MODERATE MOISTURE STORAGE EFFECTS ON STRENGTH, COLOR, STICKINESS, AND CARBOHYDRATE CONTENT OF RAW COTTON

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Abstract

Honeydew contaminated cottons were specially treated to reduce sticki-ness. Sticky cottons were stored at moisture levels of 10 and 14.5 percent for 1, 5, 10, and 20 days at room temperature. Reducing sugars, thermodetector stickiness, and individual sugar contents, as determined by High Performance Liquid Chromatography (HPLC) were conducted to determine effectiveness of these treatments. Fiber quality measurements in the form of fiber strength and colorimeter reflectance and yellowness were also determined for each treatment. Minor reductions in stickiness were achieved at 14.5% moisture levels and longer storage times. However, fiber strength, yellowness, and reflectance was adversely affected. The 10 percent treatment up to 20 days had no effect on cotton stickiness, strength or color.

Introduction

Under normal growing conditions physiological sugars are found on the surface of raw cottons. Levels of these sugars depend upon such variables as area of growth, variety, and weathering history. Plant sugars (except where there is extreme microbial damage) consist primarily of the mono-saccharides glucose and fructose, a disaccharide sucrose, and a variety of smaller amounts of other di- and monosacchrides. In textile processing, when plant sugar levels approach or exceed certain limits (concentrations greater than 0.40% based on the lint weight) the possibility for sticky materials to build up on machinery increases. Long term sticky deposits accumulate, especially on card crush rolls, prompting frequent shut downs to clean up; hence, production efficiency suffers.

Another source of stickiness in cottons comes from insect contamination commonly known as "honeydew". Random droplets from aphids and whiteflies on the surfaces of cotton fibers, leaves, and other plant parts are extremely sticky. These excrements when collected and analyzed have been identified as a variety of carbohydrates, primarily complex sugars (#2, 5, 6, 10, 15, and 23).

The presence of honeydew on the surface of cotton in even small quantities along with the normal plant sugars can cause lint to be sticky in all stages of ginning and yarn manufacturing. Honeydew clings to rolls, saw blades, crush rolls, chutes, spinning machinery, and other equipment sometimes making processing virtually impossible.

Honeydew has been found to contain the sugars trehalulose (a glucose isomer) and melezitose (a trisaccharide) along with other high molecular weight oligosaccharides (2, 4, 5, 6, 7, and 11). These two sugars are unique to insect honeydew. Because of the uniqueness of these sugars, honeydew contaminated cottons can be differentiated from plant sugars by High Performance Liquid Chromatography (HPLC). Concentrations extracted from honeydew contaminated cotton lint vary depending upon the species of insect, the insect population, the species of plant upon which the insect is feeding, microbial activity, and weathering history (9,13). Sporadic occurrences worldwide for a number of years and the severity of contamination has prompted a number of approaches to either reduce or eliminate the potential stickiness associated with honeydew (4, 8, 12, 14, 17, 19, 21).

Studies to identify and quantitate natural and honeydew sugars found on cotton lint and their individual relationships to the minicard and thermodetector (TD) stickiness tests (3, 5, 6, 7, 8, 9) are designed to assist in the development of treatment protocols to reduce and control the processing of potentially sticky cotton.

Strategies at the mill to reduce stickiness on cotton contaminated with high plant and/or honeydew sugars usually encumber selective mixing of sticky and non-sticky cottons in laydowns to obtain a processible mix. Addition of enzymes to decompose the offending sugars, and using oversprays to enhance processing are other approaches taken (18, 21).

Treatment of sticky cotton with high moisture levels for extended times (as in a module) to decompose the offending sugars is one approach being investigated (1, 8, 12). However, these treatments may adversely affect certain fiber properties such as strength and color. Elevated moisture levels may initiate microbial damage (8, 12). This paper describes a study in which a honeydew contaminated raw cotton was treated at moderate moisture levels for different storage times at ambient temperatures to determine effects on stickiness. Thermodetector (TD) stickiness, reducing sugar content, and quantitative individual carbohydrate contents for each sample were determined. Physical property measurement of strength and colorimeter reflectance (Rd) and yellowness (+b) were determined to examine any adverse effects of these treatments on the cotton quality.

