WET COTTON AND HIGH TEMPERATURE DRYING

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Abstract

Seed cotton was harvested both wet and dry from the same field and subjected to different drying treatments. The goal was to determine the quality effect of using high drying temperatures on both wet (18% moisture) and dry (6% moisture) cotton fiber. As was expected, high drying temperatures on already dry cotton damaged fiber length and strength but resulted in better trash removal during cleaning. However, high temperatures correctly used did not damage the length and strength of wet cotton fiber when compared to an already dry control that received no drying. The effects of drying damage carried into spinning, with the overdried fiber producing weaker and less uniform yarn.

Introduction

Seed-cotton drying has been of considerable interest to ginners since the 1920's, when the USDA developed a seed-cotton drier which allowed for the processing of green or wet seed cotton (Bennett, 1928). Bennett (1932) stated that cotton was dried in order to generate lint samples that had excellent or extremely smooth "preparation." Both Gerdes et al. (1941) and Gerdes and Martin (1949) describe the configurations and problems of the "Government," or vertical tower dryer, as well as other types of driers used after the 1930's. Ginners were warned to avoid drying temperatures over 93° C (200° F) because of "a slight weakening of the fibers" and "ginned lint with a slightly shorter staple length." Also, cotton dried at temperatures above 93° C (200° F) was said to produce slightly weaker yarn. Ginners were in a quandary, since they needed to dry green or wet seed cotton in order to maintain a good ginning throughput rate and obtain a good sample, but were now being told that high drying temperatures would damage the fiber.

Following the early development, testing, and general acceptance and use of drying systems, many studies have examined the relationship of drying, cleaning, bale value, and fiber quality. Whether these studies were done in the midsouth (Grant et al., 1962), on the Texas High Plains (Childers and Baker, 1976), or in the far west (Stedronsky, 1965), many of the results were the same: overdrying cotton tended to result in lower bale value due to weight loss, fiber breakage, increased short-fiber content, weaker yarn, and decreased yarn appearance. However, drying also enhanced lint cleaning which increased grade. These studies did vary somewhat as to exactly what temperatures were needed. Therefore, the 1977 "Cotton Ginners Handbook" did not recommend specific drying temperatures but did say that no portion of the seed-cotton drying system should exceed 177° C (350° F). This was a compromise between considerations of ginning efficiency, fiber quality, and bale value.

With the recent development and application of several new drying systems (Hughs, 1989) and the increased interest by the textile industry in knowing how drying temperature affected fiber quality (Brushwood, 1989), more drying research was needed, particularly on wet cotton. This paper describes current research on the effects of high-temperature drying on cotton spinnability. The specific goal was to better determine the effects of high temperature on long-staple upland cotton under both high- and low-moisture conditions.

Experimental Procedures

Ginning

The variables which tested the temperature effects on fiber quality were drying-system mixpoint temperature and initial fiber moisture at time of processing. The treatment definitions are as follows:

Treatment Number	Lint Moisture,%	Mixpoint #1 Temp., °C (°F)	Mixpoint #2 Temp.,°C (°F)
1	18	177 (350)	204 (400)
2	6	177 (350)	204 (400)
3	6	Ambient	Ambient

The cotton used was Stroman 254 which is a long-staple upland (average staple length of 38) grown in the Mesilla Valley of New Mexico. All cotton used in the test was harvested from the same field. However, to obtain a high lint-moisture content, the cotton for Treatment 1 was harvested green, before frost, so that it would have a higher moisture content. Also, the cotton was harvested early in the morning while there was still dew present and with the spindle-picker moistening water turned up as high as possible. Average moisture content for this cotton averaged 18.8%. The drier cotton (Treatments 2 and 3) was harvested approximately 2 weeks later after frost, and was harvested later in the day after the dew had dried and with normal spindle water. Between harvests, the weather was clear with no rain. This cotton averaged 6.5 and 6.7% for Treatments 2 and 3, respectively. Because the high-moisture cotton had to be processed right away after harvest to avoid spoilage, it was not possible to randomize the ginning treatments. All three treatments were replicated four times for a total of 12 ginning lots.

