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THE EFFECT OF OUTSIDE AMBIENT AIR CONDITIONS ON THE INTERSTITIAL RELATIVE HUMIDITY OF LINEAR LOW DENSITY POLYETHYLENE FILM WRAPPED COTTON BALES

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Abstract

The J.G. Boswell Company operates a unique, proprietary designed, warehousing facility for baled Pima cotton. An integral part of this storage facility is the bale packaging material – a specially formulated linear low density polyethylene (LLDPE) film bagging. After the cotton is ginned on a roller gin, the naked bale is inserted into the LLDPE film bag and hermetically sealed. The protected bales are then placed in open storage.

The recommended storage conditions state that relative humidity in excess of 50% should be avoided, since high humidity conditions have been documented to have an adverse effect on the maintenance of cotton fiber quality during storage. Limited published research information is available concerning the effects of long term storage on cotton fiber, and no published information exists on the relative humidity of the interstitial area of hermetically sealed LLDPE film wrapped cotton bales.

Research was conducted to determine the relative humidity of the interstitial space of a cotton bale wrapped with LLDPE film bagging, and to determine if a constant low relative humidity is maintained regardless of outside ambient air conditions. This research demonstrated that even though the ambient temperature (43°F to 74°F) and relative humidity (44% to 93%) varied significantly, the relative humidity of the interstitial environment remained constant and low (10% or less relative humidity). In addition, anecdotal evidence collected to date by the J.G. Boswell Company indicates that no fiber damage has been incurred when the hermetically sealed, specially formulated LLDPE film bagging is utilized. Therefore, this design and operation for cotton warehousing is as protective of baled cotton as other cotton warehouse storage facilities currently insured in CCC licensed warehouses.

Introduction

The J.G. Boswell Company Warehouses store cotton grown on their land and ginned exclusively in their facilities. The packaging material utilized in the warehousing operation is Linear Low Density Polyethylene (LLDPE) (Simpson and Vaughn, 2001) film bagging (Mesa, 2002; supplied by Shields Bag & Printing Company) that exceeds the current bale packaging material standards required by the Joint Cotton Industry Bale Packaging Committee (JCIBPC) (Thompson, 2002; JCIBPC, 2002). The bale is hermetically sealed, protected by UV inhibitor and color additives specified within the manufacture of the product. These specifications are unique to the J.G. Boswell Company.

The original purpose for warehousing cotton, as with any perishable agricultural commodity, was to protect and preserve the lint quality. In the case of cotton, the environmental elements that can have an adverse impact on maintaining the quality of the product include, but are not limited to, relative humidity, temperature, sunlight/UV radiation, water, fire, wind, and dispersed particulate matter.

In the early part of the 20^{th} century, in response to market demands, a regulatory system was enacted which defined the roles and responsibilities of the warehouse operators in relationship to producers and the marketplace. The original Agricultural Adjustment Act (AAA) was passed by Congress in 1938 in response to dire agricultural pricing and the need to address surplus stores. In 1945, the name was changed to PMA –(Production Marketing Administration). In 1953, again the name changes to ASC – (Agricultural Stabilization and Conservation). Then in 1961, "Service" was added and was known as ASCS. In 1995 in response to the Farm Bill, the agency name was again changed to the Farm Services Agency. The warehousing industry provides the market mechanisms and instruments for stabilizing the commodity pricing, protecting the producer, and insuring that the quality of the commodity is preserved. To insure proper marketing and management of CCC inventories such as cotton, criterion has been established for CCC licensed warehouse operations approval. One criterion is that the facility be suitable for the protection of the commodity in storage.

Previous studies by Nickerson (1964), Cable et al. (1964), and Knowlton (2002) have indicated that relative humidity and temperature are important environmental factors that can affect the quality (particularly color) and grade of cotton fiber. Cable et al. (1964) reported that the deterioration in quality of cotton grown in relatively dry areas can be reduced by storing it in the area of growth, rather than storing it in more humid areas. Insuring the stability of a low humidity environment within the interstitial environment existing between the LLDPE film bagging and the fiber should reduce the potential for deterioration in quality of cotton sometimes experienced during long term storage in high humidity, high temperature areas.

Materials and Methods

The purpose of this research was to determine if the outside ambient air relative humidity and temperature affect the interstitial relative humidity of a UD cotton bale with a LLDPE film protective wrapping. The relative humidity conditions were measured within the interstitial atmosphere of the bale protective wrapping and compared to outside ambient air conditions.

