USE OF HIGH COTTON MOISTURE CONTENT DURING STORAGE TO REDUCE STICKINESS

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Abstract

Studies were conducted to examine the feasibility of using high cotton moisture content during storage to reduce cotton stickiness. Initially, water alone was added to bring the moisture content to 15%, 30% and 40% moisture. The cottons were stored for 5, 11 and 15 days at 10◦C. At each storage period, microbial population, cotton quality (strength and color), cotton stickiness, and cotton dust potential were determined. Later, a second set of cottons were brought to 30% moisture using water augmented with urea or ammonia to minimize microbial effects. The cottons were stored for 15 days at room temperature. Microbial population, cotton quality (strength and color), cotton stickiness, and cotton dust potential were determined. A long term storage test was conducted on wet cotton to check for production of dangerous levels of methane. The cotton quality and stickiness results, and the methane production results will be presented as well as evidence that aggressive processing tends to break up large sticky spots to more numerous smaller sticky spots.

Introduction

Cotton fiber contains natural fiber sugars and may also become contaminated with honeydew. When either or both natural sugars and honeydew levels are high, the cotton is referred to as being 'sticky'. Sticky cotton can be a serious production and quality problem which varies with location and year (Perkins, 1971), resulting in fibers sticking onto the rolls of processing equipment, producing knots, interrupted processing, reduced fiber quality resulting from microbial activity, etc. Many approaches have been taken to improve processability of sticky cotton such as blending, spraying with yeast, bacteria, surfactants, or enzymes, and increasing the moisture levels or otherwise enhancing the environmental conditions to activate natural microorganisms, washing the cotton, etc. (Balasubramanya, 1985; Heuer & Plaut, 1985; Hendrix et al., 1993; Perkins, 1993; Perkins et al. 1986). One promising approach initiated by Hendrix et al. (1993) is the application of enzymes as the cotton is being harvested and placed in cotton modules before ginning. Part of the success of enzyme application may be that microbial activation occurs from the application of the enzyme solution (Heuer & Plaut, 1983; Hendrix et al., 1993). Heuer and Plaut (1985) noted that when ammonium compounds at low moisture contents (7.2% to 12.2%) was applied to sticky cotton, stickiness was reduced without affecting quality. As part of the ongoing studies on microbial effects on cotton quality, this paper will report on the effect of high cotton moisture content during storage on stickiness reduction, cotton quality changes and microbial population, and on the effect of urea and ammonia on high moisture content cottons to minimize microbial effects (Chun & Lockwood, 1985; Chun et al., 1984).

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Methods and Materials

Sampling for Methane Production.

In 1994, using cotton on hand, eighty-five 1.0 gram lint samples were placed in air tight 40 ml glass sampling vials. Either 0, 0.25, 0.5, or 1.0 ml of de-ionized water was added to each vial. The vials were stored for 0 to 4 weeks at 27°C. At weekly intervals, 5 vials from each moisture level were removed from storage and the air space above the cotton was sampled with a Hewlett Packard 5710A Gas Chromatograph (FID; 6' x 1/8" column, 3% SE-52, 80/100 Chromosorb WH [MR58993, Supelco]) and a Hewlett Packard 3390A Integrator. The column used was unable to separate the various gases for identification. However, the location against a methane standard (methane standard curve: 0 to 500 ppm, made up fresh for each sampling period, $R^2 \geq 0.97$), gave presumptive identification and quantification. Even though the peak area of the presumed methane peak may be composed of other unidentified gases as well as methane, all the gases in the peak area were assumed to be methane to present a worst case possibility.

Cotton

Cotton used throughout the stickiness-moisture study was Arizona Pima cotton from the 1995 harvest year. The cotton was provided as unginned cotton by Dr. Don L. Hendrix (Western Cotton Research Laboratory, USDA, ARS, PWA, 4135 E. Broadway Rd, Phoenix, Arizona 85040). Shortly after arrival, the cotton was ginned with a 7 blade (6 in. dia.) saw gin. The ginned cotton was then homogenized. The first homogenization step involved passing the cotton through a blender (Syncromatic Blending System, Fibers Control Corporation, P.O. Box 1358, Gastonia, NC) three times. At the third and final passage through the blender, the entire cotton lot was passed through a pin beater (Model No. HV10024, Fibers Control Corporation) and underwent a final blending and collection on the apron of a Trützschler Axi-flo (type No, 052-25-02, Trützschler Gmbll and Co., KG, Textilmachinenfabrik, Mönchengladbach 3, Fed. Rep. Germany). The homogenized cotton was then stored in the original 55 gallon shipping barrel until used.

