1605 Investigations of the Impacts of Instrumental and Operational Variables on Color Measurements

James Rodgers, Devron Thibodeaux, Xiaoliang Cui, Vikki Martin, Mike Watson

Abstract

Color measurements for the classing of U.S. cottons have been performed on the Uster™ High Volume Instrumentation (HVI) instrument for several years. Two color parameters specific to cotton—Rd (reflectance) and +b (yellowness)—are used in the color measurement of cotton. Since Rd and +b do not readily relate to other well known and globally recognized color systems, a program was implemented to evaluate and validate the relationships of Rd and +b to a globally recognized color system (L*a*b*) and to investigate the impacts of key instrumental and operational variables on the color results. Tile and cotton samples were measured on 8 color spectrophotometers (bench-top and portable). Strong L*↔Rd and b*↔+b correlations were verified and validated on all color units. Thus, the use of L*a*b* for relating globally recognized color parameters from a color spectrophotometer to the HVI's Rd and +b color parameters was validated. The primary variable that impacted the color agreement between units was the use of HVI glass in front of the sample. L* was the color parameter that was most impacted by the use of glass in the tile and cotton fiber color measurements. Distinct differences were observed between the different spectrophotometers for L* and L*↔Rd correlation agreements when glass is used.

Introduction

Color is composed of 3 components and results from the interaction of a light source, an illuminated object, and the eye/observer or a "visual system" (Harold, 1992; Billmeyer and Hammond, 1996; Billmeyer and Saltzmann, 2000; HunterLab, 2000). Light is the electromagnetic radiation observed by the human eye, with the visible color spectral region consisting primarily from between 400nm (violet) and 700nm (red) (figure 1).

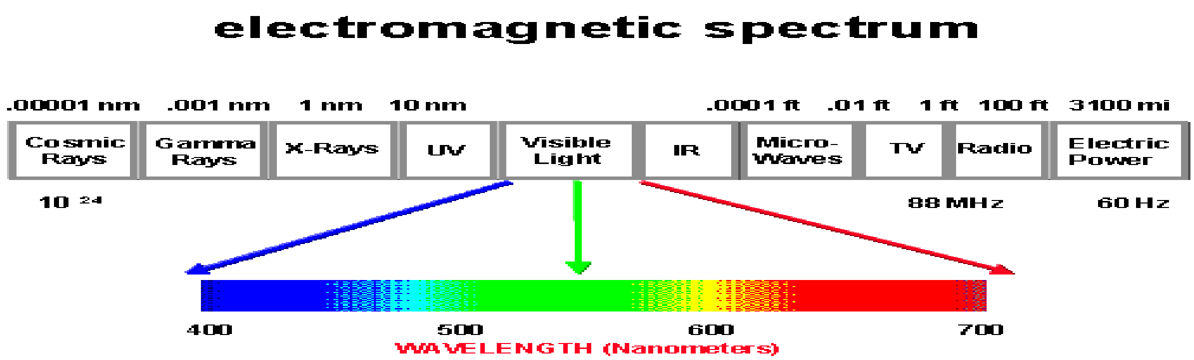

Figure 1. The electromagnetic spectrum (visible region between 400-700nm).

The goal for color measurements is a set of numbers that will be representative of the total spectrum and indicative of the color of an object. The color of an object can also be represented as a 3-dimensional or "tristimulus" color space. (Billmeyer and Hammond, 1996; Billmeyer and Saltzman, 2000; Harold, 1992) Algorithms from the Commission on Illumination (CIE) can be used for the color results from color instrument to obtain the CIE XYZ tristimulus values for an object. The CIELab (L*a*b*) color space system was derived from the XYZ tristimulus values. In L*a*b*, L* represents lightness or darkness of a sample; a* represents redness or greenness of a sample; and b* represents the yellowness or blueness of a sample. There are two main types of color instruments used to measure the color of textile products— colorimeters and spectrophotometers (Billmeyer and Saltzman, 2000; Hunter, 1975). The Uster™ High Volume Instrumentation (HVI) is a cotton colorimeter.