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Seed-cotton and lint processing included the following: green-boll trap; unloading separator; flow control; tower dryer at 177° C (350° F) or ambient; 2nd separator; 1st 6-cylinder cleaner; 1st stick machine; separator; tower dryer at 204° C (400° F) or ambient; separator; 2nd 6-cylinder cleaner; 2nd stick machine; separator; distributor; feeder; 93-saw Continental/Moss Gordon gin stand; one saw-type lint cleaner; press condenser; and bale press. Seed cotton was processed through seed-cotton cleaning and drying at about 1.5 bales per 30.5 cm (1 ft) of width per hour. Ginning rate averaged 11.4 kg (25 lb) of lint/saw/hr. Seed-cotton samples for moisture determination were taken at the wagon, after the first and second drying stage, and at the gin feeder apron. Ginned lint samples for fiber analysis were taken before lint cleaning and at the bale press. The 12 bales (ginning lots) were sent to the Southern Regional Research Center in New Orleans for textile processing.

Textile Processing

One of the four replications from each ginning treatment (3 total) was randomly set aside and not tested any further. This was done to reduce the time and overhead of textile processing. Each ginning lot was processed into yarns by four methods. All cotton first went through a Superior cleaner, FCC fine opener, and Crosrol condenser. Next, the fiber was split two ways, with one processing path going through a Crosrol chute feed into a Crosrol Mark 4 single card and a Saco Lowell DE7C Versamatic drawframe followed by a Saco Lowell Versamatic DF11A drawframe. The other path went through a Crosrol chute feed into a Crosrol Mark 4 tandem card and a Saco Lowell Versamatic drawframe followed by a Saco Lowell Versamatic DF11A drawframe. Each of these two processing paths were split again and went through either a Rieter M1/1 rotorspinner or else through a Saco Lowell Rovematic followed by a Saco Lowell Spinomatic ring frame. Yarn counts for the ring-spun yarns were 50/1, 36/1, 30/1, 22/1, and 16/1. Rotor-spun yarn counts were 36/1, 30/1, 22/1, and 10/1. All of the resulting yarns were then analyzed for yarn properties. The 36/1 ring-spun yarn was processed into both knitted and woven cloth for analysis. Some small amount of cotton from each lot was also combed to estimate the level of combing wastes that could result from each ginning treatment.

Results

Ginning

Tables 1 through 7 show the ginning and fiber test results and Tables 8 through 15. the textile test results. Statistical analysis was performed by version 6.04 of PC-SAS. Means in the tables which are followed by different letters are significantly different at the 5% level as determined by Duncans Multiple Range Test.

Table 1 shows the average lint moisture content for the three treatments during the ginning process. Lint moisture at the wagon, and 1st and 2nd drier were for the lint portion of seed cotton, while the moisture at the lint cleaner was for ginned lint. Lint moisture on the seed cotton was determined by taking a seed-cotton sample at each location and splitting it into two subsamples. One subsample was used to determine the overall seed-cotton moisture content. The second subsample was immediately ginned on a small laboratory roller gin to separate the lint from the seed. Since the lint will change moisture content very rapidly during handling, it was discarded, but the seed was used to determine a seed moisture content. Knowing the overall seed- cotton and seed moisture content, and the relative proportions of lint and seed by weight for the seed cotton, the lint moisture content could then be calculated mathematically.

There were significant lint and seed moisture differences due to treatment at each measurement point, with Treatment 2 being dried to below 3% moisture content after the second stage of drying. The other two treatments were both within the USDA recommended moisture range of 6.5 to 8% after the second drier and did not change appreciably through ginning to lint cleaning.

Table 2 shows the seed moisture both in seed cotton (wagon and 1st and 2nd drier) and as ginned seed (seed belt). Seed moisture for Treatment 3 (no drying) did not change during gin processing, but both Treatments 1 and 2 affected seed moisture, with the wetter seed (Treatment 1) drying an average of 1.5% during the 2 stages of high temperature drying, and seed from Treatment 2 being reduced from statistically equal to Treatment 3 on the wagon to significantly less on the seed belt. This gives some indication that the seed serve as reservoirs of moisture for lint during the seed-cotton drying process.

