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STORAGE OF COTTON BALES AT MARGINAL MOISTURE LEVELS

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Abstract

Previous studies clearly indicate that water droplets sprayed directly on cotton fiber at the lint slide cause color change and weight loss during storage. This report describes research to determine the impact of moisture added by the humidified air and direct spray approaches to cotton bales at a commercial gin. The study involved 48 bales of cotton from six different modules of seed cotton with several different moisture restoration regimes applied. The regimes included 1) standard processing without the addition of moisture, 2) humidified air, 3) direct spray, and 4) combination of one and two. Generally the test sequence was as follows: 1) gin one module for practice, 2) gin the first bale of the test module for practice or warm-up, 3) apply one of the four treatments on two consecutive bales, 4) process two practice bales to adjust for the next restoration condition, and 5) continue with next treatment. A standard ginning sequence for the cotton including two driers, two cylinder cleaners, one stick machine, extractor-feeder, gin stand, and one lint cleaner was used. Two driers at 200 ºF were used on the low moisture treatments, one drier at 200 °F was used on the medium moisture treatments, and one drier at 100 °F was used on all the high moisture treatments. A strip-laminated, woven-polypropylene, bagging was used on all bales. The amount of water added per bale ranged from 0 to 4%. The bales were weighed on 8 occasions, beginning with immediately after packaging. The class data after moisture restoration was subtracted from the class data before the moisture restoration for each factor and the difference between the means was zero in all cases. After storage for six months the bales were shipped to Clemson for opening and subsequent moisture analyses and HVI testing. Average bale moistures at Clemson ranged from 6.5% to 7.3% and back-calculated moistures based on weight change to estimate the actual moisture before storage ranged from 4.6% to 8.1%. Minor changes in Rd and +b occurred until moistures reached about 7.3% (wet basis), then the Rd changed substantially. This test clearly showed the negative effect of low levels of moisture, beginning at about 7% moisture content.

Introduction

Cotton may be harvested, ginned and initially stored at moistures below equilibrium moisture content even if the cotton growth area is humid. The cotton bales seek equilibrium with the moisture in the air and usually gain but sometimes lose weight during storage. Farmers are paid on the certified weight at the gin or warehouse so ginners often restore moisture at the lint slide to recover the weight lost during field drying and gin processing, and to reduce bale-packaging forces. Two basic methods of moisture restoration are used—humidified air and direct water spray. The humidified air approach rarely adds more than 2% (4.54 kg or 10 lb) moisture to a bale but the direct spray approach can add far more moisture. Thus, the direct spray approach must be used with great care because of applying too much water.

The addition of moisture to cotton fiber immediately before baling reduces compression forces, increases bale weight and reduces equilibration time. The direct-spray method can add a much greater amount of water but is generally limited to keep final bale moisture to less than 8%. Bales are currently (2004) packaged at high density levels and covered with bagging of low permeability; both retarding the escape of moisture from the bale. Research by Anthony (2002a, 2002b and 2003) suggests that even lower levels of moisture should be used. Recent complaints from the textile industry suggest that fiber color sometimes changes substantially during storage prompting some to suspect excess moisture as the causative (Brandon, 2003).

The change in color during storage can be devastating to the cotton industry. Most ginners believe that they add 5 to 15 pounds of water per bale with their moisture restoration systems. Anthony (2002a, 2002b and 2003a) evaluated the impact of spraying moisture on cotton fiber quality at the lint slide in three studies. In these studies, water was sprayed on cotton lint as it came down the lint slide, and the resulting bales were packaged at universal density in 1) polyethylene, 2) strip-laminated woven polypropylene, and 3) fully coated woven polypropylene bags and stored for several months. Across the three studies, color was reduced for the bales initially above 8% moisture content. The grayness and yellowness were negatively impacted at moisture levels as low as 7.3%. As a result of these findings, ginners were cautioned against applying excessive moisture to cotton before long-term storage and noted that bales should be stored below 8% moisture content, wet basis, regardless of the permeability of the bale covering materials in order to avoid color degradation. The Quality Task Force of the National Cotton Council recommends that bales not be packaged at moistures above 7.5% (wet basis) in order to avoid the possibility of fiber quality degradation (National Cotton Council, 2003).

Anthony (2003b) surveyed moisture restoration practices in 18 gins in Mississippi and Arkansas in October and November 2002. The purposes of this survey were 1) to determine the amount of moisture added to cotton at the lint slide in gins in the Midsouth using commercially available moisture restoration systems, and 2) to determine the number of bales packaged above 8.0% moisture. The types of moisture restoration systems surveyed were: 1) lint slide grid, 2) humidified air at/near the battery condenser, 3) direct water spray at the lint slide, and 4) combination of 2 and 3. Moisture was over 8% in 8.6% of the bales. Ten of the 18 surveyed gins produced bales that exceeded the 8.0% moisture content, most of these used the direct spray or combination methods of moisture restoration. These bales may experience color degradation during extended storage. Moisture restoration practices were again surveyed in 20 gins in Mississippi and Arkansas in September-November 2003 (Anthony 2004). In this survey, 7.8% of the bales were above the National Cotton Council recommended storage moisture content of 7.5%. Twelve of the 20 surveyed gins produced bales that exceeded the 7.5% recommended moisture level and 22.9% of the total bales surveyed exceeded 7.5% moisture. Almost all of these occurred at gins using the direct spray method of moisture restoration. These bales may experience color degradation during extended storage.

The purpose of this research was to determine the impact of moisture added by the humidified air and direct spray approach to cotton bales at a commercial gin.