Materials and Methods

We selected a 1995 New Mexico upland cotton heavily contaminated with whitefly honeydew for our study. Preliminary screening HPLC tests determined

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 1:696-702 (1998)
National Cotton Council, Memphis TN

concentrations of the major honeydew sugar trehalulose to be in excess of 30% of the total sugars.

Thirty gram samples of the sticky cotton were treated at room temperature (20-24°C) at three controlled atmospheric conditions in desiccators. These atmospheres were created by conditioning over saturated water solutions of ammonium hyprophosphate ($NH_4\ H_4\ PO_4$) at 93% relative humidity and ammonium sulfate ($NH_4\ SO_4$) at 81% relative humidity and a control sample open to room atmosphere at 60 to 65% relative humidity. Preconditioning of test samples of this cotton for three days in the desiccators, yielded lint moisture contents of 14.5 and 10%, respectively. The untreated control cotton was determined to have a 6.9 ± 0.10% moisture content.

Samples were prepared by addition of the proper amount of water to bring moisture to desired levels. Water was sprayed as a fine mist onto the surface of the cotton on a top loading balance. When the desired moisture content was reached, samples were placed in the appropriate desiccator for conditioning. Pre-preparation eliminated the extra 24 hours or so necessary for the unwetted cotton and the desiccator to reach equilibrium conditions. Control (untreated) 30 gram samples were also collected for each treatment time period. Once removed from the desiccators, each sample was dried in a forced draft oven at 116°C (241°F) until the original untreated mass of 30 g ± 0.2 g was reached. The cottons were stored at standard conditions for at least two weeks and were then blended and tested.

Carbohydrate concentrations at each treatment level and storage time were determined using a Dionex series DX-300 system by a procedure described earlier (4). Calculations for specific carbohydrates concentrations were based on comparisons to authentic calibration standards tested periodically during analysis to correct for variations in column and detector sensitivity. Single chromatograms of each sample were averaged (five replications/ sample) for each treatment level and storage period.

Data from high performance liquid chromatography (HPLC) analysis to characterize and quantitate individual carbohydrates extracted from treated and untreated cottons were averaged and compared. Total reducing sugars (five replications/sample) including honeydew and plant sugars were determined for each cotton using the routine potassium ferricyanide reducing sugar test (16). Thermodetector (TD) stickiness tests (also five replications/sample) were determined as previously specified (3, 20) and classed according to the standard rating system shown in Table 1. Fiber strength was determined by Stelometer method. Reflectance (Rd) and yellowness (+b) were determined by the colorimeter. Five replications of each of these fiber quality measurements were made.

Data was analyzed by PC/SAS as a 2-factor factorial with five replications and the following model.

$$Y = M + D + M * D + e$$

where Y = Dependent Variable
M = Moisture Content
D = Days in Storage
M * D = the interaction of M and D, and
e = Experimental Error

Results and Discussion

Levels of specific carbohydrates and physical properties of samples from each water treatment are shown in Figures 1 through 16. Analysis of variance results are summarized in Table 2. The unheated control reducing sugar averages (5 replicates/sample) varied from a low of 1.3 to a high of 1.6%, indicating a high variability within the cotton. Perhaps additional blending of the sample would have decreased this variance. HPLC analysis determined that five sugars accounted for 85% of total aqueous extracts from the surface of the cotton. These were glucose - ranging from 1220 to 1570 mg/kg, fructose - 2080 to 2240 mg/kg, sucrose - 360 to 630 mg/kg, and the honeydew sugars trehalulose - 3320 to 3410 mg/kg and melezitose - 1570 to 1655 mg/kg. Trehalulose and melezitose combined averaged 47.0% of total sugars in the control samples.

