AT-LINE COTTON COLOR MEASUREMENTS BY PORTABLE COLOR SPECTROPHOTOMETERS

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Abstract

As a result of reports of cotton bales that had significant color changes from their initial Uster® High Volume Instrument (HVI™) color measurements, a program was implemented to measure cotton fiber color (Rd, +b) at-line in remote locations (warehouse, mill, etc.). The measurement of cotton fiber Rd and +b using a small, hand-held color spectrophotometer was shown to be feasible, and the technology was incorporated into the Engineered Fiber Selection® system MILLNet™ software. The portable spectrophotometer measurements were rapid, precise, and accurate. Field trials were performed on over 400 bales that exhibited color changes, with very good agreement observed between the updated HVI™ and spectrophotometer color results for +b. The impact of sample preparation and presentation on the color results was investigated. Protocols and procedures for determining color instrument agreement between multiple color units were established.

Introduction

Cotton classification in the U.S. is performed with the Uster® High Volume Instrument (HVI™). Fiber color classification is determined by the HVI's Rd (surface diffuse reflectance) and +b (yellowness). The Agricultural Marketing Service (AMS) of the United States Department of Agriculture (USDA) provides two types of HVI™ color standards—a set of 5 ceramic tiles and a set of 12 cotton fiber biscuits. The Rd and +b color terms are cotton-specific and have been in use for several decades. (Nickerson, 1931; Nickerson et. al., 1950) However, they do not relate directly to the main globally recognized 3-dimensional color systems, such as 3-dimensional tristimulus color (XYZ), such as L*a*b* or CIELAB. The fiber's lightness or darkness is given by L*, redness or greenness by a*, and yellowness or blueness by b*. (Berns, 2000) The 3-dimensional color systems often are measured by spectrophotometers, which can measure the sample's reflectance over the entire visible spectral region (normally 400nm-700nm). The strong and linear correlations between L*↔Rd and b*↔+b were established in previous evaluations. (Rodgers, et. al., 2008; Rodgers, et. al., 2009)

Cotton is a global crop, and most of the U.S. produced cotton is exported. It has been recently reported that some bales exported outside the U.S. appeared to have changed color dramatically, primarily yellowing (increase in +b). An on-site, at-line color measurement of "+b" was developed using a portable color spectrophotometer. (Rodgers, et. al., 2012) Excellent linear agreement was obtained between HVI™ +b and the portable HunterLab MiniScan EZ spectrophotometer (MSEZ) b*, with R^2s > 0.97 and over 90% of the samples agreeing within ±0.5 +b – b* color units. The MSEZ color measurements were rapid, accurate, and precise, and all end-state criteria were achieved.

The at-line color measurement program was expanded to include Rd measurements, to establish the interface capabilities of the portable color spectrophotometer to other systems, to determine surface impacts, and to determine inter-instrument agreement between multiple portable color spectrophotometers.

Material and Methods

The samples used in this evaluation consisted of AMS standard tiles (n=10 total) and cotton biscuits (n=36 total), 45 routine cotton samples, and over 400 cottons measured at a foreign textile mill. Five (5) replicates per sample were performed on the USDA-Agricultural Research Service (ARS)-Southern Regional Research Center (SRRC) HVI-1000 and multiple HunterLab MiniScan EZ (MSEZ; 5 total) portable spectrophotometers fitted with a 30 mm glass-covered nose cone/sampling port (Figure 1). With the exception of the foreign mill measured samples, all fiber measurements were made under standard conditions of $21\pm1^{O}C$ and 65±2% relative humidity (RH) at SRRC.

Manufacturer operational procedures were followed. The MSEZ Rd and + b values were computed from bias-adjusted MSEZ b* values (illuminant D65/10^{O} observer) and Y values (illuminant C/2^{O} observer).

Surface impact measurements were performed with 37 routine cotton samples (AMS) under 3 surface preparation conditions—as is (placed directly in the sample box; no sample preparation), smoothed (placed in the sample box; hand smoothed sample preparation, and blended (fibers aligned in a fiber blender; blended fiber placed into the sample box).