U.S. produced cotton is classed and most of its quality parameters are determined by the HVI. Cotton color is classed on the HVI by two parameters— Rd (diffuse reflectance) and +b (yellowness). The Rd and +b color parameters are specific to cotton fiber, and they do not readily relate to other well known and globally recognized color systems (e.g., L*a*b*). The standards used for the HVI units are Agricultural Marketing Service (AMS) reference ceramic tiles and cottons.

A program was implemented to perform comparative color analyses with multiple color units from several vendors in order to study the "universality" of the relationship(s) of Rd and +b to L*a*b* and to study the influence of various instrumental and sampling variabilities on the color result. In this investigation, the comparative program was expanded to 8 bench-top and portable color spectrophotometers from four vendors. The L*↔Rd and b*↔+b relationships and the impact of instrumental and sampling/procedural variabilities on the color result were investigated.

Experimental

The samples analyzed were color tiles, AMS standard tiles, and AMS standard cotton fiber batts. The samples were measured on 8 color spectrophotometers from four color instrument manufacturers. The bench-top color spectrophotometers were the MacBeth CE7000A (reference), X-Rite 8400, Minolta CM7000, and HunterLab UltraPro. The portable spectrophotometers were the MacBeth XTH, X-Rite SP64, Minolta CM2600d, and HunterLab MiniScan XE-Plus. Each sample was measured 5 times on each color instrument, and the instrumental settings were illuminant D65, 10^{O} observer, large area of view, and specular component excluded. The samples were measured “without glass” (samples placed directly against the spectrophotometer port) and/or “with glass” (glass plate placed between the sample and the spectrophotometer port). Each unit was compared for the impact of instrumental and sampling variables on the color results.

Results and Discussion

A preliminary study with one bench-top color spectrophotometer had observed a distinct linear relationship between L*↔Rd and b*↔+b on AMS standard tiles and standard cotton fiber batts. (Thibodeaux, et. al., 2005) A program was implemented to perform comparative color analyses with multiple color units (bench-tops and portables) from several vendors to study the “universality” of the observed relationship(s) to Rd and +b to L*a*b* and to study the influence of various instrumental and sampling variabilities on the color results. Preliminary L*a*b* results on the 4 different color spectrophotometers (2 vendors, 2 types of units) tracked very well with each other. (Rodgers, et. al., 2006) In this investigation, the comparative program was expanded to 8 color spectrophotometers from four vendors.

The L*a*b* and the DE* color agreement between bench-top and portable units was compared. Very good to excellent color unit agreement was observed for L*, b*, and DE* between the bench-top units for the color tiles and AMS tiles, but only fair to very good agreement for L*, b*, and DE* was observed for the portable units. Figures 2 and 3 indicate the comparative agreement for L* between the various bench-top spectrophotometers on AMS tiles, both with and without glass. The use of glass significantly impacted inter-instrument color agreement (especially for the portable units), and this impact was readily observed with the color measurements on cotton fiber (glass only measurements). L* is the color parameter that is most impacted by the use of glass in the color measurement. These results indicate that the development and use of “traceable” standards for HVI cotton color measurements is feasible, especially for a system in which ceramic or metal tiles are used on a bench-top spectrophotometer with no glass use.

