BALE MOISTURE ADDITION – A CASE STUDY

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Abstract

The measurement and control of moisture during cotton harvest, ginning, and textile processing is a very important quality consideration. Research has long shown that, in general, cotton should be harvested below 12% moisture, cleaned, and ginned between 6 to 8% moisture to preserve cotton-fiber quality during the ginning process. It has also been industry practice to try to maintain the 6 to 8% fiber-moisture level at baling for ease of press operation and to maintain fiber quality during long-term bale storage. Recent moisture-addition-equipment developments have made it possible to bale cotton at moisture contents higher than the old recommended 6 to 8% range. There were concerns by some segments of the cotton industry that baling cotton at the higher moisture levels would lead to fiber-quality degradation during bale storage. Recent research has shown that baled cotton fiber does significantly change color during 6 months' storage at moisture levels above 8%. These results have led the National Cotton Council to recommend that the moisture content of U. S. cotton bales be kept at or below 7.5%.

Introduction

Moisture and moisture control from cotton harvest through ginning and beyond to the textile mill has been an important area of research and management as long as there has been a cotton industry in the United States. Research has shown that seed cotton harvested and moduled above 13% moisture content (wet basis) would probably suffer lint quality degradation during storage, while seed cotton moduled and stored below 12% moisture should retain its inherent quality (Lalor et al., 1994). Moisture is also very important to the ginning process. Seed cotton having too high a moisture content will not clean or gin properly and may form wads that choke and damage gin machinery or stop the ginning process (Hughs et al., 1994). Cotton with too low a moisture content may stick to metal surfaces as a result of static electricity generated on the fibers and cause ginning machinery to choke and stop. Fiber dried to very low-moisture content becomes brittle and will be damaged more by the mechanical process required for cleaning and ginning. When pressing and baling such low-moisture cotton, it is often difficult to achieve the desired bale weight and density without adding moisture.

Moisture recommendations for ginning and baling have varied, but generally the rule of thumb has been that cotton moisture in the 6 to 7% range is best for seed-cotton cleaning, ginning, and lint cleaning to preserve fiber quality, and a 6- to 8%-moisture range for ease of press operation and long-term bale storage (Hughs et al., 1994 and Anthony et al., 1994). These recommendations represent research done over many years by many people on the importance of moisture in cotton harvesting, ginning and quality preservation. For example, Parker and Wooten (1964) documented that increased seed-cotton-moisture levels at time of harvest and during storage before ginning have an adverse effect on cotton color and grade. At the same time, decreased moisture levels at harvest and ginning had an adverse effect on fiber length and strength. Moore and Griffin (1964) documented that, as seed cotton was dried from 10 to 4 % during the ginning process, trash was removed more efficiently, cotton grades improved, and manufacturing waste declined in the textile mill. At the same time, as seed-cotton moisture was decreased, fiber length decreased, resulting in decreased yarn strength at the textile mill.

Griffin and Harrell (1957) looked at the cotton-quality effects of using spray nozzles to add moisture at the press lint slide. This work was done in the Mississippi Delta, and they concluded that, in humid cotton-growing areas, bales of cotton packaged at less than 7% moisture may be expected to gain weight; those packaged at more than 7% moisture may be expected to lose weight. Other than the bale weight issue, Griffin and Harrell (1957) found no fiber- or textile-quality improvements resulting from adding moisture to ginned cotton at the press lint slide. The test bales used in 1957 were flat bales of much lower density than today's UD bales. Most of the test bales reported by Griffin and Harrell (1957) were wet to no more than 9% and, when opened after 91 days, had all moved toward the 7%-moisture content range. The exception was two bales that were initially wet to 15.4 and 18.8% moisture. When these two bales were broken open for inspection, there was mildew and fungus damage throughout the bales. Later work by Mangialardi and Griffin (1977) confirmed the earlier work that moisture addition at the lint slide provides no quality improvement. They stated that moisture addition does eliminate some problems associated with static electricity, minimizes postginning bale-weight changes, and allows the use of lower hydraulic-press pressure which reduces press horsepower requirements. The average moisture content at the bale press after moisture addition in the tests reported by Mangialardi and Griffin (1977) averaged about 6%.