Viable Microbial Counts

Viable total and Gram-negative bacterial populations were determined for each samples as described in Chun & Perkins, Jr., 1991. The plates were incubated for 3 days at 28°±0.5°C before being counted. Fungal population determinations were made using potato dextrose agar with chloramphenicol and rose bengal (250 mg/L and 100 mg/L, respectively [Chun and McDonald, 1987]) and incubating at room temperature (20°±2°C) for a week. The microbial data will be reported elsewhere (Chun, 1997).

Cotton Dust Potential, Stickiness and Quality Determinations

The cottons were tested for stickiness on a thermodetector as described by Brushwood and Perkins (1993) and the percent sugar was also determined. Quality measurements were made by the Testing Laboratory at the Cotton Quality Research Station. Strength was measured on a stelometer as average grams per tex and color as reflectance and yellowness on a colorimeter. Cotton dust was collected on a Microdust & Trash Monitor ([MTM], Zellweger Uster, Inc., Technologies, Knoxville, TN) as described by Chun and Perkins, Jr. (1992). The cotton dust results will be reported elsewhere (Chun, 1997).

Effect of Water Alone

Eighty 30-gm cotton samples were sprayed with sufficient water (plus 0.005% Tween-80) to make up 20 samples each of ambient (~7.0%), 15%, 30%, and 40% moisture content. Each sample was stored in pleated Ziplock Gripper Zipper sandwich bags (6 1/2 x 5 7/8" [16.51 cm x 14.92 cm] DowBrands L. P., P.O. Box 68511, Indianapolis, IN 46268I-0811). Treatment assignments were applied randomly to the cotton samples. The samples were placed in a 10°±2°C incubator and stored for 0, 5, 11 and 15 days. At each sampling period, 20 samples were removed for microbial population, moisture content, stickiness, quality and dust potential determinations. For the 30% and 40% moisture content samples, lint was removed for microbial population determinations and the remainder of the sample was quick dried in an oven (105°±2°C) to approximately ambient moisture content before stickiness, quality and dust potential determinations were made.

Effect of Ammonia and Urea on Stickiness

Forty eight 30-gm cotton samples were sprayed with freshly prepared ammonia solution or urea solutions to a moisture content of 30%. A water and waterless control were used, 0.005% Tween 80 surfactant was used throughout. Treatment assignments were applied randomly to the cotton samples. A zero time and 15 day storage at room temperature (22°±2°C) reading were taken of microbial population, moisture content, stickiness, quality and dust potential as described above.

Results & Discussion

Methane Production in Stored Wet Cotton

Since this study involved storage of wet cotton, the possibility of dangerous levels of methane was considered since the United Nations and its International Maritime Organization subcommittee has classified baled cotton as "hazardous" as far as overseas shipping is concerned, even though no claims in over 35 years remotely suggest that baled cotton, wet or dry, spontaneously combusts, in or out of containers, warehouses, mills or laboratories (Rekerdres, 1993). For this reason, a small study done in 1994 is presented here to allay this fear. As shown in Table 1, over a four week storage period, cotton wetted from ambient to approximately 50% moisture did not generate more than 50 ppm methane. In one sample, two weeks storage and approximately 50% moisture content, 110 ppm methane was generated. Even this single anomalous sample was distinctly below the approximately 5% to 15% limit of explosiveness for methane (Anonymous, 1992; Winholz et al., 1983). The conditions under which cotton is normally shipped or stored would not be so wet, anaerobic, and the cotton would not be in such deteriorated condition as to expect spontaneous combustion (Brock, 1979; Gregory et al., 1963).