Methodology

As a result of considerable interest in moisture restoration at the lint slide area for the last few years, a study was conducted at a commercial gin using commercial moisture restoration systems. Since previous studies at the Stoneville Laboratory have shown that moisture levels above 8% were detrimental to color grade, the test was designed to produce bales of cotton that were below 8% as well as above 8% in order to try to further refine the safe level of storage for the cotton. The study involved 48 bales of cotton from six different modules of seed cotton with several different moisture restoration regimes applied. The regimes included 1) standard without moisture added, 2) humidified air, 3) direct spray, and 4) combination humidified air and direct spray. A standard ginning sequence for the cotton included two driers, two cylinder cleaners, one stick machine, extractor-feeder, gin stand, and one lint cleaner. The intent was to have a low and high level of humidified air, a low, medium, and high level of direct spray, and a combination that involved a low, medium, and high level. Each of those was compared to no water being added (standard). Two driers at 200 °F were used on the low moisture treatments, one drier at 200 °F was used on the medium moisture treatments, and one drier at 100 °F was used on all the high moisture treatments. Two standard (standard moisture) bales were used for each module. A woven-polypropylene, strip laminated bagging was used on all bales. Six modules of cotton at Griffin Gin, Elaine, Arkansas, were selected for study. Generally the test sequence was as follows: 1) gin one module for practice, 2) gin the first bale of the test module for practice or warm-up, 3) apply one of the three treatments on two consecutive bales, 4) process two practice bales to adjust for the next restoration condition, and 5) continue with next treatment. Prior to conducting the test, the gin manager was asked to ensure that the Samuel Jackson Moisture Restoration System (Steamroller) and the Lewis Electric Direct Spray System were functioning in accordance with manufacturer's recommendations.

The gin sequence used in the study is shown in Table 1. The treatments were applied in different orders to each module and most modules received the same treatments. The intent was to have bales of cotton with and without different levels of moisture restoration and different types of moisture restoration within the same module.

Ten samples were taken for moisture before and after moisture restoration and placed in sealed cans. Ten samples were also taken for AFIS, and HVI classification before and after moisture restoration, and placed in paper bags. A separate sample was taken from the bale exterior at each of the two sample cut areas and sealed in cans. The "before" samples were taken from the lint flue as the cotton came up toward the battery condenser. The after samples were taken at the lower end of the lint slide, and because of the number of samples taken and the 45 bale per hour ginning rate, large armfuls of lint cotton were taken at one time, placed in a plastic bag, and then sub-samples were rapidly taken from those bags and either stored in sealed cans or paper bags as appropriate. Since previous research indicated an extremely high variability in the moisture content after application of the direct-spray method of moisture restoration, a more accurate method to estimate the moisture content was to back-calculate the moisture based on the final moisture and the change in bale weight during storage. Thus, the following calculation was used to determine the moisture before storage.

Initial moisture= final moisture (%) – ((initial weight-final weight)/initial weight)*100 (1)

Moisture content indications were also taken from an infrared moisture meter before moisture restoration as well as a microwave-based MALCAM instrument after moisture restoration. These moisture indications were compared to the oven-based moisture contents.

After the bales were packaged and weighed, they were temporarily stored at Griffin Gin. They were subsequently transported to Leland Compress for long-term storage of about six months. At Leland Compress, the bales were weighed initially and about every three weeks after that until they were taken out of storage on May 8, 2003. The bales were transported to the Cotton Quality Research Station at Clemson, South Carolina, where they were opened and 1 sample taken from each of 10 layers inside the bale for HVI, AFIS, and moisture determinations.

Results

Results of the study in terms of final moisture after packaging at the gin are shown in Table 2. The 6 modules of cotton and the order of ginning including the actual moisture content based on 10 samples taken at the lint slide after moisture restoration are given. For Module 1, moisture ranged from 5.6% for the standard bale to 6.9% for the bale with humid air applied. For Module 2, the moisture content ranged from 5.2% for a standard bale to 9.4% for a direct spray, medium level bale. For Module 3, a standard moisture content bale was lowest at 5.5% and highest at 7.7% for a direct-spray high bale. For Module 4, a standard treatment bale was lowest at 5.7% moisture compared to 7.9% moisture for a humidified air approach at the high level in combination with the direct spray at the medium level. For this module, about 12 lbs of water were added per bale. For Module 5, the lowest moisture was a standard bale at 6.0% and the highest was a high-humidified air and high direct-spray bale at 7.4%. Bales from module 6 contained the most amount of moisture added because the ginning rate was reduced to 30 bales per hour to increase the amount of moisture added. A standard bale at 5.4% was the lowest moisture whereas 11.6% was the highest for a low humidified air and low spray bale.

Moisture content means for each bale are in Table 2 for the infrared moisture reading before moisture restoration, the moisture content based on the MALCAM instrument after moisture restoration, and the oven-based moisture before, and after moisture restoration. Based on the oven method, 13 of the 48 bales were above regression analysis of the infrared and MALCAM estimate of oven moisture produced R square values of less than 0.1.

The moisture content from the sample on each side of the bale as well as their average is shown in Table 3. For 11 of the bales, the moisture on each side differed by over 1% indicating non-uniform water application; all these 11 bales included the direct spray method. This suggested that the samples with or without water applied were on both sides of some bales but not others.

The HVI classification data before and after the moisture was applied is at Table 4. The HVI data after moisture restoration was subtracted from the HVI data before moisture restoration for each factor and the difference between the means was zero in all cases.

Analysis of variance for the data from the samples collected before moisture was added was analyzed for moisture level based upon the anticipated moisture content of the cotton (Table 5). Only the micronaire was significant at the 5% level of probability or higher. Similar analysis for the HVI factors immediately after moisture was applied are shown in Table 6; only the micronaire was significant at the 5% level or better.

The bales were stored at Leland Compress until shipping to Clemson, SC, for sampling. The bales were weighed on 8 occasions, beginning with immediately after packaging and continuing to May 8, 2003. The bales were shipped to Clemson for subsequent weighing, sampling and testing. Moistures after storage from November to May are given in Table 7 as well as the weight change and weight change adjusted to a common 500-lb bale. Average bale moistures at Clemson ranged from 6.5% to 7.3% and back-calculated moistures ranged from 4.6% to 8.1%.