Average HVI fiber length, strength, and micronaire measurements are given in Table 3. There were significant differences in these properties between wet fiber dried at high temperatures (Treatment 1) and naturally dried fiber processed without any drying, for both length and micronaire. As was expected, the overdried cotton showed significantly reduced length when compared to the other two treatments. The significantly higher micronaire reading for Treatment 1 could possibly be because of the method of split harvest that was used to obtain the test seed cotton resulted in slightly more mature cotton at the earlier harvest.

Tables 4 and 5 illustrate why drying of seed cotton is done and why it may be done to excess. Historically, grade has been a major factor in determining the value of a bale of cotton. The dry seed-cotton treatment that received still more drying in the gin (Treatment 2) had a significantly higher grade than the other two treatments. The higher grade corresponded to the significantly lower HVI trash index and Shirley total trash percent of Treatment 2. It has long been common knowledge that it is easier to remove trash from dry cotton than it is from wetter cotton. However, excessive drying during processing which removes too much moisture also significantly reduces turnout as shown in Table 5. Reduced turnout decreases the value of the bale as there is less weight to sell, and the higher grade usually does not provide a sufficient price premium to compensate.

Table 6 shows a tendency for Treatment 1 to have longer and more uniform fiber, although only the AFIS upper quartile length data was significantly different. Treatment 1 tended to have fewer neps and short fibers than the overdried Treatment 2. However, Treatment 3, which received no gin drying, tended to be shorter and less uniform by AFIS measurement than either of the other two treatments. It would be expected that Treatment 3 would tend to be longer and more uniform than Treatment 2, rather than the reverse.

Table 7 gives fiber length measurements by the Almeter. These length measurements show the cotton from Treatment 1 to be the longest and most uniform, with the least amount of short fiber. According to these measurements, Treatment 3 is either not significantly different from Treatment 1, or else falls in between Treatments 1 and 2. This result is what would be expected from the ginning treatments that were tested, and agrees with the HVI data in Table 3.

Treatment 2 had significantly lower total carding waste than did either of the other two treatments (Table 8). This is in line with its lower trash content after gin processing. However, Treatment 2 had significantly higher combing wastes which may reflect more fiber damage from being overdried.

Single-carded ring-spun yarn skein strength data for all the yarn numbers are shown in Table 9. The cotton from Treatment 1 was significantly stronger than Treatment 2 in all cases. Yarn strength from the cottons processed by Treatment 3 was intermediate between Treatments 1 and 2 and tended to be significantly different than either of the other two treatments. The data is not shown because of space, but similar trends were observed for the cottons that were double carded.

The skein strength of yarns that were single carded and rotor spun is shown in Table 10. The differences are not as pronounced as with the ring-spun yarns, but Treatment 1 always has a higher average yarn strength than Treatment 2. However, the differences are less and in some counts are nonsignificant. Similar results were noted in comparing other rotor- versus ring-spun yarn measurements. The trends were similar, but the ring-spun yarns showed larger and more significant effects from gin processing than did the rotor-spun yarns. Therefore, due to space considerations, the remainder of the discussion will center around ring-spun yarns.

There was no significant difference in yarn uniformity between Treatments 1 and 3 for the yarns tested (Table 11). However, Treatment 2 was significantly less uniform except 36's, where it was not significantly different from Treatment 1.

Tables 12 and 13 show the average Uster yarn thin and thick places, respectively, for the single-carded ring-spun yarns. Similar trends can be seen with both measurements. The yarns from ginning Treatments 1 and 3 are usually not significantly different from each other, while Treatment 2 results in significantly higher thin and thick places in almost all cases.