Actual Moisture Content of Water Treated Cottons

The actual percent moisture was very close to the calculated percent moisture. Overall, the ambient moisture, 15% moisture, 30% moisture, and 40% moisture content throughout the study averaged 7.2% (2 s.e. = 0.2011), 14.1% (2 s.e. = 0.5364), 30.1% (2 s.e. = 2.4572), and 38.1% (2 s.e. = 1.7966), respectively. The individual changes over storage time is shown in Figure 1. The greatest variation was observed immediately after moisture was applied which is expected; but as a whole, very close agreement between calculated moisture and actual moisture was obtained.

Quality Measurements over storage time

The microbial population tended to increase over time despite the cool conditions of storage which prevents excluding microbial effects on cotton properties as had been attempted (Figure 2). Very likely this may have contributed to changes in cotton quality. Reflectance values remained unchanged for the ambient and 15% moisture cotton throughout the 15 days of storage at 10°C storage (Figure 3). However, 30% and 40% moisture cotton showed significant decreases in reflectance after only 5 days storage and this drop in reflectance becomes very noticeable after 11 and 15 days. The extent of microbial effect is puzzling since a tendency for reflectance to decrease is observed with 40% moisture cotton at the 0 day storage which should preclude microbial activity. Possibly this initial decrease of cotton reflectance is purely a physical effect of high moisture 'dulling' the reflectance of lint. This same trend was observed with development of yellowness (Figure 4). Ambient and 15% moisture cotton remain unchanged through storage, but the 30% and 40% moisture cotton increases significantly in yellow after only 5 days in storage. Again, a tendency for yellowness to increase at the 0 days storage with the 40% moisture cottons suggest a physical effect of water. A tendency was observed with both reflectance and yellowness to decrease and increase, respectively, with increase of cotton moisture in the 0 days storage which suggests that initially water has a physical effect by itself independent of microbial effects. However, the changes over time probably reflect microbial effects. Strength measurements showed significant reduction after 11 and 15 days storage with 40% moisture cotton and significant reduction of the 30% moisture cotton after 15 days (Figure 5). The ambient and 15% moisture cottons retained their strength through the 15 days storage.

Stickiness

Increasing moisture content has noticeable effects on sugar content and stickiness. Addition of water by itself doesn't significantly alter the percent sugar except at the 40% moisture level (Figure 6) where the sugar content is reduced. Very likely, the high moisture content was sufficient to 'activate' microbial activity to cause utilization of sugars between the time moisture was applied and the lint was dried to ambient moisture and sugar content measured. Over storage time, all levels beyond ambient moisture show reduced sugar on the lint with storage. While the sugar content with 15% moisture was already significantly lower than the ambient moisture cottons after only 5 days, it tended to be significantly higher than the 30% and 40% moisture levels. Stickiness essentially follows sugar content (Figure 7). All levels of moisture beyond ambient moisture content showed significantly reduced stickiness with storage. After as little as 5 days storage, even the 15% moisture content cottons shows greatly reduced sticky spots. The 15% and 40% moisture content cottons had significantly lower thermodetector spots than the ambient control with 0 days storage. Possibly the moisture softened localized sugar spots or again, microbial activity may have reduced sugars enough to result in reduced number of thermodetector spots which becomes more pronounced as storage time increases.

We have been asked about the effect of processing on stickiness. To answer this, thermodetector stickiness was determined for the same cotton samples after the cottons had been processed through the MTM (Figure 8). The MTM aggressively processes cotton with pin and perforated rollers to separate fibers from large and small trash material (Sasser et al., 1986; Shofner et a., 1983). Comparison of Figure 7 and 8 show no significant differences. However, the ambient moisture cottons after MTM processing tended to have more slightly more thermodetector spots. Practically, this difference is too small to lead to practical use but does lend support to the idea that processing tends to break up large areas of localized stickiness into more smaller areas of localized stickiness.

Actual Moisture Content of Water plus Urea or Ammonia Treated Cottons

The actual percent moisture of the cottons made up to 30% moisture content and over 15 days storage at room temperature (22°±2°C) was between 22% and 24% (Figure 9). The difference between the two calculated 30% moisture contents (Figure 1 and Figure 9) was probably due to the higher temperature of storage.

