Elong) Reflectance degree (Rd), Yellowness (+b), Trash /gram (TRCNT/(gr)), trash Area (TR/Ara), and degree of polymerization (DP).

Appendix 2-A ; Simple correlation between Degree of polymerization, trash count, trash area and fiber properties for for Lima cotton variety

UHML	UI	SFI	MIC	MR%	FS	Elong	RD	+b	TRCN T/(gr	TR/Ara	DP
1	.953**	-.932-**	.964**	.987**	.971**	.961**	.964**	-.950-**	-.964-**	-.957-**	.939**
.953**	1	-.830-**	.932**	.934**	.948**	.916**	.982**	-.898-**	-.920-**	-.892-**	.939**
-.932-**	-.830-**	1	-.870-**	-.898-**	-.919-**	-.918-**	-.820-**	.860**	.857**	.869**	-.898-**
.964**	.932**	-.870-**	1	.983**	.912**	.888**	.965**	-.966-**	-.988-**	-.979-**	.880**
.987**	.934**	-.898-**	.983**	1	.937**	.927**	.964**	-.961-**	-.983-**	-.988-**	.906**
.971**	.948**	-.919-**	.912**	.937**	1	.980**	.943**	-.900-**	-.903-**	-.909-**	.975**
.961**	.916**	-.918-**	.888**	.927**	.980**	1	.907**	-.914-**	-.905-**	-.896-**	.979**
.964**	.982**	-.820-**	.965**	.964**	.943**	.907**	1	-.923-**	-.953-**	-.941-**	.908**
-.950-**	-.898-**	.860**	-.966-**	-.961-**	-.900-**	-.914-**	-.923-**	1	.989**	.947**	-.888-**
-.964-**	-.920-**	.857**	-.988-**	-.983-**	-.903-**	-.905-**	-.953-**	.989**	1	.972**	-.880-**
-.957-**	-.892-**	.869**	-.979-**	-.988-**	-.909-**	-.896-**	-.941-**	.947**	.972**	1	-.877-**
.939**	.939**	-.898-**	.880**	.906**	.975**	.979**	.908**	-.888-**	-.880-**	-.877-**	1

Upper half mean length (UHML), Uniformity index (UI), Short fiber index (SFI),Micronaire (MIC), MR% (Maturity ratio), fiber strength (FS),Elongation (Elong),Reflectance degree (Rd), Yellowness (+b), Trash /gram (TRCNT/(gr)), trash Area (TR/Ara), and degree of polymerization (DP).

Appendix 2-B ; Simple correlation between Degree of polymerization, trash count, trash area and fiber properties for Adesa cotton variety.

	UHML	UI	SFI	MIC	MR%	FS	Elong	RD	+b	TRCNT/	TR/Ara	DP
UHML	1	.959**	-.976-**	.991**	.978**	.970**	.923**	.932**	-.946-**	-.980-**	-.973-**	.909**
UI	.959**	1	-.914-**	.957**	.929**	.887**	.912**	.908**	-.959-**	-.959-**	-.934-**	.846**
SFI	-.976-**	-.914-**	1	-.980-**	-.977-**	-.971-**	-.851-**	-.935-**	.947**	.983**	.973**	-.841-**
MIC	.991**	.957**	-.980-**	1	.982**	.951**	.899**	.951**	-.965-**	-.988-**	-.975-**	.882**
MR%	.978**	.929**	-.977-**	.982**	1	.962**	.889**	.965**	-.949-**	-.986-**	-.952-**	.882**
FS	.970**	.887**	-.971-**	.951**	.962**	1	.892**	.907**	-.900-**	-.946-**	-.947-**	.914**
Elong	.923**	.912**	-.851-**	.899**	.889**	.892**	1	.856**	-.866-**	-.867-**	-.872-**	.968**
RD	.932**	.908**	-.935-**	.951**	.965**	.907**	.856**	1	-.975-**	-.947-**	-.953-**	.850**
+b	-.946-**	-.959-**	.947**	-.965-**	-.949-**	-.900-**	-.866-**	-.975-**	1	.965**	.972**	-.825-**
TRCNT/(gr	-.980-**	-.959-**	.983**	-.988-**	-.986-**	-.946-**	-.867-**	-.947-**	.965**	1	.959**	-.835-**
TR/Ara	-.973-**	-.934-**	.973**	-.975-**	-.952-**	-.947-**	-.872-**	-.953-**	.972**	.959**	1	-.861-**
DP	.909**	.846**	-.841-**	.882**	.882**	.914**	.968**	.850**	-.825-**	-.835-**	-.861-**	1

Upper half mean length (UHML), Uniformity index (UI), Short fiber index (SFI),Micronaire (MIC), MR% (Maturity ratio), fiber strength (FS),Elongation (Elong),Reflectance degree (Rd), Yellowness (+b), Trash /gram (TRCNT/(gr)), trash Area (TR/Ara), and degree of polymerization (DP).

		UHML	UI	SFI	MIC	MR%	FS	Elong	RD	+b	TRCNT/(gr	TR/Ara	DP

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تقدير درجة البلمرة في الاصناف المصرية والقطن الابلند واثرها علي الخصائص الميكانيكية للالياف

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المستخلص:

تم اجراء هذا البحث في موسم 2023 علي ثلاث اصناف من القطن المصري بثلاث رتب لكل صنف من هذه الاصناف وهم "جيزة 95، سوبر جيزة 94 طويل التيلة وأكسترا جيزة 96 فائق الطول، هذا بالاضافة الي صنفين من القطن الأبلند وهما اديسا وليما" وذلك لايجاد العلاقة بين درجة البلمرة والصفات الميكانيكية للتيلة . وأسفرت النتائج عن أن هناك أختلاف معنوى بين الاصناف والرتب فى جميع الصفات تحت الدراسة ما عدا اصفة شدة اللون K/s. كما سجل جيزة 96 اعلي القيم في الصفات محل الدراسة فيما عدا صفة الاستطالة.بينما صنف القطن اديسا اعطي اقل نتيجة للصفات مثل طول أطول الشعيرات ، النضج، المتانة ودرجة البلمرة... الخ، واعطي ايضا اعلي قيمه بالنسبة للشعيرات القصيره ونسبة الشوائب. ايضا جيزة 97 اعطي اعلي نسبة نضج ودرجة البلمرة واقل قيمة بالنسبة للشعيرات القصبرة ودرجة الاصفرار والشوائب. ولقد لوحظ ان هناك أرتباط معنوى عالى بين درجة البلمرة وكلا من المتانة والاستطالة للشعرة .

الكلمات المفتاحية: اصناف القطن، درجة البلمرة، الانماط الجينية، الصفات الفيزيائية والميكانيكية.