HVI data before and after storage as determined at Clemson are given in Table 8. The change in Rd and +b for selected bales with moistures from 7.1% to 8.1% are given in Table 9 and graphically illustrated in Figure 1. Minor changes in Rd and +b occurred until moistures reached about 7.3%, then Rd changed substantially.

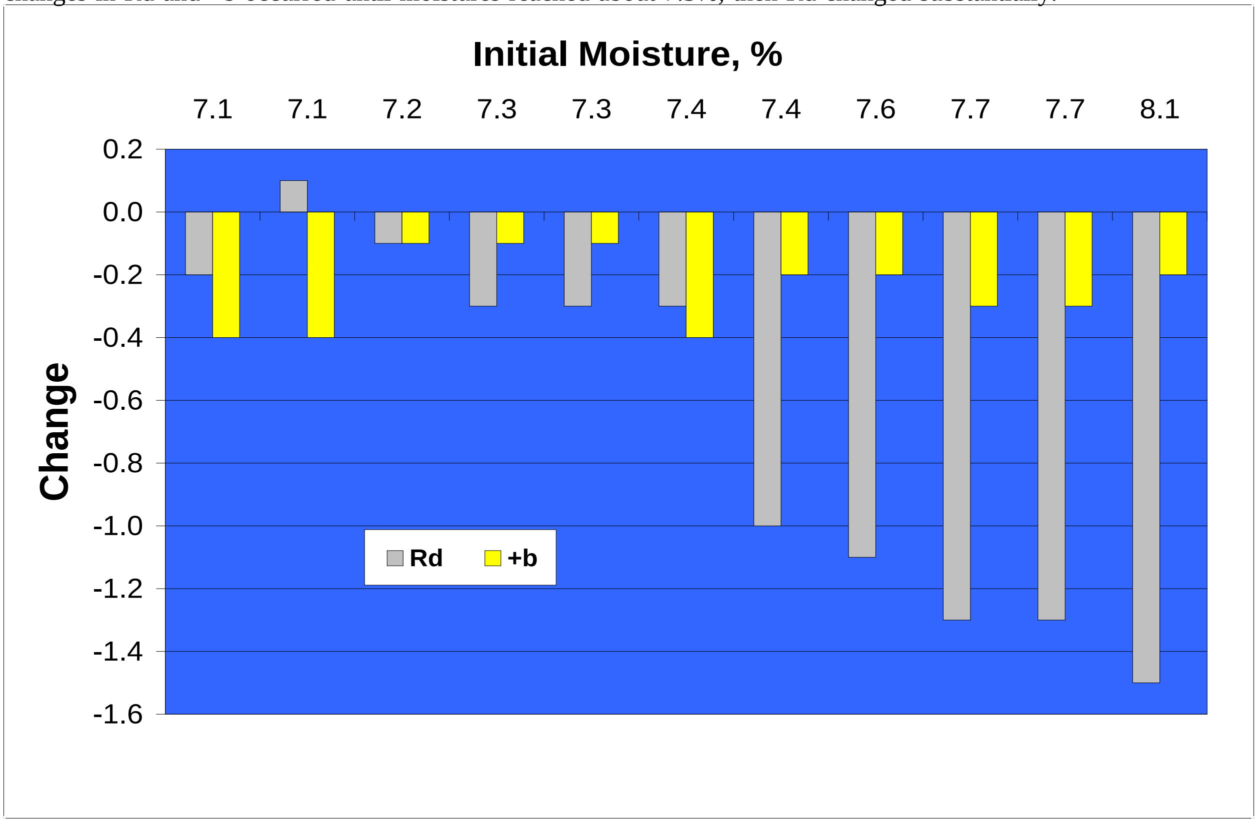

Figure 1. Change in Reflectance (Rd) and Plus b (+b) as a function of moisture during storage.

Summary and Conclusions

This study evaluated the change in bale weight and HVI factors during six months of storage of 48 bales that had moisture added by the humidified air or direct spray approach. For Module 1, moisture ranged from 5.6% for the standard bale to 6.9% for the bale with humid air applied. For Module 2, the moisture content ranged from 5.2% for a standard bale to 9.4% for a direct spray, medium level bale. For Module 3, a standard moisture content bale was lowest at 5.5% and highest at 7.7% for a direct-spray high bale. For Module 4, a standard treatment bale was lowest at 5.7% moisture compared to 7.9% moisture for a humidified air approach at the high level in combination with the direct spray at the medium level. For this module, about 12 lbs of water were added per bale. For Module 5, the lowest moisture was a standard bale at 6.0% and the highest was a high-humidified air and high direct-spray bale at 7.4%. A standard bale at 5.4% was the lowest moisture whereas 11.6% was the highest for a low humidified air and low spray bale. The bales produced from Module 6 contain considerably more moisture than did the bales from the other 5 modules. The bales were stored at Leland Compress until shipping to Clemson, SC, for sampling. The bales were weighed on 8 occasions, beginning with immediately after packaging and continuing to May 8, 2003. The HVI data after moisture restoration was subtracted from the HVI data before moisture restoration for each factor and the difference between the means was zero in all cases.

The bales were then shipped to Clemson for opening and subsequent moisture analyses and HVI testing. Average bale moistures at Clemson ranged from 6.5% to 7.3% and back-calculated moistures to estimate the actual moisture before storage ranged from 4.6% to 8.1%. Small changes in Rd and +b occurred until moistures reached about

7.3%, then Rd changed substantially. This test clearly showed the negative effect of low levels of moisture, beginning at about 7% moisture content.

Disclaimer

Mention of a trade name, propriety product or specific equipment does not constitute a guarantee or warranty by the United States Department of Agriculture and does not imply approval of a product to the exclusion of others that may be suitable.