Quality Measurements: Water plus Urea or Ammonia Treated Cottons

The general microbial trend follows that of the total bacterial population (Figure 10). Only the 10% ammonia treated cottons show bacterial levels lower than the 30% water content cottons and even this reduced population level is higher than found on untreated cotton. Reflectance was lower for all 30% water content cottons (Figure 11) compared to the ambient control cottons. The 10% ammonia treated cottons showed the next highest reflectance. Yellowness was increased for all 30% water content cottons (Figure 12) compared to the ambient control cottons. Cotton strength is reduced with water treatment (Figure 13). However, the 1% urea and 10% ammonia treated cottons are only slightly lower than the untreated controls.

Stickiness

As before the 30% water content cottons showed reduced percent sugar and reduced number of thermodetector spots (Figures 14 & 15). Compared to the untreated controls, the least reduction of sugar and thermodetector spots were found in the 10% ammonia treatments and the 5% and 10% ammonia treatments, respectively.

The question on the effect of processing on stickiness was more pronounced. Thermodetector stickiness was determined for the same cotton samples after the cottons had been processed through the MTM (Figure 16). Comparison of Figure 15 and 16 show no significant differences. However, the control cottons after MTM processing tended to have slightly more thermodetector spots. Even with the urea and ammonia treated cottons, after MTM processing there is a trend for more spots. Practically, these differences were too small to lead to practical use but is consistent to the earlier study which supports the idea that processing tends to break up large areas of localized stickiness into more smaller areas of localized stickiness.

Summary

A long-term storage test that was conducted on wet cotton to check on methanogenesis indicated little or no danger of spontaneous combustion under moisture conditions that cotton is normally shipped or stored. Microbial population increases occurred over time with high moisture content cottons (30% and 40%) increasing at greater rates than with low moisture content cottons (ambient [~7%] and 15%). While stickiness was significantly reduced with high moisture content cottons, reflectance and strength decreased over time with the high moisture content cottons. Yellowness increased with the high moisture content cottons. However, cottons stored under a cool temperature and with a moisture content of 15% not only had less stickiness, but suffered no significant deterioration of quality of the cottons. Treatment of cottons with urea and ammonia did not appear to offset the quality deterioration of the cottons by the 30% high moisture content cottons when stored for 15 days at room temperature. Treatment with the 30% moisture content significantly reduced percent sugar and thermodetector spots of all treatments. Heavy processing of sticky cottons tends to increase the number of thermodetector spots.

Acknowledgment

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Disclaimer

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Table 1. Methane Gas Generated From Stored Wet Cotton.

	Weeks in Storage Methane Detected in ppm				
Water[1] (ml)	0[2]	1	2	3	4
0.0	0.0	42.0	12.8	0.0	0.0
	(0.0)	(0.0)	(13.4)	(0.0)	(0.0)
0.25	0.0	42.0	2.5	18.4	9.6
	(0.0)	(0.0)	(3.1)	(13.6)	(6.3)
0.5	0.0	45.9	0.0	5.2	21.2
	(0.0)	(6.6)	(0.0)	(6.8)	(17.1)
1.0	0.0	44.1	39.7[3]	2.0	24.3
	(0.0)	(2.4)	(40.4)	(2.6)	(28.0)

[1]Deionized water (ml) added to 1.0 gram blended cotton prior to storage (Initial moisture content, 6.7%).
[2]Average of 5 samples. Values in Parenthesis represent 2 s.e.
[3]One of the five sample had an unusually high value of 110 ppm methane.

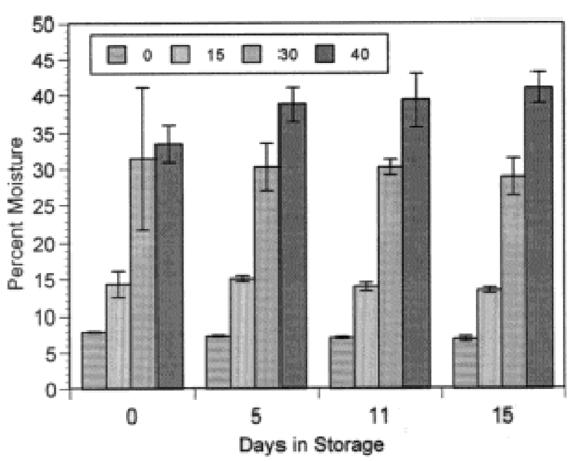

Figure 1. Actual moisture content and variation vs. Calculated moisture of moisture of lint over 15 days storage (each half bar represents 2 s.e.).

