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EFFECT OF ELEVATED TEMPERATURE AND EXPOSURE PERIOD TO HEAT ON FIBER AND YARN PROPERTIES OF EGYPTIAN COTTON

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Abstract

Two Egyptian cotton varieties, Giza 75 and Giza 76 were used in the present study. From each, two lint cotton grades; Fully Good Fair (FGF) and Good/Fully Good (G/FG) were used to provide two distinctly different levels of fiber maturity. The lint cotton samples were subjected to the temperatures of 20°C (unheated), 80°C, 140°C and 200°C for 20 minutes. Further, the samples were exposed to the highest temperature of 200°C for 5, 10 and 20 minutes.

The results obtained indicated that there was a consistent pattern of increase in the degree of Yellowness (+b) with the elevation of heating temperature and with the increase of exposure period to heat. On the other hand, heat treatments brought about a slight reduction in fiber length and more obvious reductions in strength and elongation of fibers and yarns. As for chemical properties, wax content decreased whereas reducing sugars content tended to increase with elevating heat and prolonging exposure period.

The two lint cotton grades of the two studied varieties responded almost similary to heat treatments with regard to all properties considered in this study except reducing sugars content which increased more obviously in the higher grade G/FG than in the lower grade FGF.

INTRODUCTION

Cotton ginning procedure has expanded to comprise drying to an appropriate level of moisture, seed cotton cleaning prior to ginning and lint cotton cleaning after ginning. Dry cotton is easy to clean but at the same time it is easily damaged whenever it is subjected to mechanical manipulation. However, ginning at about 7% moisture has been found to be a good balance between the need for cleaning and the need for undamaged fibers. Normally, cotton at the gins and at the textile mills is liable to overheating and overdrying. Hence, deleterious effects on fiber and yarn quality characteristics are likely to occur. The extent of such adverse effects depends upon the temperature and the exposure period to which cotton has been subjected to heat treatments.

Hessler and Workman (1959) used cottons representing 3 stages of maturity in their study. Heating in the laboratory was conducted at 70^{o}, 80^{o}, 90^{o}, 110^{o}, 150^{o} and 200^{o}C. The duration of heating was 10, 20 and 30 minutes. They found that a slight decrease in tensile strength was noted upon drying at moderate temperatures, i.e. up to 150^{o}C, whereas a substantial drop in strength occurred by drying at 200^{o}C. They clarified that high heat has decreased the degree of polymerization which could weaken the fiber and possibly explain some of the effects of overdrying during mill spinning. Nelson *et al.* (1959) used in their study two series of gin-dried cottons and one series that was flashheated in the laboratory. They reported that nearly all tests showed no evidence of radical permanent changes in lint properties. The one significant finding was an altered fiber length distribution in some heated lots such that the proportion of shorter fibers was increased while the percentage of long fibers was slightly decreased. This change appeared to be correlated with poorer yarn appearance and a slight reduction in yarn strength. Further, laboratory tests showed that fiber strength was lower when tested immediately after heating beacause, when the moisture was regained, it was temporarily greatly reduced. Zeronian and Ellison (1979) pointed out that with regard to cellulose fibers, the increase in brittleness that occurs at temperatures above 170^{o}C is probably due to the increased order of the polymer chains in the amorphous regions. Hebeish *et al.* (1981) working with the Egyptian cotton variety Giza 75, found that thermal treatments at 160^{o}C and 210^{o}C for varying times were accompanied by a loss in strength of either scoured or mercerized yarns. The magnitude of that loss was dependent on the duration and temperature of treatment. However, the loss in strength for a given condition, was greatly higher in case of scoured cotton yarn compared with the mercerized yarns. Elongation of scoured yarn decreased significantly as the duration of thermal treatment increased regardless of the temperature of the treatment and the same was true for the mercerized yarns. Brushwood (1988), reported that excessive heating of cotton caused visible discoloration as well as lower fiber strength and elongation. The adverse effects associated with heating were more pronounced on the lower micronaire cottons than the higher micronaire cottons. Natural waxes decreased and sugars increased with increasing heating temperature. Both ring and open-end spun yarns produced from heated cottons were poorer in quality than yarns produced from unheated cottons. Mahmoud (1990) used 8 commercial Egyptian cotton varieties in her study and found that treatments with high temperatures for varying exposure times mostly resulted in significant decreases in fiber length, fiber strength, fiber elongation, yarn strength, yarn elongation and wax content. On the other hand, colour yellowness (+b) and reducing sugars content were found to increase with heat treatments. She added that the different Egyptian cotton varieties showed differential responses to heat treatments.