Uster yarn nep counts, shown in Table 14, show a somewhat different result than the other Uster measurements. Only the yarn nep measurements for the 16/1 yarn show significant differences, and Treatment 2 tends to be lower than the other two treatments. Even though none of the other yarns exhibit significant differences in the nep counts, Treatment 2 tended to have one of the lower measurements across the yarn counts tested. This may be a result of the raw ginned cotton from Treatment 2 being the cleanest before textile processing.

Table 15 shows the analysis of greige and dyed cloth. All of the cloth was made from 36/1 single-carded ring-spun yarn. There were no significant differences or trends in either the greige knit or greige woven average particle counts between any of the ginning treatments. The overall level of visible particles on the two greige fabrics was very similar in magnitude. A quantity of the woven greige fabric was dyed and examined for dye spots or neps. Again, there were no significant differences in dye spots between the treatments.

Bale value is a major concern to the producer and is a way of evaluating ginning treatment effects. Using the average color and trash index, staple length, micronaire, and turnout from each of the three treatments, the amount of seed cotton required to yield a 218 kg (480 lb) bale and the bale value would be as follows:

Treatment No.	Seed cotton weight, kg (lb)	Bale value, $
1	716 (1579)	194
2	674 (1486)	260
3	652 (1437)	257

These values are based on 1997-98 government loan prices for the El Paso, Texas, area. Due to the interaction of turnout and trash removal as affected by moisture content for the various treatments, the cotton that was field dried and received no gin drying and the overdried cotton had similar bale values. The wet cotton treatment had the lowest bale value. Processing Treatment 1 through a second lint cleaner would have improved its grade and trash index and increased its bale value.

Summary and Conclusions

High temperature drying of seed cotton is normally assumed to permanently damage fiber quality factors such as length, uniformity and strength. However, the relatively high temperatures used in this study on wet seed cotton did not adversely affect length, strength, or uniformity in any way when compared to field dried cotton processed without any heating. The strength of a cotton fiber does vary directly with its moisture content. Depending on its moisture content, at the time of processing, a cotton fiber will be able to withstand a certain amount of mechanical stress before any fiber damage occurs. This ability to withstand mechanical stress can be increased or decreased by moisture change without necessarily making any permanent change in fiber properties. However, if fibers are heated to a high temperature, usually assumed to be somewhere above 200° F, permanent changes in strength and increased mechanical damage of cotton fiber have been observed to take place.

The already dry seed cotton (Treatment 2) subjected to high drying temperatures exhibited the expected change in average length and short fiber content that would be expected with excessive temperature. However, the wet seed cotton subjected to the same drying temperatures (Treatment 1) did not suffer any apparent damage when compared to a control. If anything, Treatment 1 tended to be superior to the control in terms of raw fiber length parameters.

The reason for the difference in result between Treatments 1 and 2, is probably that the fiber in Treatment 1 did not reach a temperature much over 200° F due to the presence of the excess water. As long as there was excess moisture to actively vaporize, the fiber temperature would stay at about the boiling point of water or even cooler due to evaporative cooling which can use heat faster than it transfers into the fiber, if there is a strong drying vapor pressure gradient. The already dry cotton would not have the moisture to vaporize and so would approach the higher drying air temperature much sooner. The cotton in Treatment 1 did not get overdry; Treatment 2 did. The damage was probably due to damage from temperature and processing while too dry.

The one advantage that Treatment 2 showed over Treatment 1 was better trash removal during the ginning process. This resulted in lower HVI trash and color indices and a significantly greater per bale value as determined by the government loan schedule. Overall, the field dried treatment without gin drying used as a control (Treatment 3) would result in a good return to the producer, and perform well in the textile mill. Cotton from Treatment 1 would perform as well or better in the textile mill as shown by spinning tests.

Of the two yarn spinning systems used in the test, ring spinning appeared to be the most sensitive to the effects of ginning treatment. Treatment 1 made yarn that was consistently significantly stronger and more uniform for all yarn counts than yarn made from cotton that had been overdried. Treatment 3 tended to fall in between the yarn quality of Treatments 1 and 2.

Rotor-spun-yarn data were not as clear cut in the differences between Treatments 1 and 3 compared to Treatment 2. However, in general, there still appears to be a small tendency for the overdried cotton fiber to produce somewhat inferior yarn when compared to the other two treatments.

