PRELIMINARY ASSESSMENTS OF PORTABLE COLOR SPECTROPHOTOMETER MEASUREMENTS OF COTTON COLOR

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Abstract

Cotton in the U.S. is classified for color with the Uster® High Volume Instrument (HVI), using the parameters Rd (diffuse reflectance) and +b (yellowness). It has been reported that some cotton bales, especially those transported overseas, appear to have changed significantly in color from their initial HVI color measurements, especially for yellowness. Interest has been expressed in "on-site"/remote location measurements of cotton color that will yield "real time" color values, with emphasis on yellowness. A program was implemented to determine the feasibility of using portable color spectrophotometers to measure cotton color in remote locations. Using AMS standard tiles and cotton samples, comparative evaluations were performed to establish the relationships between the HVI +b and portable spectrophotometer L*a*b* color parameters. Preliminary results were very encouraging. For HVI +b and portable spectrophotometer b*, excellent linear agreement (high R^2s), low spectrophotometer standard deviations, and a low number of outliers were observed. The portable spectrophotometer measurements were rapid, precise, and accurate.

Introduction

U.S. produced cotton is classified for quality with the Uster® High Volume Instrument (HVI). An important cotton fiber property for classification is fiber color, which is represented by the cotton-specific color parameters Rd and +b. Rd is the measurement of the sample's overall diffuse reflectance, and +b is the measurement of the sample's yellowness. The HVI uses a colorimeter, which has two filters to determine the sample's Rd and +b and which covers only 2 specific regions of the visible spectrum. Two types of HVI color standards are provided by the Agricultural Marketing Service (AMS) of the United States Department of Agriculture (USDA)—a set of 5 ceramic tiles and a set of 12 cotton fiber biscuits (Figure 1).

Figure 1. AMS color standards, ceramic tiles (left) and cotton fiber biscuits (right).

The major and globally recognized color systems are based on 3-dimensional tristimulus color (XYZ), such as L*a*b* or CIELAB. In L*a*b*, L* denotes the lightness or darkness of the sample, a* denotes the greenness or redness of the sample, and b* denotes the blueness or yellowness of the sample. (Billmeyer and Saltzman, 2000). Spectrophotometers are often used to measure samples for 3-dimensional color, since they cover the entire visible spectral region (typically 400 nm-700 nm, at a minimum). Although the ceramic tiles can be placed directly against a spectrophotometer's sampling port, the use of clear glass is normally required for fiber color measurements. The glass is placed against the sample port, and the cotton fiber is placed against the glass, which results in the presentation of a smooth fiber surface and prevents contamination of the spectrophotometer.

Previous HVI-spectrophotometer evaluations on AMS standards, using multiple bench-top and portable spectrophotometers, established and verified strong and linear correlations between L*↔Rd and b*↔+b. (Thibodeaux, et. al., 2008; Rodgers, et. al., 2008a; Rodgers, et. al., 2009) Excellent HVI-spectrophotometer color agreement was often observed when glass was not used in the spectrophotometer color measurements, but color agreement deviations were often significant when glass was used in the spectrophotometer color measurement, especially for L*. Further evaluations established that the glass impact could be significantly reduced to minimal impact with the use of specific instrumental conditions, glass correction factors, and/or the use of glass calibration (calibration of the instrument with a thin clear glass, such as a microscope slide). (Rodgers, et. al., 2008b)

Most of the cotton produced in the U.S. today is exported globally, primarily to China. Recently, it has been reported to the industry that some bales, especially those transported overseas, appear to have changed significantly in color compared to the original HVI measurements, especially for +b. Industry representatives have expressed an interest in "on-site"/remote location measurements of cotton color that will yield "real time" color values, with emphasis on +b. These remote location measurements will necessitate the use of a portable color spectrophotometer. A program was implemented to determine the feasibility of using portable color spectrophotometers to measure cotton color in remote locations, with primary emphasis on +b. The program was a joint project between Cotton Incorporated and the Cotton Structure & Quality (CSQ) research unit with the Southern Regional Research Center (SRRC) of the Agricultural Research Service (ARS). The proposed portable spectrophotometer method could provide on-site cotton fiber color measurements in remote locations (mill, warehouse, etc.), as well as in the laboratory, that can be used to determine the "present" cotton specific color value for +b.