The reports cited above are examples of the research that determined and supported the cotton-moisture recommendations made by USDA, ARS scientists to the ginning industry (Anthony et al., 1994 and Hughs et al., 1994). Moisture addition to cotton has typically been done in the ginning industry by either some form of water spray or by the use of humid air (Hughs et al., 1994). Water spray has been somewhat limited because of the problems associated with liquid water wetting metal surfaces that contact cotton in the gin plant. Cotton will immediately stick to wet metal and will cause chokage and processing stops unless the cotton is mechanically forced to move. Even if the cotton is mechanically forced to continue to move over a wet metal surface, the increased friction forces between the cotton and wet metal can cause mechanical problems. Humid air systems also have to be operated so as to not cause water condensation on metal surfaces contacting cotton. They are operated to keep metal surface temperatures above dew point and avoid condensation. Humid-air systems tend to be limited in the amounts of moisture that can be added, because of their operational requirements. Lint moisture is usually increased no more than 1 to 2% by humid-air systems, and this amount of moisture has been shown not to cause quality problems during bale storage.

Lewis Electric Corporation has recently developed and marketed a water-spray system that overcomes the metal wetting problem of earlier water-spray systems. The Lewis system uses electronic sensing to detect the presence of cotton flow on the press lint slide. If the lint flow is interrupted for any reason, the water spray is also interrupted to avoid spraying water directly on the bare metal lint slide. The Lewis system also uses a relatively sophisticated gin-feeder speed sensing, infrared moisture detection, and water pumping system to apply varying amounts of water to the lint, depending on cotton processing rate and desired final bale-moisture content. The design of the Lewis system allows it to apply more water per unit of cotton at the press lint slide than older systems without causing problems that interrupt cotton flow. This has meant that in field applications the USDA recommendation of baling cotton at 6 to 8% moisture can be significantly exceeded. This adds increased weight to the bale, but it may also cause fiber-quality problems with long-term bale storage. The objective of the study reported here was to determine an acceptable bale-moisture range within which fiber-quality degradation can safely be avoided during varying periods of bale storage.

Methods and Procedures

To ensure that the initial variability of the cotton would be minimized, Holguin Farms, Inc., a New Mexico family-owned farming business, agreed to supply four modules of an upland variety (DPL 565) that had been grown under normal production practices and harvested in good condition. The modules committed to this study came from the same field and were harvested during the same timeframe.

Furthermore, the cotton contained in the modules was harvested under dry field conditions, was properly shaped and compressed to normal density, and was protected from rainfall by module covers. The harvest season was generally dry and open, with very little precipitation occurring at any time during the season. After harvest and before ginning, the modules were stored on well-drained, sandy ground.

During the processing of the above-described modules, the gin plant (Mesa Farmers Coop Gin, Vado, New Mexico) operated near its designed ginning capacity of 18 bales per hour. The only change to normal ginning practice for the test was that all seed-cotton driers were turned off during the test runs. It had earlier been determined that the lint fraction of the moduled seed cotton to be used in the test was at approximately 6% moisture (all moisture % reported as dry base) under ambient conditions. This 6% moisture was used as a base from which all increased moisture treatments were added.

Mesa Farmers Coop Gin is equipped with the Lewis Electric Corporation's Moisture Reintroduction System (henceforth designated the Lewis System). Using real-time data, the system continuously adjusts its spray level by activation up to five active spray nozzles to apply the desired amount of moisture based on preset lint-moisture conditions and the measured gin processing rate. For the purpose of this test, the infrared moisture sensor and control component of the Lewis System was bypassed as the fiber-moisture control. Instead, the system applied a preset amount of water, measured in pounds, based on the dynamic ginning rate, to achieve bale moisture levels above the assumed 6% base moisture content. The selected weights of water applied to each bale for 8-, 10-, and 12%-moisture treatment levels were approximately 10, 20, and 30 pounds per bale, respectively, based on a target bale weight of 480 pounds. The control treatment of 6% moisture was processed without adding any water with the Lewis System.

In order to limit bale-moisture loss or gain during the planned storage period, bale wrapping was a key consideration. The National Cotton Council supplied 6-mil, no-vent-holes, polyethylene bagging for use on the test bales. The open bag ends were secured by duct tape.

The Southwestern Cotton Ginning Research Laboratory personnel took four lint-moisture samples from the press lint slide during the time each bale was being ginned. These samples were taken sequentially and just below the location of the Lewis System on the lint slide. Two samples were taken at the approximate middle of the lint slide, and two samples were taken approximately between the midpoint and an outer edge of the lint slide.