Differences in yarn quality from ginning treatment did not appear to carry over to cloth appearance. Visible particle counts in greige knit or woven cloth and dyeing spots in woven cloth were not significantly different for any of the treatments.

Waste levels during the textile process were dependent on the particular process and the ginning treatment. The cleaner, overdried cotton resulted in lower total carding waste, but both the cotton harvested wet and gin dried and the cotton field dried with no gin drying had significantly lower total combing wastes. The combing result may reflect less short fiber and fiber damage from these two ginning treatments.

In conclusion, these results again confirm that cotton which was field dried and needed no drying at the gin would, in general, be the most desirable from the standpoint of net return to the producer per bale, expense and ease of ginning, quality of the ginned fiber, and probably for the quality of the yarn that the fiber makes. Also, if it is necessary to use elevated temperatures at the gin to correctly dry and process wet seed cotton, the spinning quality of the fiber is not likely to be harmed. Trash removal from the initially wet cotton could be a problem, so the ginned cotton should probably be processed through two lint cleaners and not just one as was done for this test.

The overdried cotton received the better HVI color and trash classification of the three treatments. This factor of lint color and trash content, which used to be called grade, has caused gins to overdry in the past in order to get the maximum cleaning and the highest grade. The HVI factor of trash index may well continue to cause overdrying in the future, if other quality factors including yarn quality are not taken into account.

Disclaimer

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Table 1. Average lint moisture percent at various points during ginning.

Treatment No.	Wagon	1st Drier	2nd Drier	Lint cleaner
1	18.8 a	12.0 a	6.8 a	6.2 a
2	6.5 b	3.4 b	2.6 b	3.1 b
3	6.7 b	6.2 b	6.6 a	6.2 a
OSL	0.0001	0.0030	0.0052	0.0001

*For Tables 1 through 15, column averages followed by different letters are different at the 5% level by Duncan's Multiple Range Test.

Table 2. Average seed moisture percent during ginning process.

Treatment No.	Wagon	1st Drier	2nd Drier	Seed belt
1	9.3 a	8.4 a	7.8 a	7.8 a
2	6.9 b	6.6 b	6.3 c	6.3 c
3	6.9 b	6.9 b	6.8 b	6.8 b
OSL	0.0001	0.0001	0.0010	0.0001

Table 3. Average HVI fiber length and strength.

Treatment No.	Staple, 32nd	Length, cm	Length, (in.)	Strength, g/tex	Uniformity ratio	Micronaire reading
1	38.8	3.07	(1.207) a	31.3	83.5	3.47 a
2	37.8	2.97	(1.170) c	29.8	82.3	3.10 b
3	38.5	3.02	(1.190) b	31.5	83.0	3.10 b
OSL	0.2093		0.0016	0.0785	0.4392	0.0032

Table 4. Average HVI grade, color, and trash measurements.

Treatment No.	Grade index	Color index	Rd	+b	Trash index
1	41.3 a	33.5	76.3 b	8.5 a	7.1 a
2	31.0 c	31.0	78.1 a	8.2 a	3.0 b
3	40.3 b	31.0	78.3 a	7.8 b	4.0 b
OSL	0.0001	0.4219	0.0036	0.0055	0.0024

Table 5. Average trash measurements and turnout.

Treatment No.	Wagon total foreign matter, %	Feeder total foreign matter %	Shirley total waste, %	Turnout, %
1	6.2	3.2 a	3.5 a	30.4 c
2	4.5	2.2 b	1.7 b	32.3 b
3	4.3	2.5 b	3.4 a	33.4 a
OSL	0.0520	0.0086	0.0002	0.0004

Table 6. Average AFIS measurements by weight.