MATERIALS AND METHODS

The two Egyptian cotton cultivars Giza 75 and Giza 76 were used in the present study. Giza 75 belongs to the long staple category whereas Giza 76 belongs to the extra- long staple category. From each of the mentioned varieties, the two lint cotton grades Fully Good Fair (FGF) and Good/Fully Good (G/FG) were used to provide two distinctly different levels of fiber maturity expressed as micronaire reading, i.e. 3.3 and 4.4 for FGF and G/FG grades of Giza 75, respectively; 3.1 and 3.6 for the same two grades of Giza 76, respectively. The cotton samples used in the study were taken from the 1992 crop.

The lint cotton samples were subjected to heat treatments using a laboratory forced draft oven. The temperatures considered in the study were 20 (unheated), 80^o, 140^o and 200^oC. For this series of temperatures, the exposure period was held constant at 20 minutes. Further, cotton samples were exposed to the highest temperature of 200^oC for varying exposure periods, i.e. 5, 10 and 20 minutes. After heating, samples were conditioned to regain moisture before fiber tests were carried out. Samples of the heat treated cottons were spun to 60's count yarns using the 3.6 twist multiplier.

Fiber tests performed included degree of yellowness in terms of (+b) units, fiber length in terms of 2.5% span length, fiber bundle strength and elongation at 1/8 gauge length. These tests were carried out according to the standard test methods of the American Society for Testing and Materials (ASTM, 1967), i.e. Designations, D-2253- 66, D-1447- 67 and D-1445- 67, respectively. Yarn tests were confined to single yarn strength and elongation using the Uster Automatic Yarn Strength Tester according to ASTM designation, D- 2256-66.

All fiber and yarn tests were conducted at the laboratories of the Cotton Research Institute, Agricultural Research Centre, Giza.

Determinations of wax and reducing sugars contents were made at the Cellulose and paper laboratory, National Research Centre, Dokki. The method outlined by Jayme (1942) was utilized to determine wax content while the method of Michel *et al.* (1956) was used to determine reducing sugars content.

The data obtained were statistically analyzed according to the procedures outlined by Little and Hills (1978).

RESULTS AND DISCUSSION

1- Effect of heat treatment on cotton colour

Chroma which refers to the degree of intensity of yellowness in cotton and expressed in terms of (+b) units, has been taken as an indication of cotton colour.

From Tables 1 and 2, it is quite apparent that for both studied varieties, there is a consistent pattern of increase in the degree of yellowness (+b) with the elevation of heat temperature and with the increase of exposure to heat period. However, the increase in yellowness was moderate up to 140^{o}C but afterwards it became more pronounced. Thus, the highest degree of yellowness was attained when cotton was subjected to the highest temperature of 200^{o}C for 20 minutes. A possible explanation for this is that at the very high temperature (200^{o}C) the noncellulosic materials in cotton fibers would become scorched and even burnt, and the result is yellowish brown discolouration.

Table 1. Effect of heating temperatures for 20 minutes on fiber and yarn properties of the Egyptian cottom varieties Giza 75 and Giza 76.