A total of 144 lint-moisture samples were taken from the 36 bales of test cotton. Of these samples, 36 came from 9 control bales with no water added; 36 from 9 bales with 10 pounds of water added; 36 from 9 bales with 20 pounds of water added; and 36 from 9 bales with 30 pounds of water added. Ambient temperature and relative humidity during ginning increased from 49 to 58º F and decreased from 26 to 19%, respectively.

When the first module of test cotton entered the gin stream, the moisture reintroduction level was zero (i.e., no spray from the Lewis System for the control condition). From this phase onward, the moisture levels were applied sequentially from the lowest setting to the highest setting throughout the entire test.

The first bale produced from the test modules was a scratch bale and was not sampled or saved. All data collection commenced with the second bale from the first test module. Nine bales were then produced with no seed cotton drying and no water added. Following the ninth bale in this set, two scratch bales were processed to clear the system, and the ginning was halted. The Lewis System was then set for the 10-pound-per-bale water application rate prior to re-initiation of ginning and data collection.

Nine test bales were then produced with the Lewis System, set to apply a total weight of 10 pounds of water per bale. As was the case following production of the nine bales in which no additional water was applied, the ginning process was then interrupted, and the Lewis System was reset to apply 20 pounds of water per bale.

When ginning resumed, two scratch bales were again processed before data collection began on the 20 pounds of water per bale test. Upon completing the next nine test bales, ginning was once again halted and the Lewis System was reset to apply 30 pounds of water per bale. When ginning resumed, two scratch bales were again processed before the final nine test bales were produced.

For all four test levels, normal bale sampling took place for USDA-AMS High Volume Instrument (HVI) testing and classing. Careful notation was made for each of the 36 test bales, indicating that the actual average ginning rate was 16 bales per hour, 16.3 per hour, 15.9 per hour, and 16.6 per hour for the 9 control bales, the 9 containing 10 pounds of water, the 9 containing 20 pounds of water, and the 9 containing 30 pounds of water, respectively. All 36 bales were bound with plastic strapping prior to being covered with polyethylene bagging and sealed.

Upon completion of the USDA-ARS supervised ginning at Mesa Farmers Coop Gin, the 36 bales were shipped to the USDA-ARS Cotton Quality Research Station (CQRS) at Clemson University in Clemson, South Carolina.

The 36 bales — 9 from each of the 4 moisture application levels — were then sampled and tested using the following protocol:

> At 1 month, 2 month, and 6 month intervals after ginning, 3 bales from each of the 4 moisture restoration (or reintroduction) levels were randomly selected and opened.

Each opened bale was submitted to the identical procedure:

> Ten incremental layers representing the entire bale were sampled for moisture content, HVI tests, and for total bacteria and gram-negative bacteria.

Results and Discussion

Bale-moisture-content data were determined using the American Society for Testing and Materials (ASTM, 1971) specific guidelines for determining moisture in cotton lint. Moisture content values were determined using the dry-basis formula. The bale-moisture-content data (Table 1) derived from the four levels of moisture restoration, taken from the lint slide and processed by the Southwestern Cotton Ginning Research Laboratory, indicate the following:

> Even though the oven-moisture measurements for the 20- and 30-pounds-per-bale application rate may be inaccurate because of sampling difficulty, it was verified by calibration that the system was indeed spraying 20 and 30 pounds of water, respectfully, as desired for the two highest rates.

The 1 month and 6 month's (NOTE: the 2-month sampling data will not be discussed henceforth, since they were derived from an intermediate data point and do not add any useful information to this discussion) moisture content data, determined by USDA-ARS Cotton Quality Research Station personnel, for the three bales opened from each target moisture level and at each time-in-storage interval, are shown in Table 2 below.

The data indicate that, over time, the moisture in the test bales increased for the control and 20 pounds of water added bales and decreased for the 10 and 30 pounds of water added bales. Probably, this can be attributed to temperature and relative humidity fluctuations that no doubt took place while the bales were in storage at the CQRS warehouse in Clemson, South Carolina. These fluctuations would influence the ambient conditions in the warehouse and the equilibrium moisture of the bales over time. However, the different levels in the test bales remained in their previously designated and statistically different low-to-high order — even after 6 months in storage (Table 2).

