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BALE MOISTURE ADDITION – A CASE STUDY, PART II

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Abstract

The study of the addition of water to cotton at ginning dates back to the early 1950's. Since this time, technologies have changed which allow for more control and higher volumes of water to be added to cotton at the lint slide than ever before. The objective of the study reported here, which is part two of the study reported by Hughs (2004), was to determine an acceptable bale moisture range within which fiber quality, yarn quality, microbial activity and dyed fabric quality degradation can safely be avoided after 6 months of bale storage. Approximately 50 pounds of cotton were sampled from each of the three bales for each moisture treatment as described by Hughs (2004) in part one of this study, after six months in storage. In addition to the HVI fiber properties reported by Hughs (2004), additional testing of the fibers was performed on the Advanced Fiber Information System (AFIS) followed by microbial activity determinations. The resulting 20/1 open-end spun yarns were subjected to typical yarn quality measurements (C.V., defects, strength, & elongation) and then circular knit into panels so that yarn from each treatment was butt-knit to more easily observe color or shade change. With respect to yarn quality, it appears that 20 or more pounds of water added to bales of cotton at the lint slide resulted in significant as well as practical reductions in yarn quality. With respect to the storage periods and treatments of this study, although there were color changes to the cotton fiber as reported by Hughs (2004) there appears to be no impact on microbial activity or the bleached and dyed fabric. Additionally, it appears that between 6-8.5% lies the point of diminishing return for adding moisture to cotton at the lint slide.

Introduction

Early research by Mangialardi et al. (1965) indicated that the advent of increased mechanical harvesting in the 1950's led to increased drying and cleaning of seed cotton in order to maintain high grades of ginned lint. However, these same researchers concede that the increased emphasis, at the time, on drying of seed cotton led to poorer fiber properties and increased production difficulties at the spinning mill. In the early 1950's research showed (Griffin, 1953) that the poorer fiber properties that resulted from over dry cotton could be overcome by adding moisture prior to the separation of seed and lint in ginning. This work showed that the addition of moisture at the suction telescope preserved an additional 1/16th of an inch staple length. Spinning tests confirmed the benefits of fiber length preservation.

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. 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) indicate studies were conducted in 1953 using misting nozzles to add moisture back to lint after ginning at the lint slide. This work concluded that there was no quality improvement in the cotton fiber as compared to similar cotton that was ginned and dried. The reasons given in this piece of research for restoring moisture at the lint slide were: improvement of the feel of the sample, easier and safer bale pressing, and minimization of post ginning bale weight changes resulting from atmospheric moisture absorption. In addition, 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 might 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 universal density (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, in 1961 and 1962, Mangialardi, Griffin and Shanklin showed that bulk cotton fiber did not readily absorb moisture if not exposed for a long period of time to the moisture restoration medium. 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 post ginning 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%.

A study by Nickerson (1959) highlighted color changes of cotton in storage. The purpose of this research was to study the degree of color change associated with different conditions of storage temperature and relative humidity (RH). Samples were stored for three years under various combinations of temperature and humidity (0°-100°F and 50 – 85% RH). Results indicated small changes in color for temperatures of 50° and less and 50% RH and less. Larger changes in color resulted from higher temperatures and relative humidity.

Aspland and Williams (1991) determined whether six different cotton samples of similar properties but different color were sufficiently different after spinning, knitting, scouring, and bleaching to produce color differences in dyed goods. The fiber samples were measured for color and then processed into yarn and knit fabric. Samples were left in the greige state; scoured and dyed; or scoured, bleached, and dyed. The samples were dyed a light shade and a dark shade. Color differences of the dyed fabric were measured on a spectrophotometer. The results indicated that the samples were significantly different in color through scouring but became indistinguishable by the time they were bleached. Although different levels of bleaching were not studied, the researchers concluded that bleaching could reduce the influence of raw cotton fiber color variation between samples on the color of dyed fabric.

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 stray has been somewhat limited because of the problem of confining the liquid water only to the cotton and not wetting any of the 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 self-limiting 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 at the press lint slide than older systems without causing problems that interrupt cotton flow. This means that the USDA recommendation of baling cotton at 6 to 8% moisture can be significantly exceeded on a regular basis. 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, which is part two of the study reported by Hughs (2004), was to determine an acceptable bale moisture range within which fiber quality, yarn quality, microbial activity and dyed fabric quality degradation can safely be avoided after 6 months of bale storage.

Materials and Methods

Approximately 50 pounds of cotton were sampled from each of the three bales for each moisture treatment as described by Hughs (2004) in part one of this study, after six months in storage. The samples were placed in airtight polyethylene bags, these samples were transported from the Clemson warehouse facility to the CQRS Pilot Spinning Laboratory, where they were held in storage until yarn manufacture.