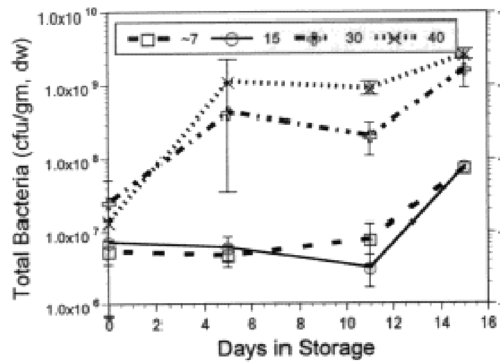

Figure 2. Total viable bacterial population during storage at 10°±2°C of cotton at different moisture levels (each half bar represents 2 s.e.; no error bars shown if 2 s.e. > than mean).

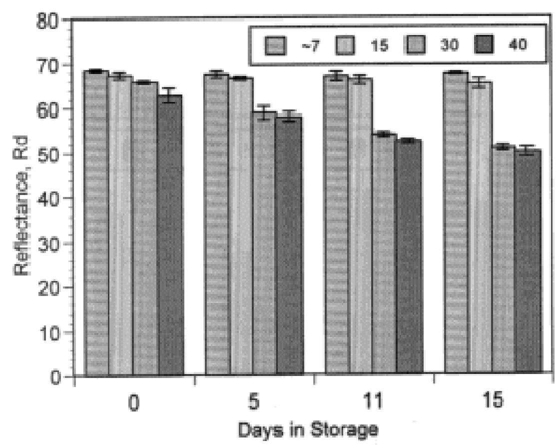

Figure 3. Reflectance of lint over 15 days storage at different moisture levels (each half bar represents 2 s.e.).

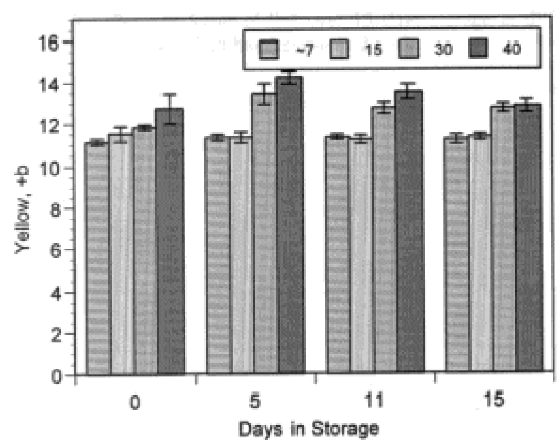

Figure 4. Yellowness of lint over 15 days storage at different moisture levels (each half bar represents 2 s.e.).

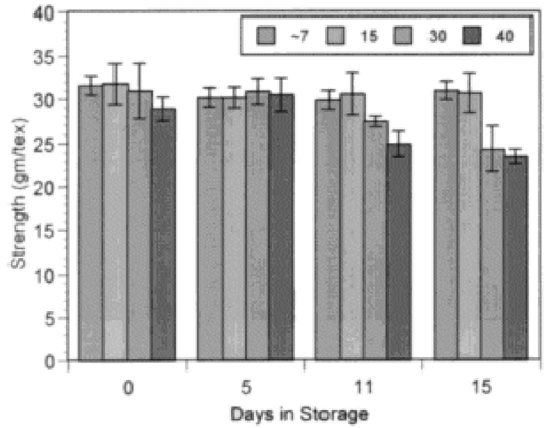

Figure 5. Strength of lint over 15 days storage at different moisture levels (each half bar represents 2 s.e.).

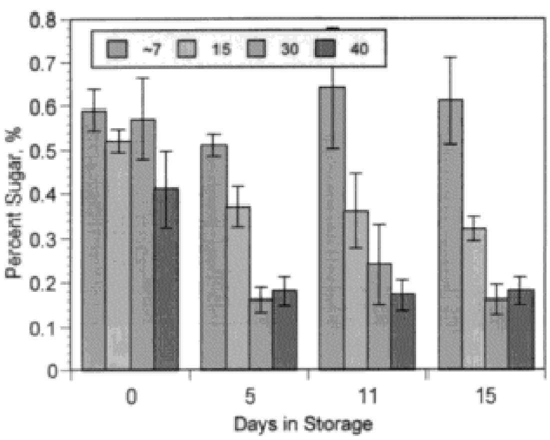

Figure 6. Percent Sugar of lint over 15 days storage at different moisture levels (each half bar represents 2 s.e.).