HVI Test Results

Since all of the ginning of the 36 test bales took place on cotton of identical variety, similarly grown and harvested, and ginned on the same day with no heat inputs and the same cleaning regimen, the only effect on fiber quality should be on those properties affected by moisture applications via the Lewis System. HVI fiber properties known to be affected by moisture are micronaire, strength, color Rd, and color +b.

Fiber length variation does not take place, except to a very minute degree — 1.1 percent when completely immersed in water — and, therefore, length and length uniformity will not be discussed, as they should be constant for all four levels of bale-moisture restoration in the study.

Micronaire Data

The micronaire data from the original Phoenix Classing Office HVI and for the 1- and 6-month sampling from the CQRS HVI are shown in Table 3 (NOTE: The CQRS's HVI unit participates in the Memphis Classing Office calibration program, meaning data from each of the HVI units are comparable). The data show that as moisture is added to cotton lint, the micronaire increases, which is due to the lateral swelling taking place as water enters the fiber structure. Since it has already been shown that the moisture applied during reintroduction at the lint slide essentially continues to be present — the low-to-high order, even after 6 months in storage — it should be expected that the micronaire values should also follow in roughly the same order, as the data confirm.

Obviously then, controlling the amount of moisture added could become important when dealing with borderline discount cottons, with respect to low and high micronaire (3.4 and below and 5.0 and above, respectively).

Strength Values

The data in Table 4 show fiber strength in grams per tex from the original Phoenix Classing Office (HVI), as well as the 1- and 6-month data from the HVI unit at the CQRS in Clemson, South Carolina. The data indicate no large gain in fiber strength directly attributable to the addition of moisture. This makes sense, as fiber strength is only increased if the fiber is being tested while at higher moisture contents. In this case, all samples were taken from the bale, sent to the HVI lab, and tested after some period of time. During this time frame, all fiber samples had either increased or decreased to close to the moisture equilibrium content dictated by the ambient environment of the HVI testing lab. Therefore, the average strength measurements, even though statistically different, were actually of no practical difference. There is no real advantage in fiber strength by storing cotton at elevated moisture contents. This result is consistent with the results as reported originally by Griffin and Harrell (1957).

Color Rd Data

The color Rd, percent reflectance, data from the original Phoenix Classing Office HVI, and the 1- and 6-month data from the HVI unit at the CQRS in Clemson, South Carolina, are shown in Table 5. All of the "original" classing samples were taken from the bale at the gin and stored loosely together with other bale samples in a canvas bag, waiting for shipment to the Phoenix classing office. During this time (a few days at most), the wetter samples would be actively drying and approaching the 6% normal equilibrium moisture. There would only be limited time for the reflectance to change because of wet storage conditions for these "original" samples as they were being transported and processed at the classing office. It is a different story for the bale samples taken at a later date. The data show that, even a few days after sampling, there is a slight darkening effect that takes place on the cotton. Special notice should be given to the change in the original Phoenix Classing Office data; i.e., the range from 82.33% reflectance to 81.00% reflectance (no water added to 30 pounds water added).

After 1 month in storage and at all target moisture levels, the cottons became slightly darker than they were originally, and they also became darker after 6 months in storage. As the data show, the difference among moisture levels was significant and ranged from essentially zero to over four reflectance units after 6 months. The most significant change in reflectance was recorded in the cotton from bales with 30 pounds of water. Here, the percent reflectance dropped from the original average of 81.33% to an average of 77.03% after 6 months in storage.

Color +b Yellowness Data

The color +b, or yellowness, data from the original Phoenix Classing Office HVI, and from the 1- and 6-month storage data from the HVI unit at the CQRS in Clemson, South Carolina, are shown in Table 6. The original color +b data from the Phoenix Classing Office show that immediately after ginning, the cottons with increased amounts of added moisture showed a progressive increase in yellowness. The data also show that yellowness increases with time in storage, and that the more moisture present, the larger the increase in yellowness +b color units, and the change in +b are statistically significant.