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Table 1. Sequence for moisture study to compare humidified air, direct-spray, and combination methods of moisture restoration and the impact on fiber quality. A "Warm-up" or practice module was used to get the Steamroller fully functional at the high moisture level. A practice module/bale was processed using the conditions for the NEXT treatment.[1]

Ginid/ Bale	Module 1	Ginid/ Bale	Module 2	Ginid/ Bale	Module 3	Ginid/ Bale	Module 4	Ginid/ Bale	Module 5	Ginid/ Bale	Module 6
1 026	Humid--High	9 059	Humid--High	17 090	Humid--High	25 124	Humid--High Spray--High	33 155	Humid--High Spray--medium	41 191	Humid--Low Spray--Low
2 027	Humid--High	10 060	Humid--High	18 091	Humid--High	26 125	Humid--High Spray--High	34 156	Humid--High Spray--medium	42 192	Humid--Low Spray--Low
3 030	Humid--low	11 063	Spray--low	19 094	Humid--low	27 128	Humid--High	35 159	Humid--High Spray--High	43 195	Humid--Low Spray--Medium
4 031	Humid--low	12 064	Spray--low	20 095	Humid--low	28 129	Humid--High	36 160	Humid--High Spray--High	44 196	Humid--Low Spray--Medium
5 034	Standard	13 067	Spray--Medium	21 098	Spray--High	29 132	Humid--High Spray--Medium	37 163	Humid--High Spray--Low	45 199	Humid--Low Spray--High
6 035	Standard	14 068	Spray--Medium	22 099	Spray--High	30 133	Humid--High Spray--Medium	38 164	Humid--High Spray--Low	46 200	Humid--Low Spray--High
7 37	Spray--High	15 070	Standard	23 101	Standard	31 135	Standard	39 165	Standard	47 202	Standard
8 038	Spray--High	16 071	Standard	24 102	Standard	32 136	Standard	40 166	Standard	48 203	Standard

[1]Humid = steamroller with humidified air. Spray = direct spray system. Standard = no moisture added.

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Table 2. Average moisture by ginid for instrument (infrared and Malcam) and oven tests before and after moisture restoration.

			Moisture content, %			
			Before restoration		After restoration	
Ginid	Treatment[1]	Module	Infrared	Oven[2]	Malcam	Oven[2,3]
1	HH	1	6.62	5.38	8.20	6.94
2	HH	1	6.70	5.57	8.50	6.78
3	HL	1	6.00	5.43	8.50	6.40
4	HL	1	6.00	5.57	8.40	6.59
5	Standard	1	6.00	5.40	8.60	5.55
6	Standard	1	6.50	5.59	8.60	5.68
7	SH	1	6.50	5.80	8.60	6.32
8	SH	1	6.50	5.80	8.60	6.74
9	HH	2	6.40	4.90	8.60	6.02
10	HH	2	6.45	4.98	8.60	6.37
11	SL	2	6.20	5.11	8.60	6.66
12	SL	2	5.75	5.40	8.60	5.84
13	SM	2	5.75	5.43	8.60	**9.40**
14	SM	2	5.50	5.37	8.60	**8.69**
15	Standard	2	6.00	5.42	8.60	5.56
16	Standard	2	5.90	5.41	8.60	5.16
17	HH	3	6.90	5.66	8.70	6.63
18	HH	3	6.95	6.25	8.70	6.60
19	HL	3	6.50	6.53	8.70	6.25
20	HL	3	NA	5.87	NA	6.51
21	SH	3	6.80	5.51	8.75	**7.03**
22	SH	3	6.30	5.78	8.60	**7.72**
23	Standard	3	NA	5.45	NA	5.46
24	Standard	3	5.50	5.45	8.60	5.74
25	HH-SH	4	6.40	5.30	8.70	6.21
26	HH-SH	4	6.75	4.98	8.70	6.19
27	HH	4	6.30	5.86	8.70	6.32
28	HH	4	6.35	5.77	8.70	**7.04**
29	HH-SM	4	6.60	5.58	8.70	**7.22**
30	HH-SM	4	6.70	5.31	8.70	**7.94**
31	Standard	4	5.50	5.89	8.70	5.68
32	Standard	4	5.50	6.01	8.70	5.91
33	HH-SM	5	6.30	5.71	8.70	6.85
34	HH-SM	5	6.50	5.61	8.70	**7.11**
35	HH-SH	5	6.70	5.85	8.70	**7.37**
36	HH-SH	5	6.80	6.08	8.70	6.64
37	HH-SL	5	6.75	6.11	8.70	**7.08**
38	HH-SL	5	6.27	6.14	8.70	6.49
39	Standard	5	NA	6.23	8.70	6.19
40	Standard	5	NA	6.66	8.70	6.03
41	HL-SL	6	6.00	6.24	8.70	**7.36**
42	HL-SL	6	5.75	5.72	8.70	**11.58**
43	HL-SM	6	5.50	5.39	8.70	6.49
44	HL-SM	6	5.25	5.12	8.70	**10.25**
45	HL-SH	6	6.10	5.00	8.70	6.81
46	HL-SH	6	6.10	4.79	8.70	**9.56**
47	Standard	6	4.50	5.20	8.70	5.39
48	Standard	6	4.45	5.31	8.70	5.60

[1] HH = high humid air; HL = low humid air; Standard = no moisture restoration; SH = high spray; SL = low spray; and SM = medium spray.
[2] Oven test based on ASTM (1977).

[3]Bold indicates moisture contents over 7.0%.
NA = not available

Table 3. Moisture based on samples from the exterior of the bale (Classing sample area). Samples from each side differing by 2 or more percentage points are denoted in bold.