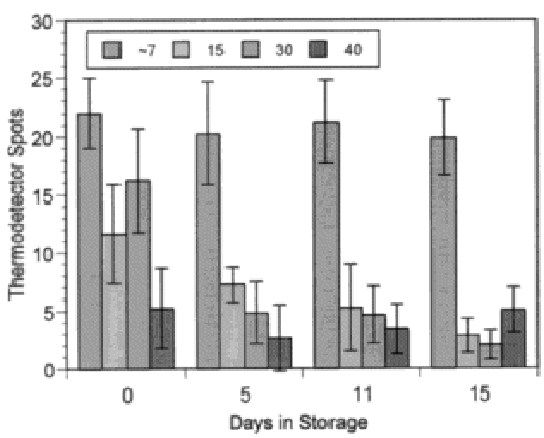

Figure 7. Stickiness, thermodetector spots, of lint over 15 days storage at different moisture levels (each half bar represents 2 s.e.).

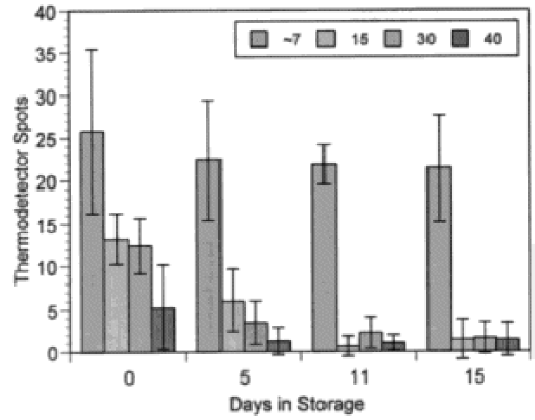

Figure 8. Stickiness, thermodetector spots, of lint over 15 days storage at different moisture levels. Thermodetector spots determined on cotton which had been processed by the MTM (each half bar represents 2 s.e.).

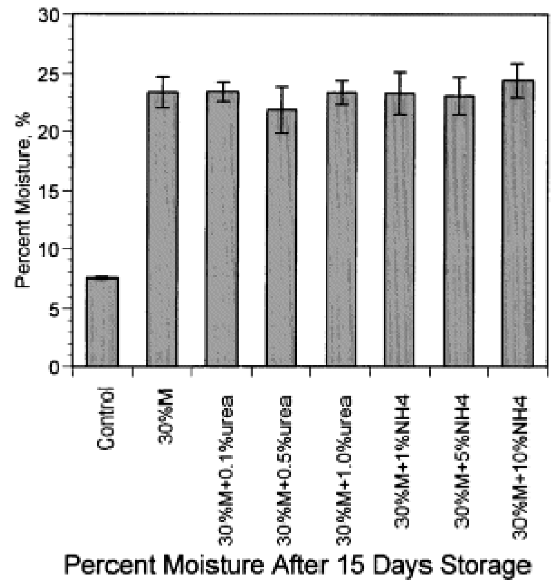

Figure 9. Actual Moisture content vs. 30% calculated moisture content for urea and ammonia treatments after 15 days storage at room temperature, 22°±2°C (each half bar represents 2 s.e.).

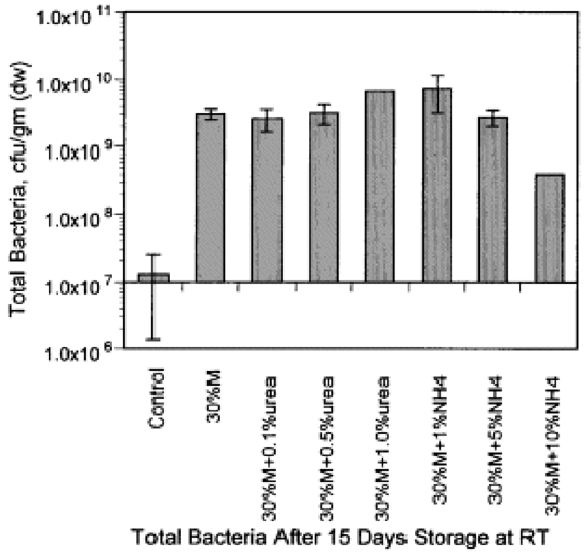

Figure 10. Total viable bacterial population after storage at room temperature (22°±2°C) on cotton at different urea and ammonia treatment levels (each half bar represents 2 s.e.; no error bars shown if 2 s.e. > than mean).