Conclusions

Based on the results of this work, the target moisture treatments of 10 and 12% resulted in a significant change in fiber color. A second report by Backe, McAlister, and Hughs, "Bale Moisture Addition – A Case Study Part II", examines the impact of the reported fiber color change on bleached and dyed fabric. Further studies have been initiated to determine the point of diminishing returns for restored moisture in cotton bales. Note that the original measure of moisture at the gin of the 20 and 30 pounds added bale may have been suspect due to the predominate surface moisture. However, the 1-month data is not suspect due to surface moisture, and ranges goes from 5.53 to 10.11% control to 30 pounds water added. Note that the amount of water added at any treatment was accurate. At the 1-month storage time, the 20 pounds water-added bale measured 8.33%. It should also be noted that there were measured significant differences from the original in color Rd at this treatment level. These data are the basis for the next study in a moisture range of 6 - 8.5 % in target increments of 0.5%. In addition, a separate test will study storage periods of up to a year with high-moisture bales. Until this and other studies can find the point of diminishing returns for moisture restoration, it should be noted that on October 14, 2003, the National Cotton Council's Quality Task Force set forth the following recommendation on moisture in baled lint: " As precaution against undue risk of fiber degradation and until definitive research data can support higher levels of moisture addition at the cotton gin, the National Cotton Council recommends that moisture levels of cotton bales at the gin not exceed the targeted level of approximately 7.5%."

Disclaimer

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Table 1. Average bale moisture content from four levels of moisture restoration.

Target Moisture Level, 9 bales/treatment	Moisture Content (% Dry Basis)*
Control (no water added)	5.80 c
10 lb water added	7.73 b
20 lb water added	12.45** a
30 lb water added	12.46** a

*All samples conditioned by standard practice. Averages followed by different letters are statistically different at the 5% level by Duncan's New Multiple Range Test.
**These data points are suspect as the moisture was sprayed on top of the batt and did not penetrate the thickness of the batt. Every attempt was made to sample through the batt during ginning, but the surface water application was dominant for the two heaviest water application rates and samples do not necessarily represent a good average. Averages followed by different letters are statistically different at the 5% level by Duncan's New Multiple Range Test.

Table 2. Average moisture content of bales at each storage time.

Target Moisture Level	Moisture Content (% Dry Basis)*	
	1 Month	**6 Months**
Control (no water added)	5.53%	5.72% d
10 lb water added	6.99%	6.68% c
20 lb water added	8.33%	8.40% b
30 lb water added	10.11%	9.50% a

*All samples conditioned by standard practice. Averages followed by different letters are statistically different at the 5% level by Duncan's New Multiple Range Test.

Table 3. Average HVI fiber micronaire values at each storage period.

Micronaire Fineness*				
Target Moisture Level	*Original*	*After 1 Month*	*Original*	*After 6 Months*
Control (no water added)	4.67	4.62	4.70 c	4.69 c
10 lb water added	4.67	4.63	4.63 d	4.66 e
20 lb water added	4.73	4.78	4.87 b	4.79 b
30 lb water added	4.83	4.86	5.17 a	5.11 a

*All samples conditioned by standard practice. Averages followed by different letters are statistically different at the 5% level by Duncan's New Multiple Range Test.

Table 4. Average HVI fiber strength values at each storage period.

Strength, g/tex*				
Target Moisture Level	*Original*	*After 1 Month*	*Original*	*After 6 Months*
Control (no water added)	29.4	29.8	29.8 a	29.9 b
10 lb water added	29.8	29.4	29.5 b	29.5 c
20 lb water added	29.3	29.7	29.4 b	29.8 cb
30 lb water added	30.1	30.2	30.0 a	30.5 a

*All samples conditioned by standard practice. Averages followed by different letters are statistically different at the 5% level by Duncan's New Multiple Range Test.

Table 5. Average HVI fiber color Rd values at each storage period.

Color, % Reflectance*				
Target Moisture Level	*Original*	*After 1 Month*	*Original*	*After 6 Months*
Control (no water added)	82.33	81.57	82.00	81.60 a
10 lb water added	82.00	81.97	80.67	81.67 a
20 lb water added	82.00	81.87	82.00	79.80 b
30 lb water added	81.00	80.03	81.33	77.03 c

*All samples conditioned by standard practice. Averages followed by different letters are statistically different at the 5% level by Duncan's New Multiple Range Test.

Table 6. Average HVI fiber color +b values at each storage period.

Color, Yellowness*				
Target Moisture Level	*Original*	*After 1 Month*	*Original*	*After 6 Months*
Control (no water added)	6.80	7.71	6.93	7.68 d
10 lb water added	7.03	7.84	7.10	7.94 c
20 lb water added	7.23	8.17	7.07	8.45 b
30 lb water added	7.47	8.48	7.17	9.32 a

*All samples conditioned by standard practice. Averages followed by different letters are statistically different at the 5% level by Duncan's New Multiple Range Test.