The Pima cotton was produced by the J.G. Boswell Company and roller ginned by J.G. Boswell Company cotton ginning facility (J.G. Boswell Company Cotton Gin #5) located in Corcoran, California. The moisture content of harvested seed cotton in the module and the cotton at the time of ginning was determined with a hand held moisture meter. The moisture content of the finished lint bales was determined in the same way. For this study, the cotton had a module moisture range of 8% and 9%; the finished bales had a moisture content of approximately 1.7%. The naked Universal Density (UD) bale (density about 24-28 lb/ft^3) after ginning is inserted in the LLDPE bagging (tri-extruded polyethylene film made from a metallocene based resin; supplied by Shields Bag and Printing Co., 1009 Rock Ave., Yakima, WA 98902; Thompson, 2002) and hermetically sealed. A random population of LLDPE wrapped UD bales was selected (Figure 1). To monitor the relative humidity of the interstitial space under the bale wrapping, as each bale was delivered to the Central Packaging and Warehousing Facility, a "Traceable Humidity On A Card" (Manufactured by Control Company, 308 West Edgewood, Friendswood, TX 77546) was attached prior to the final package being sealed (Figure 2). The card is capable of reading a maximum relative humidity of 50 – 100% in 10% increments, and current relative humidity from 10 to 100% in 10 percent increments. The "Current Relative Humidity" scale will change with current conditions and therefore are dynamic. The maximum chart gives a permanent reading of the maximum humidity attained. The bale was placed in exposed storage where a "Traceable Humidity On A Card" was taped to the outside of the LLDPE film bale bagging exposed to ambient conditions for observation (Figure 3).

After 3 hours the "Current Relative Humidity" scale on the external card changed with current conditions demonstrating that the readings on that scale give a relatively quick response to ambient conditions. Instructions from the manufacturer indicated that the maximum chart would give a permanent reading of the maximum humidity attained after 24 hours. The maximum humidity scale did change (as indicated by a bright yellow color and dissolved granules), reflecting the external ambient conditions. For all bales within the interstitial region, the "Current Relative Humidity" scale did not progress beyond 10% as indicated by a change to lavender color. The maximum humidity scale did not register, indicating that the interstitial relative humidity did not achieve a level of at least 50%.

The external ambient temperature and relative humidity conditions were obtained from the National Oceanic & Atmospheric Administration (NOAA) weather facility located in Hanford, CA. The relative humidity conditions in the interstitial environment, within the hermetically sealed bale between the LLDPE film bagging and UD cotton bale, was monitored, and the data was compared to the relative humidity of the ambient air. The relative humidity of the interstitial region and external ambient air were periodically recorded.

Each bale was considered a separate treatment; the seventh treatment was the ambient external condition. The data collected: four observations per day, per treatment, replicated for six days (168 observations). All data was collected over a 6 day period, and a statistical analysis of variance was performed to test the hypothesis that the means of the two environments are the same. The specifications to which the LLDPE film bagging is manufactured, the moisture content of the lint, and the construction of the bale are controlled determining factors, and ambient air temperature and humidity are uncontrolled variables.

Results and Discussion

The bale interstitial atmosphere relative humidity and the daily observations of relative humidity and temperature were recorded for each bale. Table 1 gives a summary of the test results. These were matched with the corresponding NOAA weather data from the Hanford weather center. All values were averaged for the bales interstitial region/atmosphere and the corresponding ambient air. The raw data values and averages are given in Table 1 for each replication.

The hypothesis tested for each set of means shown in Table 1 was that the means were the same, utilizing analysis of variance as described in Little & Hills (1978); Table 1 demonstrated that the interstitial humidity was extremely consistent (no variance occurred), whereas the ambient conditions changed over time. The results indicate that a highly significant difference (1% point for the F distribution) was exhibited between the two environments. It appears that if variance in the interstitial humidity did occur, the degree of change was within the tolerance of the monitoring card. The lack of variance in the interstitial environment could also be attributed to the dry condition of the cotton, which was less than 3% at time of baling, since Pima cotton is ginned at extremely low moisture levels to facilitate the action of the roller gin in removing lint.

Research by Wakelyn and Hughs (2002) demonstrated that the amount of airspace inside the bale and the diffusion of air into and out of the bale is directly related to bale density. Their results indicated minimal diffusion and the inability to sustain smoldering combustion even within 1.27 cm (0.5 in) of the outside edge of the bale if the bale is compressed to greater than 14 lb/ft^3. It would be expected that if there is not enough diffusion of air into and out of a bale, compressed to a density of >14 lb/ft^3 to sustain combustion, then there would also be very little diffusion of moisture/water vapor into the bale to increase the moisture content of the bale or out of the bale to significantly increase the interstitial relative humidity under the bale wrapping. The minimal diffusion suggests that the interstitial relative humidity within the LLDPE plastic bag would be maintained at a low level with the low moisture bales produced by the J.G. Boswell Company; i.e., that the relative humidity within the interstitial area most likely is maintained at a constant level, regardless of the external ambient conditions.

Comparisons of the calculated F ratios to required significance tables indicate that the LLDPE film bagging interstitial environment is significantly different from the ambient conditions. In this case, the average humidity level was extremely consistent and below that measured for ambient conditions. The statistical analysis indicated that there was a highly significant difference in the means between the interstitial environment and the ambient conditions.