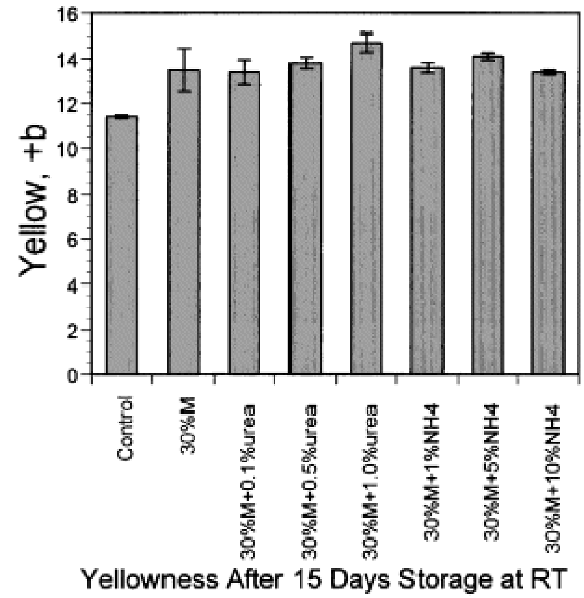

Figure 12. Yellowness after storage at room temperature (22°±2°C on cotton at different urea and ammonia treatment levels (each half bar represents 2 s.e.).

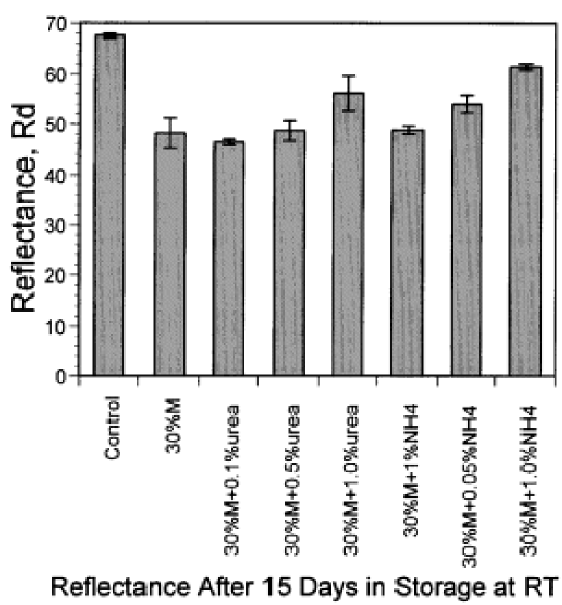

Figure 11. Reflectance after storage at room temperature (22°±2°C) on cotton at different urea and ammonia treatment levels (each half bar represents 2 s.e.).

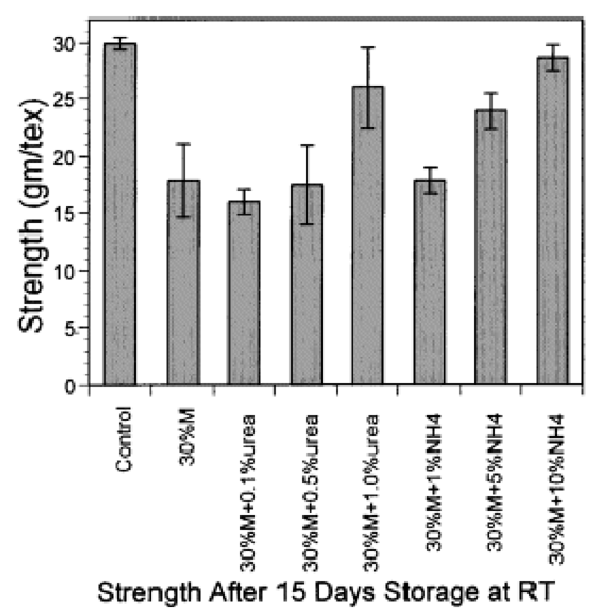

Figure 13. Strength after storage at room temperature (22°±2°C) on cotton at different urea and ammonia treatment levels (each half bar represents 2 s.e.).

