IMPACT OF STORAGE CONDITION ON FIBER QUALITY AND COLOR

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Abstract

The majority of cotton produced in the United States is exported. The exporting of the crop results in extended storage and shipping times which introduces a new challenge for cotton quality. The duration and environmental conditions of cotton storage and shipping can impact cotton quality in terms of color and processing. The most notable change is that the +b value for many bales increases between classing and processing overseas. The increased yellowness can result in appearance defects in yarn and fabric. A long-term project is underway to store multiple bales, produced from the same module, under various conditions and monitor the effects of storage condition on color and other physical properties as well as processing performance from fiber through finished fabric. Twelve bales were ginned from a single module, subjected to 18 months of storage under various conditions and then sampled and sent through textile processing. This is an update to the project, which was initially reported in 2013. The ongoing project has shown that temperature in the storage condition and sugar levels of the bales may affect color change.

Introduction

Over the last 20 years the U.S. cotton industry has evolved from an importer of raw cotton to an exporter of raw cotton. As more U.S. cotton is shipped globally, the mean time between ginning and mill-consumption has grown. This change has led to longer and more diverse storage conditions for U.S. cotton. Domestic consumption of cotton occurs in a shorter timeframe than international consumption of cotton. U.S. cotton is now stored in a variety of warehouses, shipping containers and intermodal storage locations between the gin and mill floor.

To address this issue a project was begun that involved obtaining identical bales of cotton and storing them under various conditions for 18 months. This project was introduced in 2013 (Delhom et al, 2013). Four bales of cotton were stored in each of three storage conditions: 1) Cold Storage Facility, in which temperatures were kept below 0°C (32°F), 2) Standard Cotton Warehouse, which is an enclosed but unconditioned building and 3) Shipping Container which was stored outdoors in the parking lot of a cotton warehouse. After 18 months of storage the bales were retrieved and brought to the Southern Regional Research Center (SRRC) in New Orleans, LA. The bales were subjected to an intensive sampling protocol to identify what, if any, properties had changed and where in the bale the changes had occurred, 45 samples were collected from each bale with both routine and non-standard fiber quality characterization performed on these samples. The bales were then divided into four mini bales and one mini-bale from each of the 12 bales was processed into yarn and fabric. Several mini-bales were blended from bales of different +b values to simulate mill laydown issues caused by the color shift.

Methods

The current study began with the ginning of two modules of DPL 0912 B2RF at a commercial gin in Avon, MS in October 2012. The two modules were grown and harvested in the same field and ginned consecutively under normal conditions. The first module was ginned but not sampled. The first 12 bales produced from the second module were collected for this study. Three storage conditions were selected: 1) cold storage, 2) cotton warehouse and 3) shipping container. Four bales were sent to each storage condition. The cold storage bales are used as the control, as it is accepted practice to store cotton samples in cold storage to preserve the properties.

The cottons were stored for 18 months, with data loggers placed with the bales to record temperature and relative humidity. After storage the bales were brought to SRRC for testing and processing. Each bale of cotton was sampled 45 times, with nine samples pulled from five layers per bale. The layers and positions for each of the nine samples per layer are shown in figures 1 and 2. This sampling protocol was intended to address any effect position within the bale may have on the color change.

Top (1)

Top/Middle (2)
Middle (3)
Middle/Bottom (4)
Bottom (5)

Figure 1. Side view of the bale showing sampling layers

7		4		1
	8	5	2	
9		6		3

Figure 2. Top view of the bale showing sampling locations for each layer

Each of the 45 samples per bale was subjected to HVI and AFIS testing. One bale from each storage condition was selected for all samples of that bale to be tested using the oven moisture method (Shepherd, 1972). One bale from the cold storage and one bale from the shipping container were selected for chemical analysis to measure reducing sugars using ion chromatography and also to measure amino acids present in the sample.

The 12 bales were broken down into four mini-bales and one mini-bale from each bale was sent through processing as well as three blended processing samples were created by mixing two different +b value mini-bales. Fiber samples were collected for testing throughout processing from fiber into yarn. Ne 40/1 ring spun yarns were produced on a Zinser 321 spinning frame with spinning efficiency (ends down), yarn uniformity and strength being measured as well as drafting forces. Spinning efficiency was measured by recording ends down per thousand spindle hours. Yarn uniformity was measured on 20 bobbins of yarn for 1,000 yds at 400 yds/min on an Uster Tester 4 (Uster Technologies, Charlotte, NC). Yarn strength was measured on 20 bobbins of yarns on an Uster Tensorapid 4 (Uster Technologies, Charlotte, NC). Drafting forces were measured using a draftometer custom built by USDA-ARS (McCreight, et al, 1997). Sliver uniformity for each processing lot was measured after carding and drawing on an Uster Tester 5 (Uster Technologies, Charlotte, NC).

Samples of yarn were knit on an FAK sample knitter (Lawson Hemphill, Swansea, MA) and woven fabric samples were produced for each processing lot using a CCI Tech, Inc (New Taipei City, Taiwan) sample loom. Fabric samples were measured for color in greige state as well as after each step of finishing (scouring, bleaching and dyeing).