Mean values for five other sugars components averaged 211 ± 34, 239 ± 21, 163 ± 5 mg/kg for arabitol, mannitol, and arabinose, respectively, and 305 ± 21, 151 ± 20 mg/kg for the di-saccharides trehalulose and turanose. The remainder of the other components determined by HPLC totaled about 464 ± 88 mg/kg.

Reducing sugar contents (Figure 1) did not change significantly when compared to controls. Thermodetector stickiness numbers (Figure 2) decreased significantly about 10% after 10 days of storage at the 14.5% water treatment level.

HPLC individual carbohydrate determination of the sugar fructose showed significant decreases in levels after five days of storage at 14.5% moisture (Figure 4). Duncan's multiple range tests for variability showed that glucose, sucrose, and trehalulose (Figures 3, 5, and 6) were not affected by these water treatments. Melezitose (Figure 7) was slightly affected by the 14.5% water treatment. Sugars of lesser concentrations (with the exception of turanose) were also slightly affected by the higher water treatment (Figures 8 through 12).

The carbohydrates arabitol, mannitol, and trehalose (Figure 8, 9, and 11) were of particular interest. Previous studies (8, 23) suggest that large increases in the concentrations of these components are very good indicators of microbial damage to cotton. There were significant slight decreases in overall concentrations for these three components at the 14.5% treatment after 20 days. Hence there were no apparent indications of microbial damage.

Stelometer strength measurements (Figure 14) were not affected by the 10% moisture treatments. A slight decrease of 1.3 g/tex (7%) at the 20-day storage time were observed for the 14.5% water treatment. Reflectance (Rd) values (Figure 15) for the higher water treatment decreased slightly after five days by 2% and remained at this level for the other storage times. Colorimeter yellowness (+b) values did not change for either moisture treatment time up to 10 days of storage (Figure 16). At 20 days, there was a slight significant increase in yellowness at a 14.5% water treatment (3%).

Summary

Moisture treatments of a whitefly honeydew contaminated cotton were conducted to determine the effects of several low to moderate water content treatments on the stickiness potential of cotton. Storage times for each treatment in humidity controlled desiccators were up to 20 days. Additional measurements made on these treated cottons were reducing sugar contents, individual carbohydrate contents, fiber Stelometer strengths, and color as measured by colorimeter. Control cotton (untreated) replicate samples over a 20-day treatment period varied from 17 to 25 sticky spots. Thermodetector stickiness decreased about 10% for samples stored for 10 and 20 days at the 14.5% water treatment. There was no significant change in reducing sugar content for any treated sample. The primary sugars fructose and melezitose decreased in concentration at longer treatment times at 14.5% moisture. Several lower concentration sugars were also affected by this treatment.

Stelometer fiber strengths were generally unaffected by the above treatments, except at the 14.5% treatment level. Slight decreases in strength occurred at storage times longer than ten days at this moisture. Colorimeter reflectance (Rd) values decreased about 2% after five days and yellowness (+b) increased slightly (3%) after 20 days at the higher water treatment level.

The results of these low to moderate levels of water treatment and storage times slightly reduced the stickiness of this honeydew cotton at the 14.5% moisture treatment. However, after five days of storage at this moisture, there were indications of the loss of fiber strength and deterioration of color quality.