Conclusions

A relative humidity comparison test was conducted at the J.G. Boswell Company Central Packaging and Warehouse Facility (Figure 4) to determine how the interstitial relative humidity of cotton bales wrapped with LLDPE film bagging material is affected by ambient external relative humidity and temperature conditions. The test was performed over a period of 6 days, during which the ambient relative humidity and temperature conditions were highly variable. The relative humidity levels in the interstitial environment remained very constant, at a level at or below 10% relative humidity, over the course of the trial. It is concluded, therefore, that Pima bales ginned at the J.G. Boswell Company and enclosed with the proprietary LLDPE film bagging are warehoused within a very stable low humidity environment that is consistent with preferred condition required to insure preservation of fiber quality during warehousing.

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Table 1. Humidity monitoring test results.

Each Bale		Replications , Relative Humidity, %					
		Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**
Bale	Time						
1	1	10	10	10	10	10	10
	2	10	10	10	10	10	10
	3	10	10	10	10	10	10
	4	10	10	10	10	10	10
2	1	10	10	10	10	10	10
	2	10	10	10	10	10	10
	3	10	10	10	10	10	10
	4	10	10	10	10	10	10
3	1	10	10	10	10	10	10
	2	10	10	10	10	10	10
	3	10	10	10	10	10	10
	4	10	10	10	10	10	10
4	1	10	10	10	10	10	10
	2	10	10	10	10	10	10
	3	10	10	10	10	10	10
	4	10	10	10	10	10	10
5	1	10	10	10	10	10	10
	2	10	10	10	10	10	10
	3	10	10	10	10	10	10
	4	10	10	10	10	10	10
6	1	10	10	10	10	10	10
	2	10	10	10	10	10	10
	3	10	10	10	10	10	10
	4	10	10	10	10	10	10
Average		10	10	10	10	10	10
7	1	56	54	44	54	52	48
	2	74	69	74	80	74	71
	3	86	89	91	93	83	86
	4	54	56	49	44	42	35
Average		67.5	67	64.5	67.75	62.75	60

Treatments	**Replication Averages**						**Y (sum of means)**	**Y (grand mean)**
Interstitial	10	10	10	10	10	10	60	10
Ambient	67.5	67	64.5	67.75	62.75	60	389.5	65
							449.5	37

From Table A3:	**P (%) (Level of significance)**	**F**	**Calculated F**
1 Degree for Numerator	0.1	3.29	1882
10 Degrees For Denominator	0.05	4.96	1882
	0.01	10.04	1882*

*The calculated F ratio exceeds the required F for P-0.01, indicating highly significant difference in the means.

Figure 1. LLDPE film packaged UD cotton bales selected for testing.

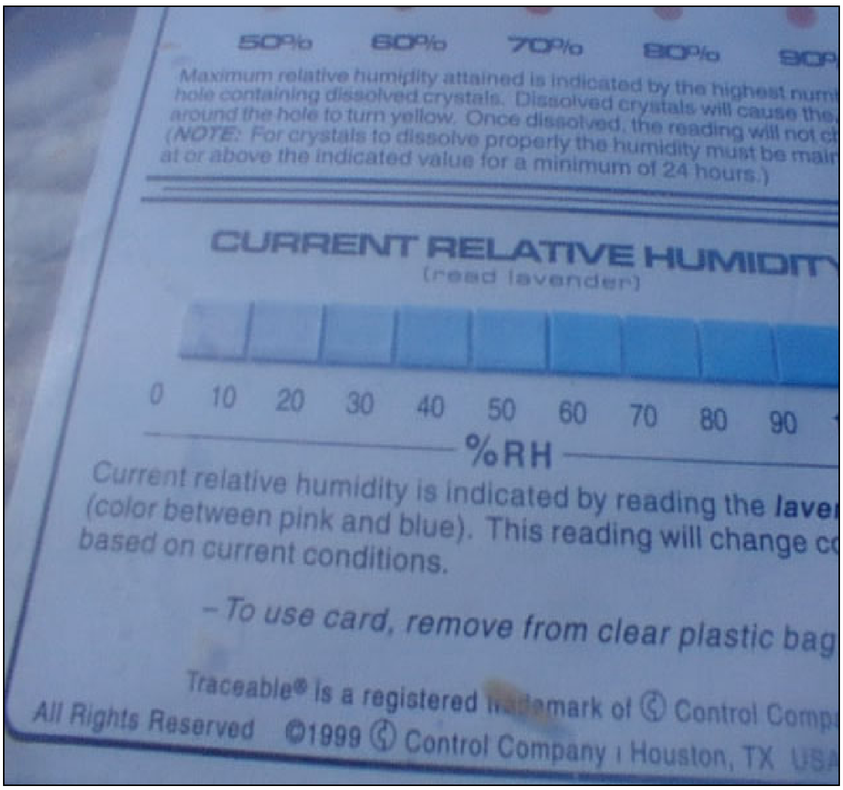

Figure 2. “Relative Humidity on a Card” monitor.

Figure 3. Relative humidity monitor on the outside of the bale bagging.

Figure 4. LLDPE film bagging wrapped cotton bales in storage.