The three 50-pound lots per treatment were un-bagged and placed behind conventional opening hoppers, each feeding an opening and cleaning line prior to carding. All four moisture treatments (including no water added) were subjected to the identical opening, cleaning, carding, drawing, and open-end spinning positions. In addition to the HVI fiber properties reported by Hughs (2004), additional testing of the fibers was performed on the Advanced Fiber Information System (AFIS) followed by microbial activity determinations.

The microbiology work was conducted at the CQRS, and all data pertaining to total bacteria and gram-negative bacteria and fungal population density were compiled. The analysis was completed in order to determine the extent of biological degradation in each of the four moisture treatments at the one-and six-month storage periods. The microbial assays used one gram of lint from 10 samples randomly selected from each of the 10 layers taken from each test bale (one sample per layer). In the laboratory examination of each one-gram sample, data was compiled pertaining to total bacterial populations, total gram-negative bacterial populations, and fungal population density.

The resulting 20/1 open-end spun yarns were subjected to typical yarn quality measurements (C.V., defects, strength, & elongation) and then circular knit into panels so that yarn from each treatment was butt-knit to more easily observe color or shade change. The knit fabric was sent to the National Textile Center at Texas Tech University in Lubbock, Texas, where it was scoured, bleached, and dyed with a critical blue dye (direct 80) used to determine even the slightest shade changes. Afterwards, the bleached and dyed fabric was returned to Clemson for whiteness measurements on the bleached fabric and Delta E measurements on the dyed fabric via a spectrophotometer. All data was analyzed through ANOVA and where necessary, mean differences are indicated in the data

Results and Discussion

As reported by Hughs (2004) there was a significant change in Rd and +b values (Tables I & II) of the fiber from the 20 and 30 lbs of water added treatments after six months of storage. These color changes are not unexpected as reported by Nickerson (1959) when cottons are exposed to high humidity and temperatures over 50°F for prolonged periods of storage. Additional fiber property data for each of the treatments collected via the AFIS indicate no significant differences in fiber properties as shown in Table III.

Yarn processing carding waste data indicates a significant increase for the 10, 20, and 30 lbs water added treatments as compared to the no water added treatment Table IV. There is a significant effect of the treatments on carding waste with an R^2=0.527.

The tensile properties of the resulting yarn were also significantly affected by the treatments (R^2=0.581 yarn strength & R^2=0.755 yarn elongation). The data in Table IV indicate a significant increase in yarn strength and elongation respectively for the 10 lbs. of water added treatment as compared to the other three treatments. It is interesting to note that the 30 lbs. of water added treatment resulted in a significant drop in yarn strength and elongation as compared to the no water added treatment.

Yarn defects and evenness data (Table IV) indicate a significant increase in neps for the 20 and 30 lbs. of water added treatments (R^2=0.947). Thick places were increased significantly with the 10, 20, and 30 lbs. of water added treatments (R^2=0.989). However, a difference from 101 to 107 thick places between the zero and 10 lbs. water added treatments is not practical. Thin places were also significantly impacted by the treatments (R^2=0.910), with increases in water added resulting in more thin places in the yarn. Again, as stated for thick place, the differences between the zero and 10 lbs. water added treatments are not practical. Long thin places in yarn were also affected by the treatments (R^2=0.600) with the 20 and 30 lbs. water added treatments resulting in increased long thin places. Differences were significant between all treatments for yarn evenness (R^2=0.910). Even so, the only practical difference is between the 30 lbs. and zero added water treatments. It is generally accepted that a difference of 0.5 or more is practical for C.V. as that is the point at which it is visible in the greige fabric as bands (barré).

Graphics constructed from the data (Figure 1) indicate that, after one month in storage, there was no difference in total bacteria, gram-negative bacteria, or fungal population density resulting from the different levels of moisture added to the test bales. After six months in storage, all moisture-content-level treatment bales were lower in total and gram-negative bacteria than after one month in storage, a phenomenon especially evident in the case of the higher moisture content bales. This attributed to there being no food source for the viability of the bacteria, which results in their dieing. Although the fungal population density increased slightly after six months storage in three of the four moisture treatments — the treatment in which 10 pounds of water was added being the exception, these differences are not significant. However, the bales from the 20 and 30 lbs water added treatments did exhibit a noticeable "musty" odor when opened for sampling at all three storage periods.

The data in TableV indicate that there is no negative impact to the fabric color as a result of the fiber color changes for up to six months storage for any of the conditions. The whiteness values are less than one point difference – no water to 30 lbs.

water – and the Delta E's are less than one unit each. In the case of Delta E's it is generally accepted that a Delta E less than one will not be a visible difference in dye shade. These results are supported by the work of Aspland and Williams (1991).