Gin ID	Moisture, %		
	Side 1	Side 2	Average
1	6.35	6.35	6.35
2	6.65	6.50	6.58
3	6.05	6.00	6.02
4	6.20	6.45	6.32
5	5.65	5.80	5.72
6	5.70	5.35	5.52
7	7.40	7.30	7.35
8	**11.15**	**8.35**	9.75
9	6.25	6.35	6.30
10	6.25	6.30	6.28
11	7.35	7.45	7.40
12	5.80	7.30	6.55
13	11.80	11.00	11.40
14	**16.60**	**13.75**	15.18
15	5.25	5.25	5.25
16	5.30	5.60	5.45
17	6.75	6.85	6.80
18	6.90	6.60	6.75
19	6.80	6.60	6.70
20	6.70	6.50	6.60
21	7.00	6.40	6.70
22	7.85	7.70	7.78
23	5.40	5.00	5.20
24	5.45	5.25	5.35
25	6.35	6.10	6.22
26	**5.85**	**8.25**	7.05
27	6.30	5.90	6.10
28	5.95	5.50	5.72
29	8.05	7.40	7.72
30	**10.45**	**8.18**	9.31
31	**6.10**	**5.55**	5.82
32	5.90	5.75	5.82
33	**6.60**	**7.75**	7.18
34	6.70	7.05	6.88
35	7.55	7.95	7.75
36	6.75	7.00	6.88
37	**6.25**	**7.45**	6.85
38	6.15	6.40	6.28
39	6.15	6.35	6.25
40	6.70	6.55	6.62
41	**6.20**	**9.35**	7.78
42	**15.70**	**7.15**	11.42
43	**13.30**	**6.00**	9.65
44	8.65	8.35	8.50
45	**9.20**	**12.15**	10.68
46	**5.80**	**10.30**	8.05
47	5.20	5.15	5.18
48	5.10	5.05	5.08

Table 4. Means for HVI variables before and after moisture restoration.

Gin	Rd		Plus b		Length, in.		Leaf	
ID	Before	After	Before	After	Before	After	Before	After
1	75.8	75.8	7.5	7.5	1.15	1.15	4.0	4.0
2	75.4	75.4	7.5	7.5	1.15	1.15	4.0	4.0
3	75.7	75.7	7.5	7.5	1.15	1.15	4.0	4.0
4	74.9	74.9	7.3	7.3	1.15	1.15	4.0	4.0
5	75.3	75.3	7.5	7.5	1.15	1.15	4.0	4.0
6	74.9	74.9	7.4	7.4	1.14	1.14	3.9	3.9
7	75.1	75.1	7.5	7.5	1.14	1.14	4.0	4.0
8	74.9	74.9	7.3	7.3	1.15	1.15	4.0	4.0
9	76.0	76.0	7.2	7.2	1.14	1.14	3.9	3.9
10	76.1	76.1	7.5	7.5	1.15	1.15	4.0	4.0
11	76.0	76.0	7.4	7.4	1.13	1.13	3.8	3.8
12	75.0	75.0	7.7	7.7	1.14	1.14	4.0	4.0
13	76.0	76.0	7.5	7.5	1.13	1.13	4.0	4.0
14	76.5	76.5	7.5	7.5	1.14	1.14	3.5	3.5
15	75.8	75.8	7.3	7.3	1.15	1.15	4.0	4.0
16	75.4	75.4	7.1	7.1	1.14	1.14	4.0	4.0
17	74.8	74.8	7.3	7.3	1.16	1.16	4.0	4.0
18	74.8	74.8	7.2	7.3	1.16	1.16	3.9	3.9
19	74.9	74.9	7.3	7.3	1.16	1.16	4.0	4.0
20	75.7	75.7	7.3	7.3	1.15	1.15	4.0	4.0
21	74.2	74.2	7.6	7.6	1.17	1.17	4.0	4.0
22	74.5	74.5	7.5	7.5	1.18	1.18	4.0	4.0
23	74.9	74.9	7.3	7.3	1.15	1.15	4.0	4.0
24	74.0	74.0	7.3	7.3	1.16	1.16	4.0	4.0
25	75.6	75.6	6.9	6.9	1.13	1.13	3.9	3.9
26	76.0	76.0	7.1	7.1	1.12	1.12	3.3	3.3
27	76.7	76.7	7.3	7.3	1.13	1.13	4.0	4.0
28	75.0	75.0	7.0	6.1	1.12	1.12	4.0	4.0
29	75.8	75.8	7.2	7.2	1.14	1.14	4.0	4.0
30	75.3	75.3	7.0	6.1	1.14	1.14	3.8	3.8
31	75.0	75.0	7.5	7.6	1.12	1.12	4.0	4.0
32	75.3	75.3	7.3	7.3	1.14	1.14	4.0	4.0
33	74.4	74.4	7.3	7.3	1.14	1.14	3.8	3.8
34	75.0	75.0	7.4	7.4	1.14	1.14	4.0	4.0
35	74.6	74.6	7.4	7.4	1.13	1.13	4.0	4.0
36	74.2	74.2	7.4	7.4	1.12	1.12	4.0	4.0
37	74.4	74.4	7.5	7.5	1.11	1.11	4.0	4.0
38	74.7	74.7	7.5	7.5	1.13	1.13	4.0	4.0
39	74.0	74.0	7.5	7.5	1.13	1.13	3.9	3.9
40	73.4	73.4	7.8	7.8	1.13	1.13	4.0	4.0
41	76.8	76.8	7.2	7.2	1.17	1.17	4.0	4.0
42	76.6	76.6	7.1	7.1	1.16	1.16	3.8	3.8
43	76.6	76.6	7.4	7.4	1.15	1.15	4.0	4.0
44	77.1	77.1	7.2	7.2	1.15	1.15	3.8	3.8
45	77.4	77.4	7.3	7.3	1.15	1.15	3.0	3.0
46	76.8	76.8	7.4	7.4	1.15	1.15	3.0	3.0
47	77.1	77.1	7.3	7.3	1.16	1.16	3.9	3.9
48	77.1	77.1	7.3	7.3	1.17	1.17	3.9	3.9

Table 4. Continued.