Table 1. Thermodetector stickiness ratings

No. Of Sticky spots	Rating
0 - 4	Non-sticky
5 - 14	Slightly sticky
15 - 2	Moderately sticky
Above - 24	Heavily sticky

Table 2. Analysis of variance results for each dependent variable

Dependent variable	Source of variation	Mean square	F - value
Reducing sugar (%)	moisture	0.0540	2.42
	days	0.1091	4.90**
	interaction	0.1031	4.63**
	error	0.0222	
Thermodetector sticky spots	moisture	122.150	4.68*
	days	11.394	0.44
	interaction	71.261	2.73*
	error	26.117	
Glucose content (mg/kg)	moisture	136468.050	2.27
	days	29480.550	0.49
	interaction	189498.383	3.15*
	error	60059.400	
Fructose content (mg/kg)	moisture	693996.817	17.60**
	days	59711.222	1.51
	interaction	41501.506	1.05
	error	39439.167	
Sucrose content (mg/kg)	moisture	91708.817	1.09
	days	710.061	0.01
	interaction	89532.061	1.06
	error	84093.808	
Trehalulose content (mg/kg)	moisture	285696.067	2.44
	days	188720.728	1.61
	interaction	30821.044	0.26
	error	117012.075	
Melezitose content (mg/kg)	moisture	107176.817	3.42*
	days	249685.467	7.97**
	interaction	68318.683	2.18
	error	31312.142	
Arabitol content (mg/kg)	moisture	2746.867	7.27**
	days	3505.356	9.28**
	interaction	2219.356	5.87
	error	377.883	
Mannitol content (mg/kg)	moisture	4431.8002	4.55**
	days	1758.156	9.74**
	interaction	550.622	3.05*
	error	180.517	
Arabinose content (mg/kg)	moisture	1026.200	4.36*
	days	595.394	2.53
	interaction	244.378	1.04
	error	235.133	
Trehalose content (mg/kg)	moisture	22717.6173	4.35**
	days	2379.978	3.60*
	interaction	2025.328	3.06*
	error	661.367	
Turanose content (mg/kg)	moisture	3051.350	2.44
	days	2187.172	1.75
	interaction	1172.906	0.94
	error	1251.033	
Other sugar content (mg/kg)	moisture	64708.467	9.61**
	days	41848.222	6.21**
	interaction	49138.822	7.30**
	error	6734.142	
Strength (g/tex)	moisture	2.261	3.69*
	days	0.654	1.07
	interaction	1.282	2.09

Table 2. Continued

Dependent variable	Source of variation	Mean square	F - value
	error	0.613	
Reflectance (Rd)	moisture	10.9312	3.94**
	days	0.653	1.43
	interaction	1.412	3.09*
	error	0.457	
Yellowness (+b)	moisture	0.355	6.30**
	days	0.131	2.33
	interaction	0.119	2.1
	error	0.056	

* significant at the 0.05 probability level
**significant at the 0.01 probability level

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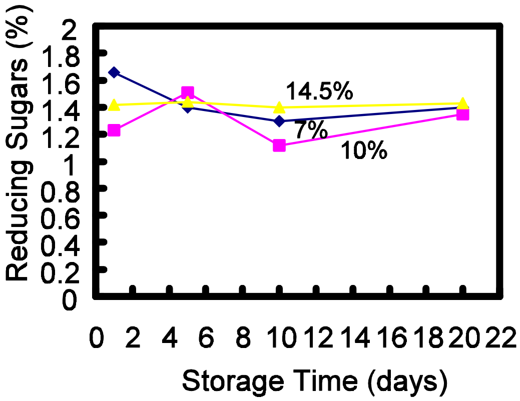

Figure 1. The effect of water treatment on the reducing sugar content of honeydew contaminated cotton.

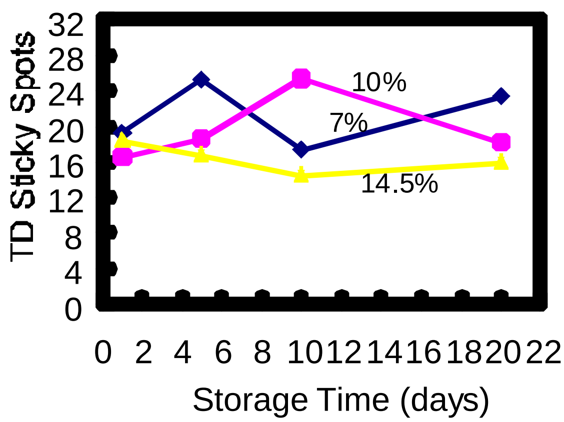

Figure 2. The effect of water treatment on the thermodetector stickiness of honeydew contaminated cotton.

