COTTON COLOR AND TRASH: 1990 HVI, 2001 HVI, AND SPECTROPHOTOMETRIC MEASUREMENTS

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Abstract

Samples from a 1990 USDA AMS study were used. A total of 78 cotton samples representing different US gins and different production areas, grown in 1989 and originally analyzed in 1990, were evaluated. HVI data from the original 1990 study were compared with HVI measurements taken on the same samples in 2001, and with spectrophotometric color measurements including CIELAB and Hunter L*, a* and b* measurements, different standard illuminants and observer functions. The spectrophotometric measurements were also taken in 2001. Simple statistics were used to evaluate changes in samples between 1990 and 2001, as determined by the two sets of HVI measurements, and to compare 2001 HVI and color spectrophotometric measurement methods.

Introduction

Factors that may influence cotton color include growth conditions, microorganisms, ageing or weathering either before or after harvest, staining by extraneous agents, and the presence of trash, dust, or oil within the cotton sample. The most highly valued cotton is white and homogeneous in color. Deviations from the ideal white include grayness and yellowness, and may include other minor hue variations such as redness.

USDA visual standards including 25 official color grades and 5 categories of below-grade color for American Upland cotton, plus an instrumental color measurement component of the USDA HVI system, have traditionally provided for both measurement and classification of cotton color. The color measurement component of the HVI system is based on a Nickerson/Hunter 3-filter colorimeter that was state-of-the-art equipment when it was initially developed, through research done in the 1940s. The system has been modified and updated periodically, and provides measurement of two parameters, namely "Rd", and "+b". The term " Rd", which represents lightness or grayness, corresponds roughly with the Hunter "L" value. The second measurement, "+b", corresponds with the positive component of the Hunter "b" scale. The Hunter "b" scale, as well as the "b" scale of other opponent theory color models, ranges from negative infinity which represents blueness, to positive infinity, which represents yellowness.

Opponent color models, such as the Hunter and the CIELAB models, are based on early theories of color vision that have been verified through physiological research. These models include three dimensions: lightness (as in the HVI Rd measurement), blueness-yellowness (as in the HVI +b measurement), and greenness-redness. These three dimensions are mathematically derived from tristimulus values, corresponding with the trichromatic theory of color vision, which has also been verified physiologically (Berns, 2000). A redness-greenness dimension has traditionally not been included in the HVI measurement, perhaps because it was not thought to be necessary in order to provide the level of accuracy desired for cotton color determination, or perhaps because early colorimeters lacked the sensitivity to distinguish the very small differences in redness among cotton samples.

In contrast to the Nickerson/Hunter 3-filter colorimeter, 31-point visible range color spectrophotometers are widely used to measure color of a variety of products. With these instruments, measurements are taken at 10 nm intervals across the visible spectrum, from 400 to 700 nm, resulting in 31 reflectance measurements which can then be combined with illuminant and observer function data within the instrument's software, to produce accurate color measurements under a wide range of simulated lighting conditions.

Another notable difference between most color spectrophotometers and the HVI system of color measurement is the instrument aperture, or port size, which controls the area of the specimen that is measured by the instrument. The HVI system measures a large area of the sample, while typical color spectrophotometers take measurements across a much smaller area. It can be argued that there are advantages to both systems. Measurement of a large area averages out variability within the sample, leading to reproducibility of measurements, while a small aperture allows one to focus on selected features of a sample and distinguish color differences within an individual sample.

Procedure

Objectives

There were two objectives to this study: (1) to compare 1990 and 2001 HVI color and trash measurements of 1989 crop samples; and (2) to compare 2001 HVI and 2001 color spectrophotometric measurements of these samples.

Samples and Measurements

A total of 78 samples, each consisting of between three and five sub-samples, of cotton fiber were studied. These samples were part of a larger set of samples that had been generated in a USDA national study of the cotton crop produced in 1989 and measured in 1990. The original study consisted of classification, fiber, and processing test results from samples taken at various ginning facilities, and also included spinning lots from different production areas in the US. Since completion of processing and measurement in 1990, the samples had been stored at the USDA Cotton Quality Lab at Clemson, SC. Although the samples were stored so as to keep them away from excessive moisture and light, storage conditions such as temperature and relative humidity were not controlled or measured.

Three sets of data were used. These included the 1990 HVI data relevant to color and trash, HVI measurements taken at the USDA Cotton Quality Lab at Clemson in 2001, and color spectrophotometric measurements taken at the University of Georgia in 2001.