Treatment No.	Length, cm	Length, (in.)	Upper quartile length, cm	Upper quartile length, (in.)	Length, CV, %	Neps, No./g	Short fiber, %
1	2.84	(1.12)	3.38	(1.33)a	27.8	103.7	4.10
2	2.77	(1.09)	3.30	(1.30)ab	29.0	118.7	4.80
3	2.72	(1.07)	3.05	(1.28) b	30.0	100.3	5.40
OSL	0.0745	0.0780		0.3325		0.2092	0.3540

Table 7. Average Almeter fiber test results,

Treatment No.	Mean length cm	Mean length (in.)	25% length cm	25% length (in.)	CV (%)	Short fiber (%)
1	2.48	(0.975) a	3.05	(1.20) a	31.2 b	7.8 b
2	2.36	(0.928) b	2.95	(1.16) b	34.3 a	11.4 a
3	2.41	(0.948) ab	3.02	(1.19) a	33.8 a	0.4 ab
OSL		0.0320		0.0071	0.0483	0.0487

Table 8. Average carding and combing wastes.

Treatment No.	Total carding, %	Combing noils, %	Total combing, %
1	5.12 a	3.17 c	17.62 b
2	4.02 b	16.07 a	19.45 a
3	4.76 a	14.25 b	18.33 b
OSL	0.0089	0.0004	0.0067

Table 9. Average single carded ring spun skein strength, CSP.**

Treatment No.	Nominal yarn number 50/1	36/1	30/1	22/1	16/1
1	2519 a	2726 a	2859 a	3026 a	3264 a
2	2283 b	2519 b	2578 c	2812 b	2971 c
3	2480 a	2657 b	2790 b	2923 ab	3166 b
OSL	0.0003	0.0026	0.0001	0.0109	0.0006

**CSP = Count Strength Product, the yarn number times the skein strength in pounds.

Table 10. Average single carded rotor spun skein strength, CSP.*

Treatment	Nominal yarn number			
No.	36/1	30/1	22/1	10/1
1	2069	2167a	2338 a	2651
2	1983	2059 b	2241 b	2635
3	2073	2175 a	2322 a	2625
OSL	0.1163	0.0054	0.0154	0.8612

*CSP = Count Strength Product, the yarn number times the skein strength in pounds.

Table 11. Average single carded ring spun Uster non-uniformity, %.

Treatment	Nominal yarn number				
No.	50/1	36/1	30/1	22/1	16/1
1	19.6 b	17.4 ab	16.3b	14.3 b	12.7 b
2	21.1 a	18.0a	17.7 a	15.5 a	13.8 a
3	19.4 b	17.0 b	16.5 b	14.5 b	12.9 b
OSL	0.0053	0.0359	0.0004	0.0002	0.0014

Table 12. Average single carded ring spun Uster thin places, No./1000 yd.

Treatment	Nominal yarn number				
No.	50/1	36/1	30/1	22/1	16/1
1	173 b	99	20 b	5.0 b	1.1 b
2	197 a	85	50 a	11.9 a	2.7 a
3	137 c	52	24 b	6.3 b	0.7 b
OSL	0.0001	0.3927	0.0007	0.0270	0.0126

Table 13. Average single carded ring spun Uster thick places, No./1000 yd.

Treatment	Nominal yarn number				
No.	50/1	36/1	30/1	22/1	16/1
1	1063	615 b	459 b	184 b	53 b
2	895	732 a	680 a	298 a	104a
3	954	567 b	458 b	188 b	62 b
OSL	0.2856	0.0298	0.0030	0.0015	0.0062

Table 14. Average single carded ring spun Uster neps, No./1000 yd.

Treatment	Nominal yarn no.				
No.	50/1	36/1	30/1	22/1	16/1
1	322	217	159	82	37 ab
2	176	223	174	82	35 b
3	318	231	186	90	42 a
OSL	0.1046	0.8622	0.2240	0.2598	0.0836

Table 15. Average cloth particle and nep counts.

Treatment No.	Greige knit particle count, No./in.^{2}	Greige woven particle count, No./in.^{2}	Dyed woven particle count, No./in.^{2}
1	6.5	5.4	1.3
2	7.4	6.4	0.7
3	7.9	6.2	1.0
OSL	0.3818	0.4313	0.7703