Gin	Micornaire		Strength, g/tex		Trash, % area		Uniformity	
ID	Before	After	Before	After	Before	After	Before	After
1	4.6	4.6	33.2	33.2	0.05	0.05	83.2	83.2
2	4.6	4.6	32.6	32.6	0.05	0.05	83.0	83.0
3	4.6	4.6	32.5	32.5	0.06	0.06	82.8	82.8
4	4.6	4.6	32.9	32.9	0.07	0.07	82.8	82.8
5	4.5	4.5	32.1	32.1	0.06	0.06	83.3	83.3
6	4.5	4.5	32.9	32.9	0.07	0.07	82.8	82.8
7	4.6	4.6	33.4	33.4	0.06	0.06	83.0	83.0
8	4.6	4.6	32.9	32.9	0.06	0.06	83.6	83.6
9	4.4	4.4	32.2	32.2	0.06	0.06	83.0	83.0
10	4.4	4.4	34.2	34.2	0.06	0.06	82.4	82.4
11	4.4	4.4	32.0	31.1	0.06	0.06	82.2	82.2
12	4.5	4.5	31.3	31.3	0.07	0.07	82.3	82.3
13	4.5	4.5	31.8	31.8	0.07	0.07	82.5	82.5
14	4.4	4.4	32.2	32.2	0.07	0.07	82.5	82.5
15	4.4	4.4	32.0	31.1	0.07	0.07	82.6	82.6
16	4.4	4.4	33.7	33.7	0.06	0.06	82.1	82.1
17	4.5	4.5	32.4	32.4	0.06	0.06	83.2	83.2
18	4.5	4.5	34.1	34.1	0.06	0.06	82.7	82.7
19	4.5	4.5	31.6	31.6	0.07	0.07	82.9	82.9
20	4.5	4.5	32.7	32.7	0.07	0.07	82.9	82.9
21	4.5	4.5	32.7	32.7	0.07	0.07	83.7	83.7
22	4.5	4.5	32.5	32.5	0.06	0.06	84.0	84.0
23	4.5	4.5	32.8	32.8	0.05	0.05	83.1	83.1
24	4.6	4.6	32.9	32.9	0.07	0.07	82.9	82.9
25	4.5	4.5	33.2	33.2	0.06	0.06	83.1	83.1
26	4.5	4.5	32.1	32.1	0.04	0.04	82.3	82.3
27	4.5	4.5	32.1	32.1	0.06	0.06	82.0	82.0
28	4.5	4.5	32.0	32.0	0.07	0.07	82.5	82.5
29	4.5	4.5	30.4	30.4	0.07	0.07	82.6	82.6
30	4.6	4.6	32.2	32.2	0.06	0.06	83.7	83.7
31	4.4	4.4	32.1	32.1	0.07	0.07	82.1	82.1
32	4.5	4.5	33.6	33.6	0.06	0.06	82.6	82.6
33	4.4	4.4	31.3	31.3	0.07	0.07	83.2	83.2
34	4.5	4.5	30.2	30.2	0.07	0.07	82.4	82.4
35	4.5	4.5	32.1	32.1	0.07	0.07	82.6	82.6
36	4.5	4.5	30.5	30.5	0.07	0.07	82.3	82.3
37	4.5	4.5	30.8	30.8	0.07	0.07	82.3	82.3
38	4.5	4.5	31.5	31.5	0.08	0.08	82.8	82.8
39	4.4	4.4	30.4	30.4	0.07	0.07	82.4	82.4
40	4.4	4.4	31.5	31.5	0.08	0.08	82.3	82.3
41	4.6	4.6	33.5	33.5	0.07	0.07	82.8	82.8
42	4.6	4.6	33.1	33.1	0.07	0.07	82.6	82.6
43	4.6	4.6	30.9	30.9	0.05	0.05	82.4	82.4
44	4.5	4.5	32.9	32.9	0.05	0.05	82.3	82.3
45	4.5	4.5	29.5	29.5	0.05	0.05	82.4	82.4
46	4.5	4.5	30.8	30.8	0.04	0.04	82.3	82.3
47	4.5	4.5	32.6	32.6	0.05	0.05	82.8	82.8
48	4.6	4.6	30.2	30.2	0.07	0.07	82.8	82.8

Table 5. Analyses of variance for HVI data **before** moisture addition.

Variable	Mean squares		F- Value	Pr > F	R-Square	Coeff-Var	Root MSE	Mean
	Level	Error						
Mike[1]	0.01	0.003	3.09	0.01	0.39	1.28	0.06	4.51
Strength	1.81	1.13	1.61	0.15	0.25	3.30	1.06	32.15
Rd	0.655	1.07	0.57	0.79	0.11	1.41	1.07	75.66
Plusb	0.19	0.25	0.74	0.65	0.13	2.17	0.16	7.30
Leaf	0.03	0.03	0.81	0.60	0.14	4.73	0.19	3.93
% Area	0.0001	0.00007	1.54	0.17	0.24	14.18	0.009	0.06
Length	0.0004	0.0002	2.02	0.07	0.29	1.15	0.13	1.15
Uniform	0.21	0.24	0.88	0.54	0.15	0.59	0.49	83.0
Mode color	0.88	3.46	0.26	0.98	0.05	4.58	1.86	41

[1] Means varied from 4.42 (spray low) to 4.59 (spray high) and the minimum significant difference was 0.1.

Table 6. Analyses of variance for HVI data **after** moisture addition.