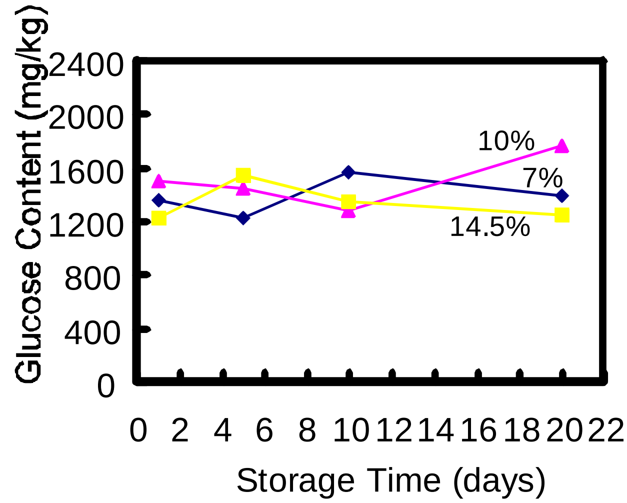

Figure 3. The effect of water treatment on the glucose content of honeydew contaminated cotton.

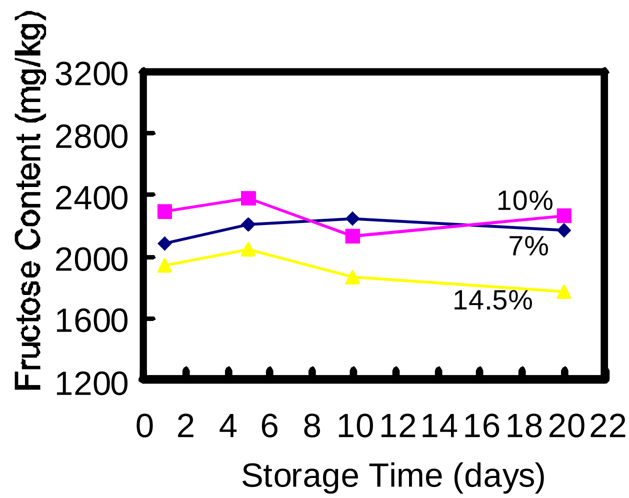

Figure 4. The effect of water treatment on the fructose content of honeydew contaminated cotton.

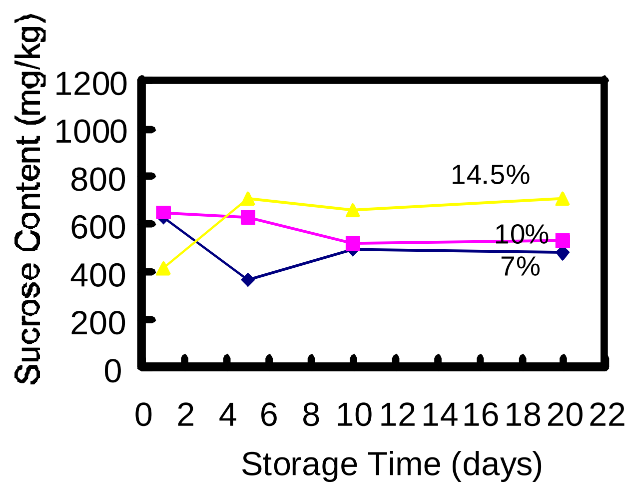

Figure 5. The effect of water treatment on the sucrose content of honeydew contaminated cotton.