A Macbeth Color-Eye 31-point visible range spectrophotometer, fitted with 1-inch diameter port with a quartz window, was used to measure color. Each sub-sample was measured at 3 sites. A "site" measurement involved removal of the 3-5 gram sample from the port and repositioning it between each measurement. Sub-sample data represented means of three site measurements. The spectrophotometric color measurements consisted of 36 terms per measurement: Hunter L, a, and b, CIELAB L*, a* and b*, each with the two standard observer functions (2-degree and 10-degree), and each with three standard illuminants: C, D-65, and cool white fluorescent. Both Hunter and CIELAB measurements were taken since the Hunter measurements are similar to HVI color measurements and CIELAB measurements are widely used in the textile industry. Inclusion of the other variables was justified because iIlluminant D-65 and the 10-degree observer function are widely used in the textile industry, illuminant C corresponds with the HVI method, fluorescent lighting is used in some processing and manufacturing facilities, and the 2-degree observer function was thought to correspond with close visual examination of samples that might occur in visual grading of samples.

In addition to the 36 spectrophotometric variables, a total of 11 HVI variables were analyzed. These included Rd and +b data from 1990 HVI using a MCI 3500 system, Rd and +b data from 1990 HVI using a Spinlab 900 system, 1990 HVI trash readings using both the MCI 3500 and Spinlab 900 systems, and 2001 HVI measurements of Rd, +b, % trash in the scanned area, number of trash particles in the scanned area, and the USDA Color Grade classification read by the 2001 HVI system.

A correlation analysis was performed on the whole set of data representing the 47 variables. Simple statistics were also used to compare data representing various samples.

Results

Correlations between many of the variables were statistically significant. Although there were differences among samples, It was not unexpected that correlations between means of CIELAB and Hunter measurements, and between CIELAB L*, Hunter L, and HVI Rd, as well as between CIELAB b*, Hunter b and HVI +b were significant, since these measurements are based on the same factors. Similarly, some of the 1990 and 2001 HVI measurements were highly and significantly correlated, since they were specifically designed to measure the same factors. Measurements of specific color terms using the different illuminants or the different observers resulted in some differences between samples, yet the correlations among these factors were statistically significant.

Color Change from 1990 to 2001

Comparison of 1990 and 2001 HVI Rd and +b measurements revealed no significant difference between the mean lightness (Rd) of 73.5 in 1990 and 73.8 in 2001. However, on the average, samples significantly yellowed over the 11-year storage period. The mean +b in 1990 was 8.9, and in 2001, it was 11.7. Comparison of the range of +b values reveals differences among individual samples. In 1990, the +b values ranged from 7.8 to 14.4, and in 2001 the range was from 8.7 to 14.9. Every sample increased in yellowness (+b) from 1990 to 2001.

2001 HVI Trash and Color

Analysis of the 2001 data showed a highly significant, direct correlation between percent trash and number of trash particles. There were highly significant negative correlations between percent trash and mean Rd values, and between number of trash particles and mean Rd values. There were no statistically significant correlations between +b values and either trash variable.

2001 HVI Trash and Color Spectrophotometric Measurements

Using CIELAB, 10-degree observer, illuminant D-65 measurements, there was a significant negative correlation between CIELAB L* and percent trash, indicating that darker samples were associated with increased % trash, but there was no significant correlation between number of trash particles and CIELAB L*. With respect to yellowness, a significant and direct correlation was found between CIELAB b* and number of trash particles, indicating a relationship between increased yellowness and number of trash particles. There was no significant relationship between yellowness and percent trash. There were no significant correlations between redness (CIELAB a*) and either trash variable. Correlation results were similar with Hunter measurements and with the other illuminants and observer function.

Range of CIELAB Values

With a large, representative data set such as the one used in this study, the range of values may be useful in determining which factors to include in a standard measurement method. Among the 78 samples, L* values ranged from 50.46 to 88.93, a* values ranged from 0.80 to 2.84, and b* values ranged from 8.77 to 14.61. The wide range of L* values shows that color variations among samples is largely due to differences in lightness, or grayness. The range of b* values is also noteworthy, indicating significant differences among samples. All of the samples were nearly neutral in redness, but even the small range of a* values would be visibly detectible. Therefore, it is expected that color could be more precisely and accurately assessed through the inclusion of a redness measurement. This observation agrees with previous research (Xu, 1998; Duckett, 1999; Epps, 2000).

Summary and Implications

Measurements of the 1989 cotton crop indicated that on the average, samples yellowed, but did not darken significantly between 1990 and 2001. Correlations among variables indicate relationships between sample color and trash content. A range of a* values among the samples point toward the need for including a redness measurement in a standard measurement procedure, as well as the usual measures of lightness and yellowness.

In comparing color spectrophotometric and HVI methods of measurement, consideration of the color model, the selection of illuminant, the observer function, and instrument aperture, in relation to the desired level of accuracy and precision, is required. While adoption of state-of-the-art technology in the field of color science can be beneficial, additional factors to be considered include the established history of the method, its basis in sound scientific principles, and its relationship to research in human color vision, as well as the ease of automation and the applicability to measurement of other fibers or products.

References

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