Variable	Mean squares		F- Value	Pr > F	R-Square	Coeff-Var	Root MSE	Mean
	Level	Error						
Mike	0.004	0.003	1.15	0.35	0.19	1.25	0.06	4.50
Strength	2.00	0.98	2.04	0.07	0.30	3.09	0.99	32.1
Rd	1.00	0.87	1.16	0.35	0.19	1.24	9.93	75.44
Plusb	0.04	0.38	1.24	0.30	0.20	2.37	0.17	7.34
Leaf	0.08	0.047	1.75	0.12	0.26	5.55	0.22	3.90
% Area	0.00006	0.00008	0.73	0.67	0.13	13.97	0.009	0.06
Length	0.0003	0.0002	1.46	0.20	0.23	1.29	0.15	1.14
Uniform	0.21	0.19	1.11	0.37	0.19	0.53	0.44	82.73
Mode color	0.32	0.40	0.79	0.62	0.14	1.55	0.63	41

Table 7. Moisture data to include the 3 sub-samples taken from 10 layers inside the bale at Clemson after storage[1].

Ginid	Initial moisture,%, charge box	Moisture measured at Clemson, %	Back-calculated moisture, %[1,2]
1	6.9	6.9	6.5
2	6.8	6.8	6.7
3	6.4	6.9	6.1
4	6.6	7.0	6.6
5[3]	5.6	6.6	5.2
6[3]	5.7	6.7	5.6
7	6.3	7.1	6.9
8	6.7	7.2	**7.4**
9	6.0	6.8	6.7
10	6.4	6.8	6.2
11	6.7	6.8	6.2
12	5.8	6.8	6.0
13	9.4	7.3	**7.3**
14	8.7	7.1	**7.3**
15[3]	5.6	6.6	4.8
16[3]	5.2	6.6	5.0
17	6.6	7.0	6.8
18	6.6	6.8	6.6
19	6.2	6.9	**7.1**
20	6.5	7.0	6.8
21	7.0	7.1	**7.1**
22	7.7	7.4	**7.6**
23[3]	5.5	6.5	5.0
24[3]	5.7	6.6	5.3
25	6.2	6.7	6.5
26	6.2	7.0	6.5
27	6.3	6.8	6.2
28	7.0	6.8	6.4
29	7.2	7.5	**7.7**
30	7.9	7.5	**8.1**
31[3]	5.7	6.9	5.5
32[3]	5.9	6.8	5.6
33	6.8	7.0	7.2
34	7.1	7.2	6.9
35	7.4	7.2	6.8
36	6.6	7.2	6.4
37	7.1	7.3	7.1
38	6.3	7.0	6.6
39[3]	6.2	6.9	5.9
40[3]	6.0	6.7	6.3
41	7.4	7.3	7.3
42	11.6	7.0	6.8
43	6.5	7.3	7.6
44	10.2	7.3	7.7
45	6.8	7.0	6.6
46	9.6	7.0	7.4
47[3]	5.4	6.7	4.9
48[3]	5.6	6.5	4.6

[1]Initial moisture= final moisture (%) – ((initial weight-final weight)/initial weight)*100.
[2]Bold indicates moisture before storage above 7.0% based on the moisture after storage measured at Clemson and the weight change.
[3]Standard, no moisture added.

Table 8. High Volume Instrument data measured at Clemson for samples taken before and after storage.

Gin ID	Micronaire		Rd		+b		Trash, % area	
	Before	After	Before	After	Before	After	Before	After
1	4.48	4.53	75.0	74.6	7.85	7.43	0.052	0.050
2	4.46	4.52	74.6	75.1	7.66	7.59	0.056	0.053
3	4.47	4.52	74.7	74.9	7.84	7.59	0.051	0.053
4	4.52	4.62	73.8	74.6	8.05	7.54	0.058	0.058
5	4.44	4.54	74.9	74.6	7.86	7.49	0.064	0.059
6	4.48	4.51	75.0	74.4	7.77	7.41	0.053	0.057
7	4.48	4.55	74.4	73.8	7.94	7.61	0.054	0.064
8	4.44	4.57	74.1	73.8	7.84	7.48	0.067	0.057
9	4.32	4.38	76.0	75.3	7.76	7.5	0.044	0.048
10	4.35	4.36	75.3	75.3	7.75	7.46	0.053	0.049
11	4.33	4.39	75.8	75.5	7.85	7.43	0.055	0.050
12	4.34	4.39	75.6	75.2	7.90	7.43	0.053	0.052
13	4.30	4.36	75.6	74.7	7.75	7.62	0.052	0.056
14	4.30	4.35	75.0	74.7	7.60	7.48	0.050	0.059
15	4.30	4.37	74.6	75.2	7.72	7.36	0.062	0.052
16	4.30	4.31	74.8	74.8	7.92	7.47	0.062	0.054
17	4.43	4.49	74.2	74.2	7.87	7.55	0.057	0.061
18	4.47	4.44	73.8	74.3	7.80	7.5	0.063	0.058
19	4.42	4.45	74.7	74.3	7.63	7.45	0.070	0.063
20	4.42	4.42	74.2	74.2	7.85	7.42	0.077	0.066
21	4.4	4.47	74.0	73.8	7.90	7.55	0.074	0.054
22	4.43	4.52	73.7	73.6	8.35	7.73	0.070	0.057
23	4.44	4.5	73.6	74.7	7.83	7.4	0.054	0.059
24	4.43	4.42	73.3	74.4	7.85	7.47	0.060	0.057
25	4.35	4.45	74.8	74.8	7.55	7.33	0.060	0.054
26	4.33	4.38	75.0	74.5	7.70	7.36	0.063	0.055
27	4.38	4.34	75.6	75.1	7.78	7.37	0.054	0.054
28	4.3	4.38	75.0	75.0	7.45	7.3	0.045	0.059
29	4.38	4.38	75.5	74.2	7.68	7.39	0.060	0.059
30	4.35	4.38	75.8	74.3	7.60	7.44	0.060	0.056
31	4.38	4.38	74.2	74.9	7.60	7.18	0.062	0.052
32	4.43	4.43	74.2	74.7	7.77	7.38	0.060	0.060
33	4.41	4.41	74.3	74.2	7.76	7.64	0.067	0.059
34	4.39	4.42	75.2	73.8	7.76	7.6	0.072	0.067
35	4.31	4.35	74.3	73.9	7.88	7.66	0.064	0.064
36	4.3	4.4	74.4	74.0	7.76	7.63	0.064	0.067
37	4.32	4.45	74.0	74.1	7.90	7.53	0.068	0.071
38	4.27	4.43	75.3	74.1	7.73	7.58	0.053	0.070
39	4.31	4.36	73.7	73.7	7.77	7.67	0.067	0.075
40	4.33	4.32	73.8	73.1	7.9	7.66	0.067	0.079
41	4.43	4.51	76.3	75.9	7.93	7.62	0.070	0.053
42	4.4	4.51	76.7	76.0	7.97	7.58	0.040	0.054
43	4.38	4.56	77.0	75.9	7.85	7.67	0.045	0.041
44	4.42	4.46	77.0	76.0	7.85	7.7	0.042	0.047
45	4.45	4.44	76.8	76.5	8.00	7.73	0.042	0.038
46	4.4	4.45	77.5	76.5	7.80	7.76	0.045	0.037
47	4.45	4.46	76.8	76.3	7.68	7.41	0.048	0.049
48	4.43	4.41	76.8	76.7	7.85	7.49	0.053	0.043