Parameters evaluated included R^2, percentage of outliers (percentage of samples outside specified > ±0.5 +b-b* color agreement between the HVI™ +b/MSEZ b* and outside > ±1.0 Rd-Y color agreement between the HVI™ Rd/MSEZ Y color terms), and average within standard deviation (SDw; surface impacts). Preliminary end-state criteria for the cotton samples were R^2s > 0.90 and the number of samples agreeing within outlier color limits being ≥ 70%.

Figure 1. HunterLab MiniScan EZ (MSEZ) portable spectrophotometer and glass-covered 30 mm sampling port

Results and Discussion

Comparisons were performed between HVI™ Rd and MSEZ color parameters on AMS and routine cotton samples. The best method agreement was observed between the HVI™ Rd and MSEZ Y (illuminant C/2^{O} observer) color terms. All end-state criteria were achieved. For AMS standard cottons and routine cottons, R^2 was ≥0.90. The number of outliers was 2% for the AMS cottons and 25% for routine cottons. The difference in the number of outliers between the AMS and routine cottons was due to surface effect (sample preparation). The AMS cottons were very uniform and consistent, while the routine cottons were measured "as is."

The MSEZ "Rd" and "+b" methods were interfaced with the Cotton Incorporated MILLNet™ component of the Engineered Fiber Selection® (EFS®) system. The combined system was field-tested at a non-U.S. textile mill on over 400 suspect aged samples. A large shift in +b was successfully detected.

The impact of surface appearance and sample preparation on the MSEZ +b and Rd results was investigated. Three distinct sample preparation/surface appearance conditions were examined—as is, smoothed, and blended. The results are given in Table I. As expected, only minor differences were observed between the 3 sample preparation/surface appearance methods for average +b. Minimal differences were observed between the as is and smoothed method for the average within standard deviation (SDw), but the blended method did yield a much lower SDw for +b. Small differences in average Rd were observed for the 3 preparation methods. For SDw, improvements were observed with improved sample preparation and more uniform surfaces. Larger changes in average Rd and SDw were observed for the blended samples, indicating that improved surface appearance improved Rd measurement variability.

Table I. Impact of surface appearance/sample preparation on MSEZ color results

PARAMETER	SURFACE APPEARANCE		
	"AS IS"	SMOOTHED	BLENDED
+b			
AVG	11.5	11.4	11.7
SDw	0.2	0.2	0.1
Rd			
AVG	69.8	70.4	72.1
SDw	0.7	0.6	0.4

Several MSEZ color units have been obtained for these measurements. The color instrument agreement between multiple MSEZ units (n=5) was investigated. The 5 units evaluated were a Loaner unit, the SRRC unit, and 3 cotton Incorporated units (CI-1,2,3). Protocols and procedures for determining color agreement were established, using AMS standard cotton biscuits (n=36). CI-1 served as the reference MSEZ unit. Excellent color agreement for Rd and +b were observed between the 5 MSEZ units, with R^2s ≥0.98 for each unit. The +b agreement between the units was excellent, with over 90% of the samples agreeing within ±0.5 +b color units. The Rd agreement between the units was also excellent, with over 80% of the samples agreeing within ±1.0 Rd color units. All end-state criteria were achieved.

Summary

The at-line color measurement program was expanded to include Rd measurements, to establish the interface capabilities of the portable color spectrophotometer to other systems, to determine surface impacts, and to determine inter-instrument agreement between multiple portable color spectrophotometers. The accurate measurement of cotton fiber Rd using a small, hand-held color spectrophotometer was demonstrated, and, in addition to +b, the technology was incorporated into the Engineered Fiber Selection® system MILLNet™ software. Distinct color changes in +b were observed on over 400 bales in field trials outside of the U.S. Surface appearance/sample preparation impacts on the Rd and +b color results were investigated, with primarily Rd being impacted. Overall, measurement variability decreased with increasing surface uniformity. Protocols and procedures for determining color instrument agreement between multiple color units were established. Excellent Rd and +b color agreement between multiple MSEZ color units (n=5) were obtained.

Acknowledgements

The authors wish to gratefully acknowledge the support of Mr. James Knowlton of the Agricultural Marketing Service (AMS) in Memphis, TN. We also wish to acknowledge Ms. Jeanine Moraitis for her outstanding work in running all samples.

Disclaimer

The use of a company or product name is solely for the purpose of providing specific information and does not imply approval or recommendation by the United States Department of Agriculture to the exclusion of others.

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