Conclusions

As reported by Hughs (2004), "Bale Moisture Addition – A Case Study" the target moisture treatments of 20 and 30 lbs. water added resulted in a significant change in fiber color. However, these color changes did not result in differences in bleach fabric whiteness and dyed fabric color. AFIS measurements of fiber properties did not indicate any differences between treatments. With respect to yarn quality, it appears that the 20 and 30 lbs. water added treatments resulted in significant as well as practical reductions in yarn quality. With respect to the storage periods and treatments of this study, there appears to be no impact on microbial activity. Further studies have been initiated to determine the point of diminishing returns for restored moisture in cotton bales. As noted by Hughs (2004) the original measure of moisture at the gin of the 20lbs and 30 lbs added bale may have been suspect due to the predominate surface moisture. However, he pointed out that one-month data is not suspect due to surface moisture and the range goes from 5.53 to 10.11 - control to 30 lbs. water added. In addition, he emphasized that the amount of water added at any treatment was accurate, and that at the one-month storage time, the 20 lbs water added bale measured 8.33 %. He reiterated that there were measured differences in Rd at this treatment level. These data are the basis being used to run 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%."

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Table I. HVI Fiber Color Rd Values After Six Month's Storage.

Target Moisture Level	Rd
Control (no water added)	81.60a
10 lbs. water added	81.67a
20 lbs. water added	79.80b
30 lbs. water added	77.03c

Table II. HVI Fiber Color +b Values After Six Month's Storage Period.

Target Moisture Level	+b
Control (no water added)	7.68a
10 lbs. water added	7.94b
20 lbs. water added	8.45c
30 lbs. water added	9.32d

Table III. AFIS Fiber Length and Fineness Measurements for Each Treatment at Six Month's Storage.

	Properties				
Target Moisture Level	Mean Length (inches)	Upper Quartile Length (inches)	Short Fiber Content (%w)	Fineness (millitex)	Maturity Ratio
Control (no water added)	1.01	1.25	9.45	170.93	0.916
10 lbs. water added	1.01	1.25	9.60	170.21	0.907
20 lbs. water added	1.01	1.24	9.40	172.71	0.919
30 lbs. water added	1.00	1.23	9.60	174.43	0.925

Table IV. Yarn Processing and Quality Results.

	Properties							
Target Moisture Level	Carding Waste (%)	Yarn Strength (g/tex)	Yarn Elongation (%)	Neps (#)	Thick Places (#)	Thin Places (#)	C.V.m (%)	Long Thin Places (#)
Control (no water added)	5.53a	11.71a	6.91a	6.33a	100.67a	62.00a	15.47a	8.67a
10 lbs. water added	7.04b	11.96b	6.99b	6.00a	107.00b	70.00b	15.60b	12.33a
20 lbs. water added	7.11b	11.75a	6.93a	10.33b	119.67c	75.67c	15.70c	17.33b
30 lbs. water added	6.21c	11.26c	6.66c	17.33c	147.67d	97.67d	16.10d	35.33c

Table V. Whiteness and Delta E Measurements for Bleached and Dyed Fabric

Target Moisture Level	Bleached Hunter Whiteness	Dyed Delta E
No water added	68.039	0.349
10 lbs. water added	67.589	0.588
20 lbs. water added	67.152	0.445
30 lbs. water added	67.070	0.461

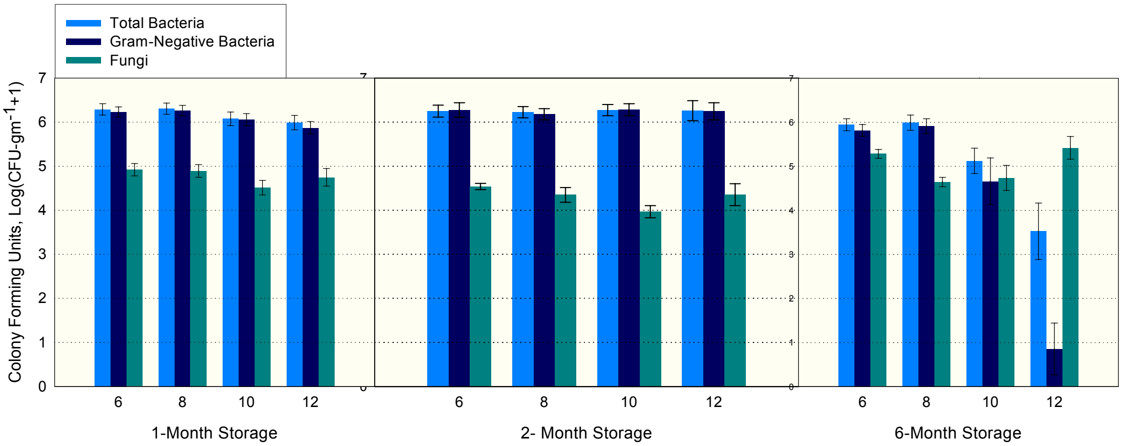

Figure 1. Bacteria and Fungal Data for Each Storage Period and Moisture Condition.