Micronaire reading and variety	Temperature (°C)	Yellowness (+b)		2.5% span length (mm)		Fiber strength (g./text)		Fiber elongation (%)		Yarn strength (g.text)		Yarn elogation (%)		Wax content (%)		Reducing sugar content (%)	
		Giza 75	Giza 76	Giza 75	Giza 76	Giza 75	Giza 76	Giza 75	Giza 76	Giza 75	Giza 76	Giza 75	Giza 76	Giza 75	Giza 76	Giza 75	Giza 76
Lint cotton grade (FGF)																	
3.3 Mic. for Giza 75	20*	10.2	9.8	29.4	36.1	28.8	33.0	5.6	5.9	14.18	19.16	6.10	5.90	0.50	0.66	0.48	0.14
	80	11.1	10.4	29.0	35.0	28.2	32.0	5.7	5.8	13.00	18.48	6.00	5.85	0.47	0.59	0.51	0.15
3.3 Mic. for Giza 76	140	12.6	11.5	28.7	34.7	28.0	31.2	5.5	5.7	12.25	18.30	5.92	5.45	0.46	0.56	0.52	0.16
	200	15.8	13.7	28.5	34.2	26.6	31.1	5.2	5.5	12.04	16.25	5.14	4.96	0.28	0.33	0.55	0.22
Lint cotton grade (G/FG)																	
4.4 Mic. for Giza 75	20*	9.0	8.9	30.8	36.0	29.5	34.3	6.3	6.1	15.24	20.22	6.52	6.00	0.45	0.53	0.42	0.12
	80	9.4	9.9	30.7	35.9	29.4	34.1	6.4	6.0	14.62	19.80	6.45	5.88	0.44	0.51	0.44	0.18
3.6 Mic. for Giza 76	140	10.8	11.0	30.2	35.4	28.7	32.5	6.2	5.9	14.32	19.36	6.14	5.52	0.40	0.46	0.48	0.20
	200	13.4	12.9	29.6	34.7	27.3	31.8	5.8	5.6	12.96	16.75	5.58	4.99	0.22	0.29	0.54	0.21
New L.S.D.	0.05	0.32	0.20	0.52	0.63	0.46	0.50	0.18	0.28	0.12	0.12	0.08	0.06	0.03	0.03	0.021	0.015
	0.01	0.43	0.26	0.68	0.86	0.62	0.67	0.24	0.40	0.16	0.17	0.10	0.08	0.04	0.04	0.28	0.020

20* = Unheated.

Table 2. Effect of heating at 200ºC for varying exposnre periods on fiber and yarn properties of the Egyptian cotton varieties Giza 75 and Giza 76.

Micronaire reading and variety	Period (minutes)	Yellowness (+b)		2.5% span length (mm)		Fiber strength (g./text)		Fiber elongation (%)		Yarn strength (g.text)		Yarn elogation (%)		Wax content (%)		Reducing sugar content (%)	
		Giza 75	Giza 76	Giza 75	Giza 76	Giza 75	Giza 76	Giza 75	Giza 76	Giza 75	Giza 76	Giza 75	Giza 76	Giza 75	Giza 76	Giza 75	Giza 76
Lint cotton grade (FGF)																	
3.3 Mic. for Giza 75	Unheate	10.2	9.8	29.4	36.1	28.8	33.0	5.6	5.9	14.18	19.16	6.10	5.90	0.50	0.66	0.48	0.14
	5	11.4	10.6	29.3	34.9	28.0	32.8	5.6	5.8	13.07	18.14	6.00	5.40	0.41	0.45	0.32	0.17
3.1 Mic. for Giza 76	10	12.5	11.3	28.9	34.8	27.6	32.3	5.4	5.6	12.20	16.96	5.68	5.12	0.40	0.36	0.52	0.19
	20	15.8	13.7	28.5	34.2	26.6	31.1	5.2	5.5	12.14	16.25	5.14	4.96	0.28	0.33	0.55	0.22
Lint cotton grade (G/FG)																	
4.4 Mic. for Giza 75	Unheate	9.0	8.9	30.8	36.0	29.5	34.3	6.3	6.1	15.24	20.22	6.52	6.00	0.45	0.53	0.42	0.12
	5	10.1	9.6	30.2	35.3	28.4	32.8	6.2	5.9	14.80	19.00	6.33	5.75	0.40	0.38	0.47	0.14
3.6 Mic. for Giza 76	10	11.2	11.1	30.0	34.9	26.9	32.4	5.9	5.7	14.22	17.25	5.98	5.24	0.30	0.32	0.51	0.17
	20	13.4	12.9	29.6	34.7	27.3	31.8	5.8	5.6	12.96	16.75	5.58	4.99	0.22	0.29	0.54	0.21
New L.S.D.	0.05	0.35	0.26	0.43	0.48	0.40	0.44	0.22	0.20	0.13	0.14	0.07	0.08	0.04	0.03	0.033	0.015
	0.01	0.47	0.35	0.60	0.66	0.55	0.60	0.29	0.25	0.18	0.20	0.9	0.11	0.05	0.05	0.045	0.020