Material and Methods

The samples used in this evaluation consisted of two sets of AMS standard ceramic tiles (n=10 total) and 3 sets of AMS standard cotton bricks (n=36 total). The tile and cotton samples were measured (5 replicates per sample) on the SRRC HVI-1000 and the HunterLab MiniScan EZ (MSEZ) portable spectrophotometer (Figure 2). Manufacturer operational procedures were followed. The MSEZ was fitted with a 30 mm glass-covered nose cone/sampling port. The glass-covered sampling port results in a glass calibration for the MSEZ, which has been shown to minimize significantly the glass impact on fiber color measurements. Comparative evaluations were performed between the HVI Rd - +b and the MSEZ L*a*b* (illuminant D65/10^O observer and illuminant C/2^O observer) and XYZ (C/2^O) parameters.

Parameters evaluated included within-pooled standard deviation (SDwp; 5 measurements), R^2, and number of outliers (number of samples outside specified > ±0.5 color agreement between the HVI +b and the MSEZ b color term selected). Preliminary end-state criteria for the cotton samples were comparable SDwps (<0.25 for portable spectrophotometer), R^2s > 0.90, and the number of samples agreeing within ± 0.5 color units (HVI +b to MSEZ b color term selected) being ≥ 70%.

Figure 2. HunterLab MiniScan EZ (MSEZ) portable spectrophotometer and glass-covered 30 mm sampling port

Results and Discussion

In order to determine the best overall portable color unit to use in this program, an extensive search was made of the portable color units available in the marketplace. The HunterLab MiniScan EZ (MSEZ; HunterLab Associates, Reston, VA) was selected for use in this evaluation. The MSEZ is a true color spectrophotometer (45/0 geometry), with a large sampling port (30 mm), a glass-covered sampling port, battery operated, and a USB download capability. The MSEZ was selected for the comparative HVI-portable spectrophotometer evaluations.

Several comparisons between spectrophotometer color parameters and HVI +b were performed (slope/bias adjustments, line fit, etc.). The best overall results were obtained for HVI +b and MSEZ b* (D65/10^{O}). Excellent linear agreement was observed between HVI +b and MSEZ b* for both ceramic tiles and cotton biscuits, with slopes near unity and high R^2s obtained (> 0.97, Figures 3 and 4). In addition, very acceptable analytical variabilities, as expressed by SDwp, were observed for both the MSEZ and HVI for the ceramic tiles (HVI = 0.01; MSEZ = 0.03) and cotton biscuits (HVI = 0.08 and MSEZ = 0.16). Although the Swp for the cotton biscuits was higher for the MSEZ, it was still less than 1/3 of the method agreement range of ±0.50 color unit and less than the end-state criteria target of 0.25.

Slightly different but significant color agreements were observed between the tile and biscuit samples. Since the main focus of this project was on fiber samples, primary emphasis was given to data analysis of the cotton biscuit measurements. In general, the HVI +b values are ~1.3 units lower than the MSEZ b* values. When this adjustment was made, excellent agreement was observed between HVI +b and MSEZ b*. The +b-b* color agreement was over 94% for the ± 0.5 specified outlier limit and over 80% for a ± 0.4 outlier limit (Figure 5). Thus, the end-state criteria of ≥ 70% of the samples agreeing within ± 0.5 color units (HVI +b and MSEZ b*) was achieved.