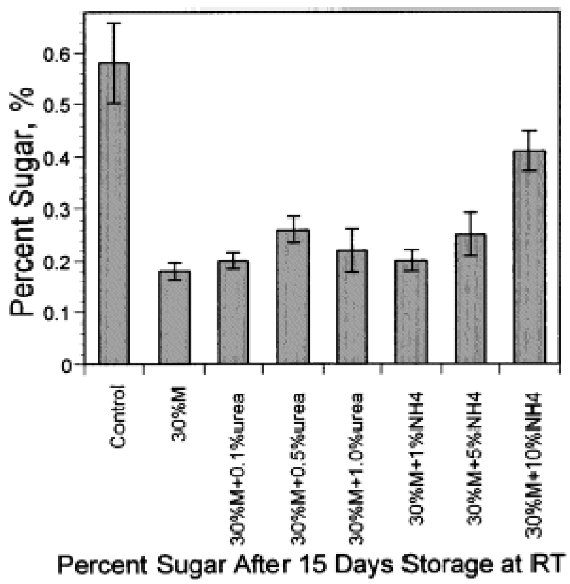

Figure 14. Percent Sugar after storage at room temperature (22°±2°C) on cotton at differnet urea and ammonia treatment levels (each half bar represents 2 s.e.).

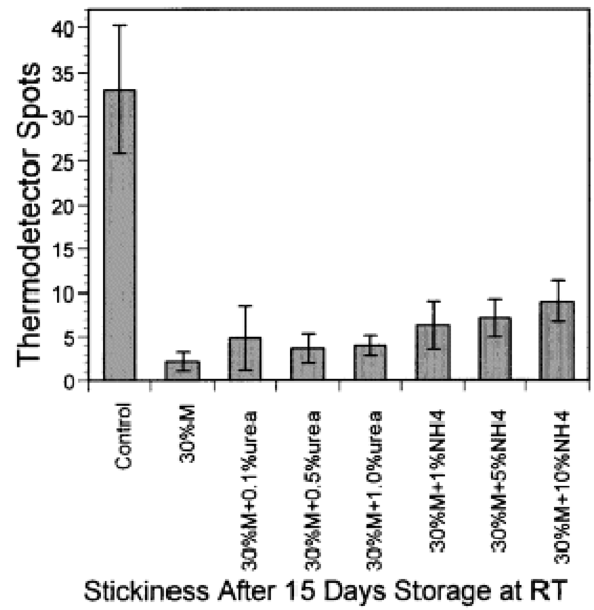

Figure 16. Stickiness, thermodetector spots after storage at room temperature (22°±2°C) on cotton at different urea and ammonia treatment levels (each half bar represents 2 s.e.). Thermodetector spots determined on cotton which had been processed by the MTM (each half bar represents 2 s.e.).

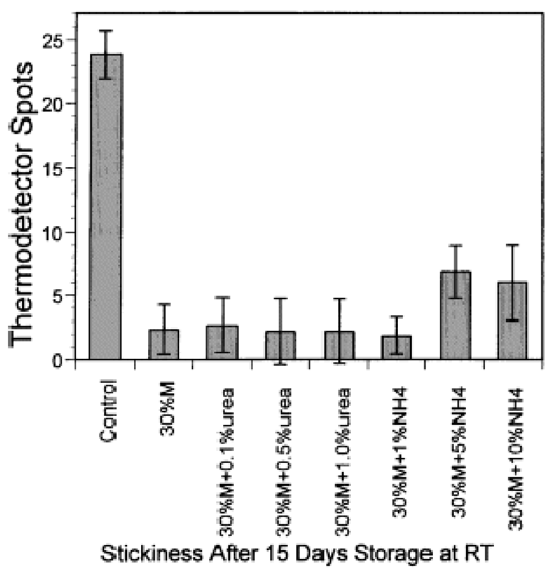

Figure 15. Stickiness, thermodetector spots, after storage at room temperature (22°±2°) on cotton at different urea and ammonia treatment levels (each half bar represents 2 s.e.).