It is rather interesting to note that the two lint cotton grades (FGF and G/FG) used in the present study to provide two levels of fiber maturity, did not exhibit marked differential response to heat treatments in both varieties under study. This may be ascribed to that the difference between the two grades is relatively narrow. Nevertheless, this finding is not in harmony with that of Brushwood (1988) who reported increases in yellowness, (+b) as time and heating temperature increased, were more propounced for the 3.6 micronaire cotton than for the higher micronaire cottons, and concluded that the low maturity cotton was more sensitive to heat.

2- Effect of heat treatments on fiber and yarn properties

From the data presented in Tables 1 and 2 it is shown that, in both studied varieties, heat treatments of progressively increased temperatures and exposure periods brought about a slight reduction in fiber 2.5% span length and more obvious reductions in strength and elongation of fibers and yarns. However, these adverse effects on the aforementioned properties were the most at the highest temperature (200^{o}C) and the longest exposure period (20 minutes). It is of particular concern to mention that the reductions in yarn strength and elongation were almost two-fold of the corresponding reductions in fiber strength and elongation.

The slight reduction in fiber length of heat-treated cotton is logically attributed to the tendency of those weakened fibers to break whenever they are subjected to a mechanical manipulation. It is known, however, that cotton samples treated with elevated temperatures in the present study were in terms of lint cotton. Hence those heat-treated samples avoided any mechanical stresses in ginning which could have caused fiber breakage. Yet, those samples, prior tp length measurement, were processed by the blender of the fibrograph which is an equipment with a potential for causing fiber breakage and thus fiber length could be adversely affected. Nevertheless, the slight reduction in fiber length of heated cotton found in the present study is in general conformity with the finding of Brushwood (1988) who pointed out that fiber length decreased only slightly at temperatures below 180^{o}C for cottons that did not receive mechanical working after heating.

The weakness and low elongation of cotton fibers treated at elevated temperature are likely due to the excessive dryness that would induce more crystalline structure leading to an increase in brittleness which reflects on a decrease in fiber strength. Zeronian and Ellison (1979) supported this view by indicating that the increase in brittleness that occurred at temperature above 170^{o}C was probably due to the increased order of the polymer chains in the amorphous regions. Also Segal and Timpa (1973) stated that heating cellulose at elevated temperatures induced intermolecular linkages. These cross-links would tend to increase the brittleness of cellulose fibers. Hebeish *et al.* (1981) reported the effect of structural parameteres such as crystallite size, degree of crystallinity and accessibility were important factors determining the rate of strength loss in thermal degradation. They added that strength decreased significantly as the percentage of bonds broken increased.

With regard to the reductions in yarn strength and elongation found in the present study as a result of heat treatments, these reductions are a direct response to the adverse effects of heat on cotton fiber length , strength and elongation. In this regard, Nelson *et al.* (1959) indicated that when cotton is heat-dried excessively, it reaches the gin-stand in a temporarily weakened condition due to its very low moisture content. The presence of a greater proportion of short fibers in such cotton after ginning, due to fiber breakage, might be responsible for the poorer yarn appearance and the slight reduction in yarn strength. Results similar to those found in the present study regarding the effect of heat on yarn properties were reported by Hebeish *et al.* (1981), Brushwood (1988) and Mahmoud (1990).

As previously mentioned, reductions in yarn strength and elongation were almost two fold those of the corresponding reductions in fiber strength and elongation. A likely interpretation for this finding is that overdried cotton fibers which are weakened because of low moisture content are further weakened by mechanical processing in spinning. Thus, the adverse effects of overheating and overdrying on yarn properties would be more pronounced than their effects on fiber properties.