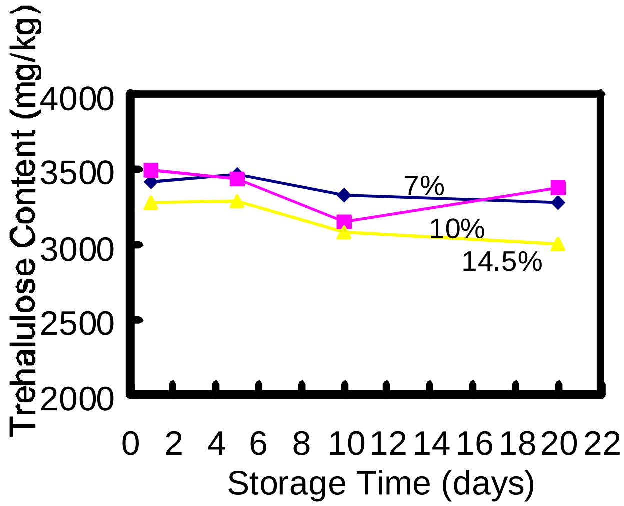

Figure 6. The effect of water treatment on the trehalulose content of honeydew contaminated cotton.

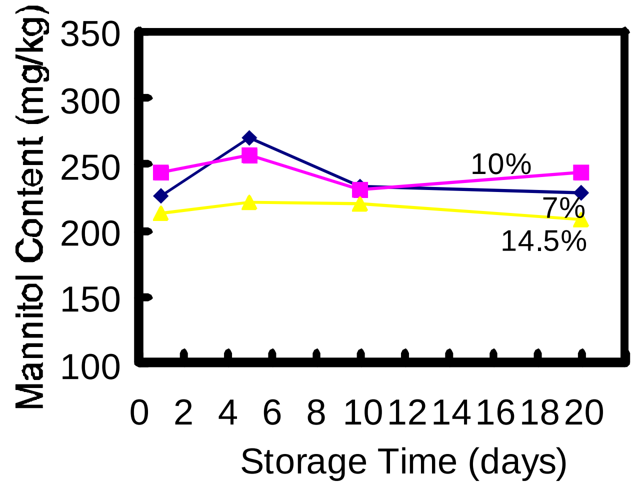

Figure 9. The effect of water treatment on the mannitol content of honeydew contaminated cotton.

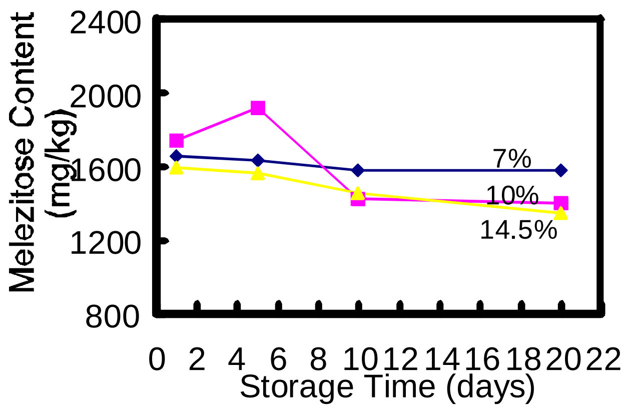

Figure 7. The effect of water treatment on the melezitose content of honeydew contaminated cotton.

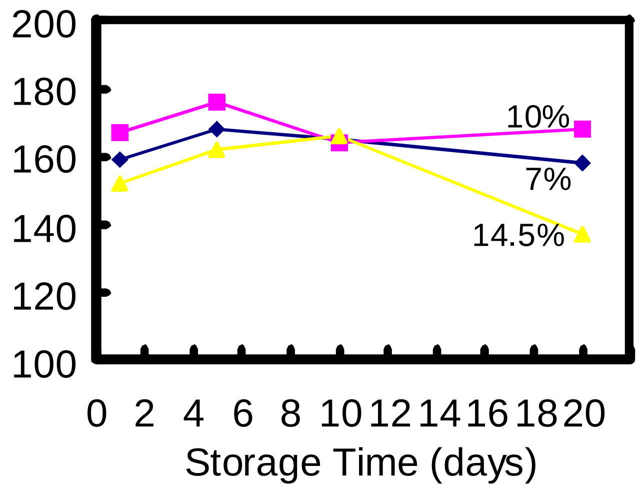

Figure 10. The effect of water treatment on the arabinose content of honeydew contaminated cotton.