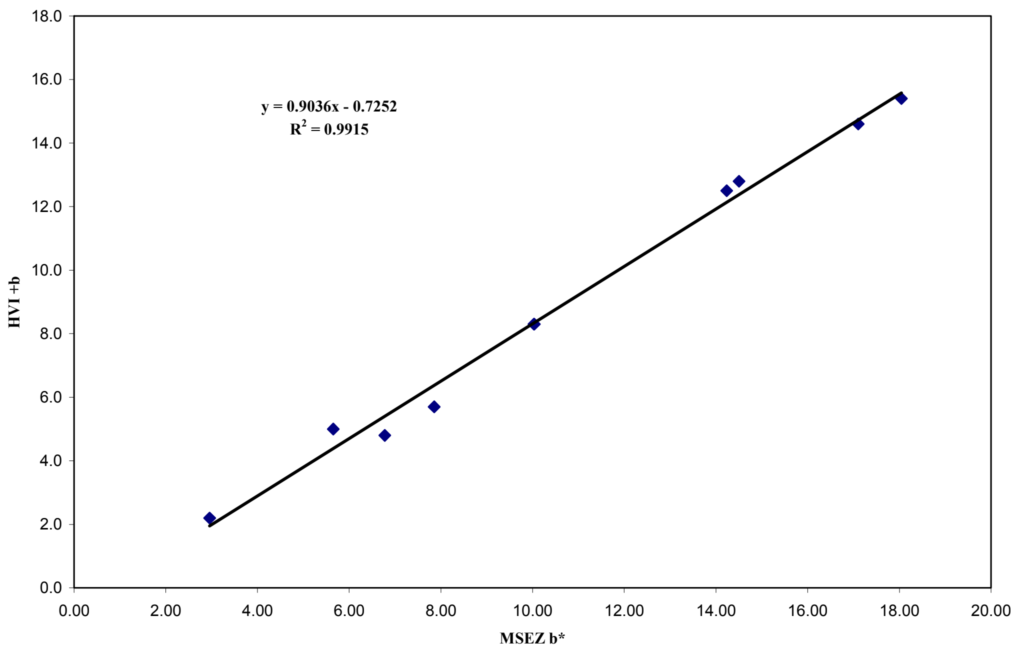

Figure 3. HVI +b vs. MSEZ b*, AMS standard tiles

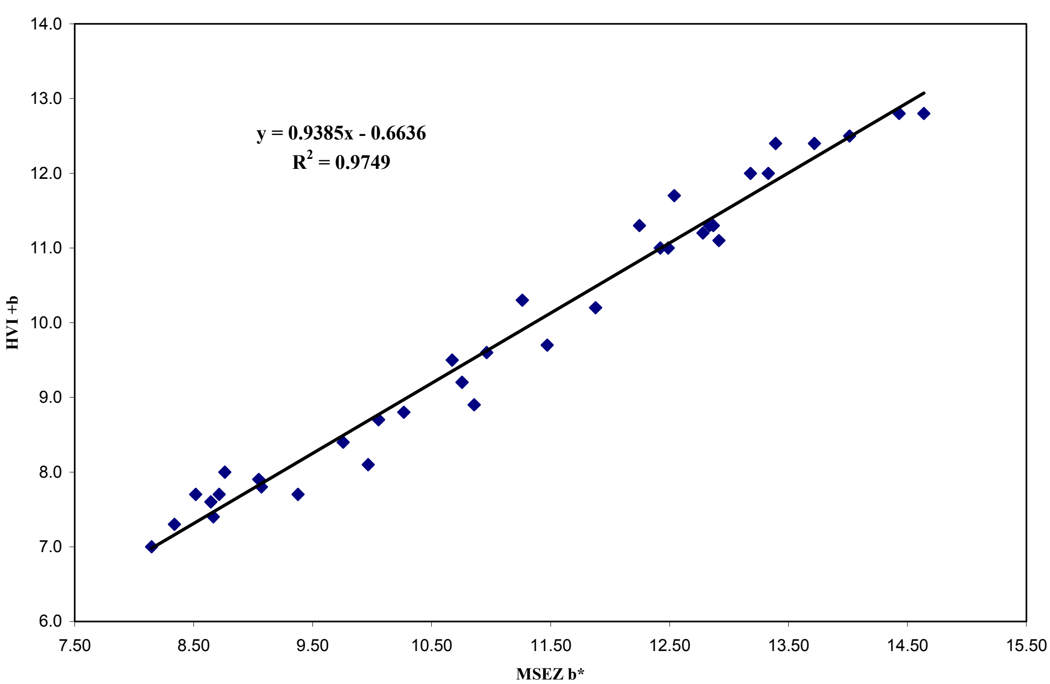

Figure 4. HVI +b vs. MSEZ b*, AMS standard cotton biscuits

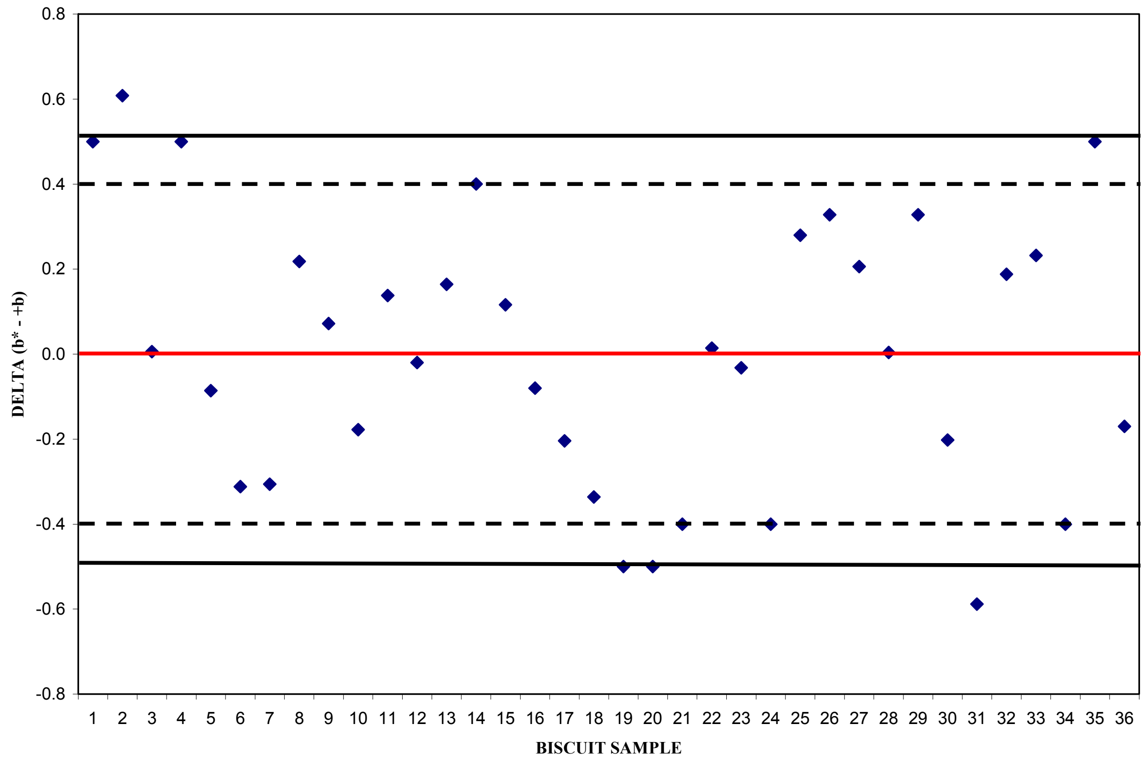

Figure 5. Differences between HVI +b and MSEZ b*, AMS standard cotton biscuits.
Dashed lines are +/- 0.4 Delta (b* - +b); solid upper and lower lines are +/- 0.5 Delta (b* - +b)

Summary

Cotton in the U.S. is classified for color with the Uster® High Volume Instrument (HVI), using the parameters Rd (diffuse reflectance) and +b (yellowness). It has been reported that some cotton bales, especially those transported overseas, appear to have changed significantly in color from their initial HVI color measurements, especially +b. A program was implemented to determine the feasibility of using portable color spectrophotometers to measure cotton fiber yellowness (a spectrophotometer "+b") in remote locations (e.g., warehouse, mill, overseas). Using AMS standard tiles and cotton samples, comparative evaluations were performed to establish the relationships between the HVI +b and portable spectrophotometer L*a*b* color parameters. Excellent linear agreement was obtained between HVI +b and MSEZ b* for both AMS ceramic tiles and cotton fiber biscuits (R^2s > 0.97). Low spectrophotometer within standard deviations (Swps) were obtained for the HVI +b and MSEZ b* measurements (<0.20 color units). Color method agreement between the HVI +b and MSEZ b* was excellent, with over 94% of the samples agreeing within ±0.5 color units. Thus, all end-state criteria were achieved. The portable spectrophotometer measurements were rapid (< 3 minute measurement per sample), precise, and accurate. The color results can be downloaded to external device for remote field operations.

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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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