Results and Discussion

The data loggers were retrieved with the bales. Figure 3 shows the temperature and humidity that was recorded inside the shipping container for one year. A high temperature of over 54°C (130°F) was experienced. This prolonged exposure to elevated temperatures matches what Gamble theorized about the Maillard reaction being responsible for the color shift (2008). The Maillard reaction is a reaction between reducing sugars and amino acids and usually occurs at elevated temperatures, i.e. browning of food during cooking. As shown in Table 1, there were color shifts in the bales from the shipping container and warehouse compared to the cold storage with the warehouse averaging an increase of 1.07 in +b and the shipping container showing an average +b increase of 1.41.

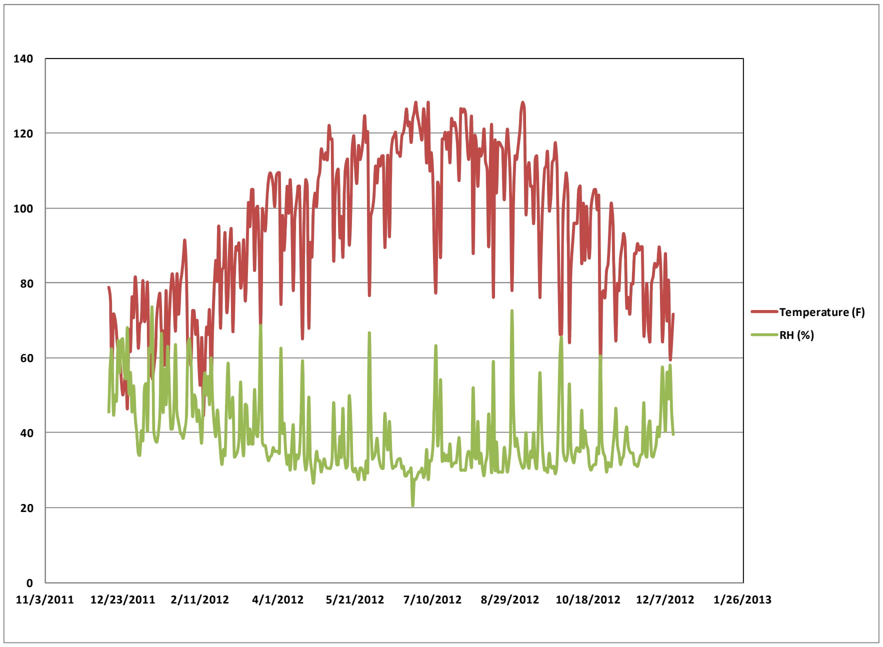

Figure 3. Storage conditions inside shipping container from one data logger for one year

Table 1. HVI Color after storage

Condition	Color Value	Mean Value	Minimum	Maximum
Cold Storage	Rd	76.03	67.57	78.87
	+b	8.13	6.65	9.69
Warehouse	Rd	75.67	67.99	78.44
	+b	9.20	7.07	10.41
Shipping Container	Rd	75.19	67.43	78.32
	+b	9.54	7.24	10.80

Fiber quality testing (HVI and AFIS) did not reveal any differences in the bales between storage conditions, with the exception of color. Color readings on the samples did not correlate to the moisture content of the sample or the location within the bale the sample was collected from (data not shown).

Ion chromatography was used to measure the 45 samples from one bale stored in cold storage and one bale stored in the shipping containers. The results (Table 2) show that there were lower concentrations (ppm) of sugars present in the yellowed samples from the shipping container compared to the control samples from the cold storage. Amino acid testing is still underway; however the results should correspond with the differences in sugars and change in color.

Processing trials on the samples allowed for a range of +b from 7.3 to 10.0 including three blends of 7.4/10.0, 8.0/9.9 and 8.0/9.5 +b values. No statistical differences were found for drafting force, uniformity (CV%, thin spots, thick spots and neps), or tensile properties. No statistical differences in spinning efficiency were found between the storage conditions. The yarns were converted into both knit and woven fabrics. Dyeing and finishing work is underway on the fabrics, however color was measured on the greige knit fabrics (Table 3) and differences were found between storage treatments.

Table 2. Ion Chromatography results for cold storage vs shipping container

Condition	Sugar	Average (ppm)	Std. Dev.
Cold Storage	Glucose	26.17	6.84
Shipping Container		14.41	3.56
Cold Storage	Fructose	15.30	4.58
Shipping Container		11.75	3.17

Table 3. Color differences of greige knit fabrics compared to cold storage

Condition	b*	ΔE*
Warehouse	1.20	1.42
Shipping Container	1.49	1.70
Blends	1.41	1.51

Summary

The change of cotton color due to storage condition is an important issue, although the problem is sporadic and thus far unpredictable. Work is underway which indicates one possible source of the color change as the Maillard reaction. There is much work left to be carried out in order to confirm the cause of the shift in color. Once the cause of the color shift is identified, work will need to be done to determine prevention of the shift. Although the color is shifting during storage, no other quality parameter is affected. The color shift represents a very real problem for textile mills in the sale of yarn if the color is inconsistent. The color shift also is a problem in textile goods as fabrics must be uniform color and shade.

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Disclaimer

Names of companies or commercial products are given solely for the purpose of providing specific information; their mention does not imply recommendation or endorsement by the U.S. Department of Agriculture over others not mentioned.

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