Another point of interest in the present study is that the two lint cotton grades of the two studied varieties which represent two levels of fiber maturity responded almost similarly to heat treatments. In contrast, Brushwood (1988) pointed out that there was a degree of severity dependence on fiber micronaire with the lower micronaire cottons being more succeptible to heat degradation.

3- Effect of heat treatments on wax and reducing sugars contents

The results recorded in Tables 1 and 2 clearly indicate that the increase of both heating temperature and exposure period were associated with an obvious tendency of decrease in wax content of the two concerned varieties particularly at the highest temperature (200°C) combined with the longest exposure period of 20 minutes. The opposite was true in case of reducing sugars content which tended to increase with elevated heat and prolonged exposure to heat.

The lower content of wax with increased temperature is actually ascribed to the decomposition of noncellulosic materials including wax. Hessler and Workman (1959) explained that the lower content of wax due to heating was apparently an oxidation since the carbonyl groups decreased. On the other hand, the increase in reducing sugars content with the increase of heating is attributed to the breakdown of cellulose, which is a compound of high molecular weight, into constituents of low molecular weight, i.e. sugars. In this respect Brushwood (1988) showed that the increase in reducing sugars observed when heating for 20 minutes imply rapid increase in the formation of low molecular weight carbohydrates above 140°C. Nevertheless, the increase in reducing sugars content would create the problem of stickiness of cotton fibers to machine parts during mill processing.

The two lint cotton grades FGF and G/FG used from both studied varieties, appeared to respond similarly to heat treatments with regard to the magnitude of decrease in wax content. On the contrary, the increase in reducing sugars content as a result of heating, was more evident in the higher grade G/FG than in the lower one FGF, in the both varieties studied.

The increase in reducing sugars content due to heating was much apparent in the extra-long staple variety Giza 76 than in the long staple variety Giza 75, regardless of the fact that Giza 75 fibers are originally characterized by higher level of reducing sugars content than Giza 76 variety. However, this finding could be regarded as a sign of varietal differential response.

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تأثير درجات الحرارة المرتفعة وفترة التعريض للحرارة على صفات التيلة والغزل للقطن المصرى

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إستخدم فى هذه الدراسة صنفى القطن المصرى جيزة ٧٥ وجيزة ٧٦ ، كما إستخدم من كل صنف رتبتى القطن الشعر (فجف) ، (جـ/فجـ) لتمثلان درجتين مختلفتين من نضج الشعيرات . وقد تم تعريض عينات القطن الشعر المستخدمة فى الدراسة لدرجات حرارة ٢٠ ، ٨٠ ، ١٤٠ ، ٢٠٠ °م لمدة ٢٠ دقيقة . وفى معاملة أخرى تم تثبيت درجة الحرارة على ٢٠٠ °م وتعريض عينات القطن لفترات ٥ ، ١٠ ، ٢٠ دقيقة .

وقد أشارت النتائج الى أنة كان هناك إتجاه لتزايد درجات الإصفرار فى لون القطن بزيادة درجة الحرارة وبزيادة فترة التعريض للحرارة . ومن ناحية أخرى فقد نتج عن هذه المعاملات الحرارية نقص بسيط فى طول التيلة ونقص أوضح فى متانة وإستطالة شعرات القطن وخيوط الغزل . وبالنسبة للخواص الكيماوية للقطن فقد وجد أن المعاملات الحرارية أدت الى نقص فى نسبة الشموع وزيادة فى نسبة السكريات المختزلة . وتجدر الإشارة الى أن رتبتى القطن الشعر اللتان إستخدمتا فى الدراسة إستجابتا للمعاملات الحرارية بطريقة متماثلة بالنسبة لجميع الصفات موضع البحث فيما عدا نسبة السكريات المختزلة والتى كانت الزيادة فيها نتيجة زيادة درجات الحرارة وزيادة فترة التعريض أكثر وضوحاً فى الرتبة الأعلى (جـ/ فجـ) عن الرتبة المنخفضة (فجف) .