Table 8. Continued.

Gin ID	Upper half mean, in.		Uniformity		Strength, g/tex	
	Before	After	Before	After	Before	After
1	1.158	1.156	83.7	83.5	32.8	32.37
2	1.154	1.148	83.6	83.2	32.96	32.66
3	1.164	1.156	83.5	83.4	32.7	32.82
4	1.158	1.164	83.3	83.8	32.48	33.54
5	1.167	1.158	83.8	83.8	33.44	32.92
6	1.157	1.157	83.5	83.5	33.15	33.12
7	1.168	1.154	83.3	83.7	33.78	33.34
8	1.161	1.157	83.5	83.6	33.67	33.54
9	1.154	1.152	83.3	83.3	32.48	32.69
10	1.152	1.148	83.5	82.7	32.38	32.32
11	1.153	1.147	83.3	83.1	32.15	32.21
12	1.147	1.146	82.9	83.2	31.96	32.58
13	1.143	1.149	83.1	83.2	31.65	32.89
14	1.15	1.147	83.9	83.3	34	32.46
15	1.14	1.146	83.4	83.2	32.78	32.44
16	1.143	1.144	82.6	83.1	32.12	32.29
17	1.162	1.161	83.6	83.6	32.53	32.7
18	1.17	1.163	84.0	83.4	33.97	33.19
19	1.177	1.158	83.8	83.6	33.92	33.00
20	1.158	1.163	83.2	83.3	32.85	33.41
21	1.16	1.163	83.7	83.8	32.24	33.15
22	1.167	1.167	83.5	83.5	32.78	33.38
23	1.163	1.16	83.3	83.4	33.18	32.82
24	1.165	1.16	83.3	83.4	33.28	32.43
25	1.145	1.133	83.5	83.4	32.72	32.17
26	1.133	1.134	83.4	83.2	31.77	32.65
27	1.136	1.131	83.6	83.1	32.28	32.49
28	1.13	1.139	83.0	83.5	31.95	32.44
29	1.128	1.14	83.4	83.2	31.8	32.38
30	1.138	1.141	83.1	83.3	32.05	32.66
31	1.138	1.136	83.8	83.0	32.46	32.98
32	1.13	1.131	83.0	83.0	32.17	32.31
33	1.133	1.143	83.1	83.0	31.84	32.17
34	1.136	1.14	82.9	83.1	32.52	32.33
35	1.132	1.14	83.0	83.1	31.86	32.7
36	1.131	1.14	83.2	83.2	32.61	32.61
37	1.136	1.137	83.4	83.3	32.26	32.28
38	1.123	1.138	82.5	83.3	31.6	32.42
39	1.131	1.136	83.3	83.2	31.93	32.16
40	1.133	1.136	83.0	83.4	31.82	32.29
41	1.18	1.168	83.5	83.5	32.57	32.27
42	1.17	1.164	83.3	83.3	32.53	32.3
43	1.158	1.165	83.7	83.4	32.53	32.13
44	1.155	1.16	83.3	83.1	31.63	32.2
45	1.147	1.16	83.1	83.2	32.13	32.04
46	1.148	1.159	83.1	83.2	31.63	32.03
47	1.165	1.148	82.8	83.1	32.15	31.53
48	1.168	1.158	83.4	83.0	32.43	32.12

Table 9. Change in Rd and +b during storage for six months in strip-coated, woven polypropylene bags for selected bales based on High Volume Instrument evaluation at Clemson..

Gin id	Initial moisture content, %, calculated from weight change	Rd change	+b change	System used to apply water
19	7.1	-0.5	-0.1	Humid
21	7.1	-0.2	-0.4	Spray
37	7.1	0.1	-0.4	Spray + Humid
33	7.2	-0.1	-0.1	Spray + Humid
13	7.3	-0.9	-0.1	Spray
14	7.3	-0.3	-0.1	Spray
41	7.3	-0.3	-0.1	Spray + Humid
8	7.4	-0.3	-0.4	Spray
46	7.4	-1.0	-0.2	Spray + Humid
22	7.6	-0.1	-0.6	Spray
43	7.6	-1.1	-0.2	Spray + Humid
29	7.7	-1.3	-0.3	Spray + Humid
44	7.7	-1.3	-0.3	Spray + Humid
30	8.1	-1.5	-0.2	Spray + Humid