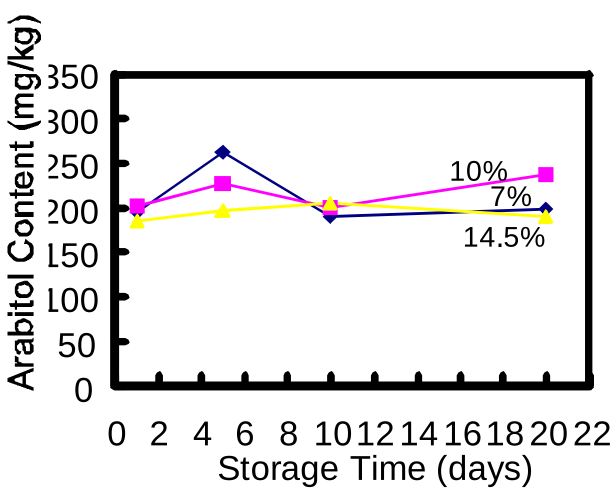

Figure 8. The effect of water treatment on the arabitol content of honeydew contaminated cotton.

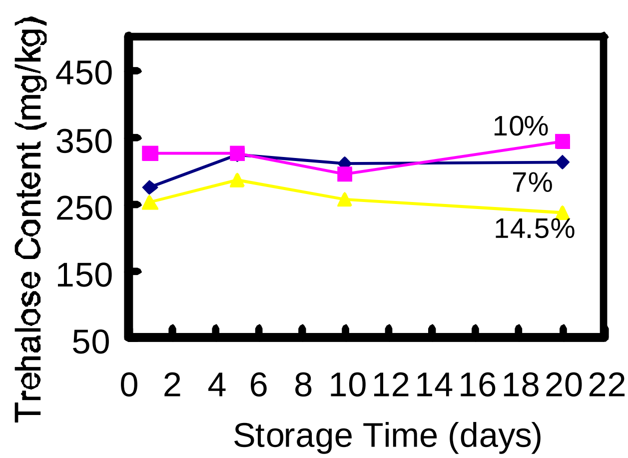

Figure 11. The effect of water treatment on the trehalose content of honeydew contaminated cotton.

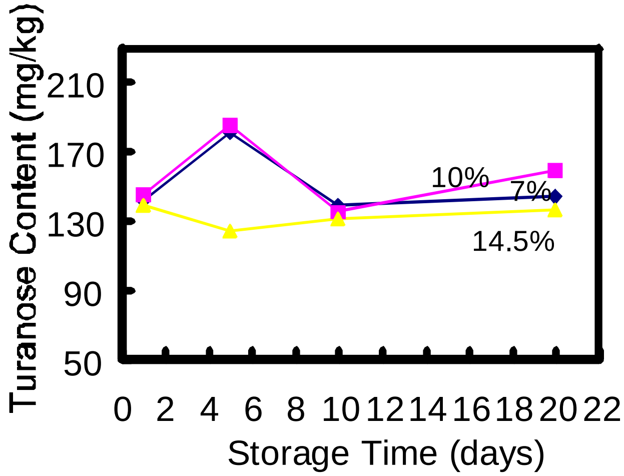

Figure 12. The effect of water treatment on the turanose content of honeydew contaminated cotton

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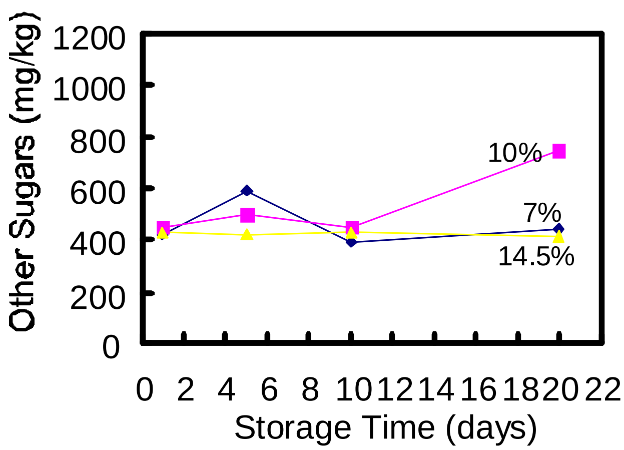

Figure 13. The effect of water treatment on the concentration of other sugars on honeydew contaminated cotton

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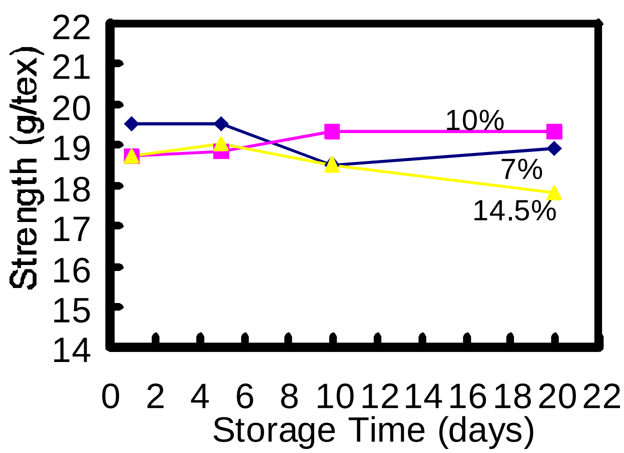

Figure 14. The effect of water treatment on Stelometer strength of honeydew contaminated cotton.

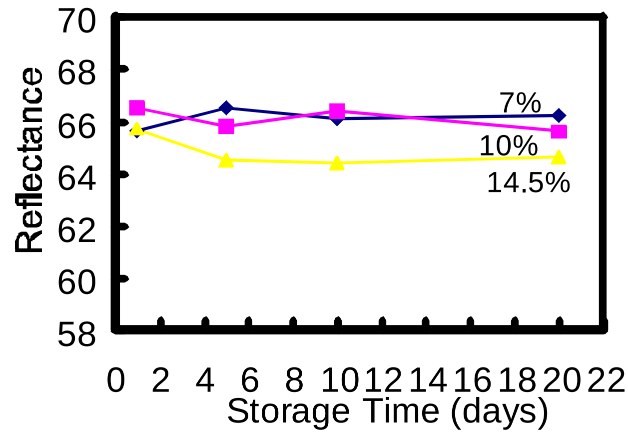

Figure 15. The effect of water treatment on the colorimeter reflectance of honeydew contaminated cotton.

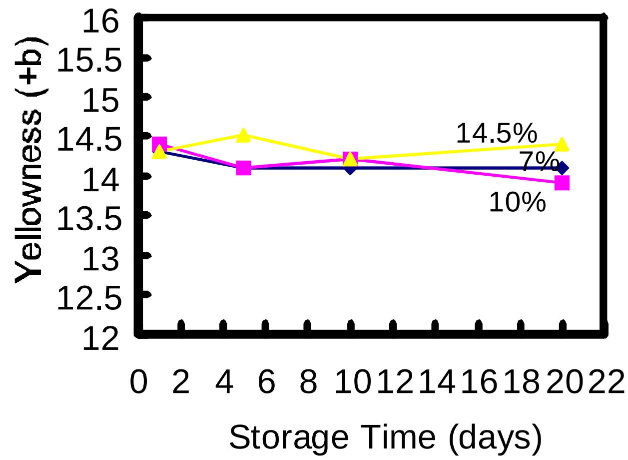

Figure 16. The effect of water treatment on yellowness of honeydew contaminated cotton.