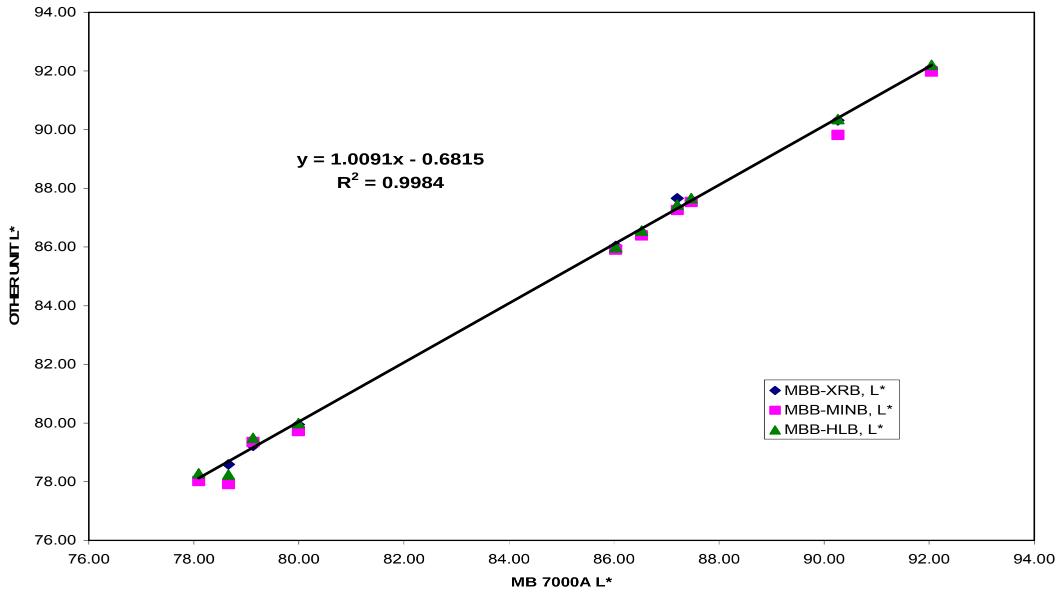

Figure 2. Comparison of L* between bench-top spectrophotometers, AMS tiles, without glass.

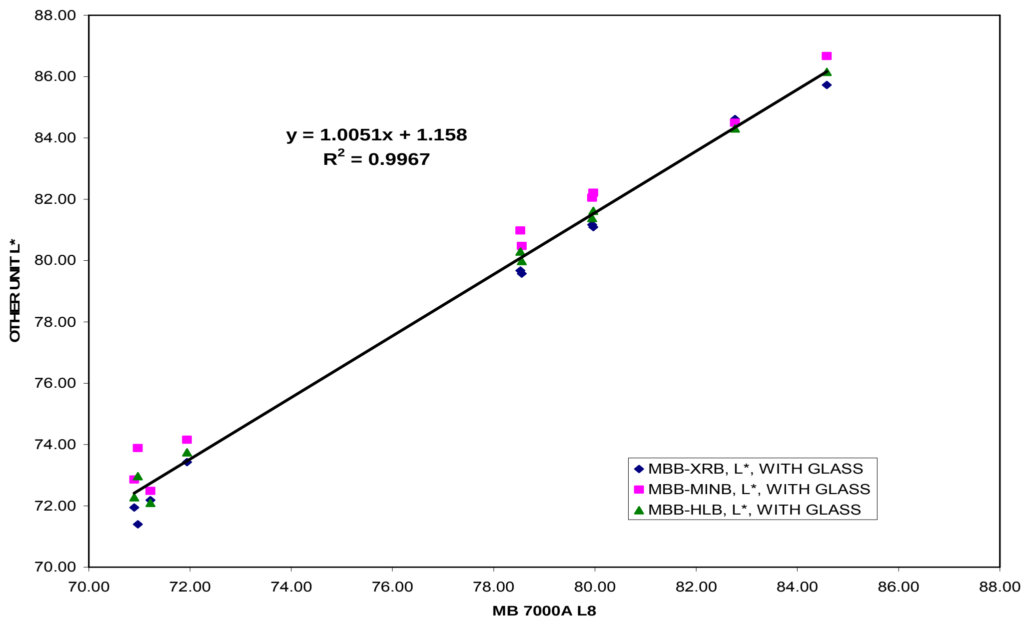

Figure 3. Comparison of L* between bench-top spectrophotometers, AMS tiles, with glass.

Next, the color parameter relationship between L*↔Rd and b*↔+b were validated. The two sets of AMS tiles were measured on the MacBeth CE7000A bench-top spectrophotometer, with glass. Very good method agreement was obtained between this study and the initial investigation. (Thibodeaux, et. al., 2005) The L*↔Rd agreement was linear with a slope of near 2.0 and a large offset, and the b*↔+b agreement yielded a linear relationship with a slope of near 1.0 and a small offset (figure 4 as an example).

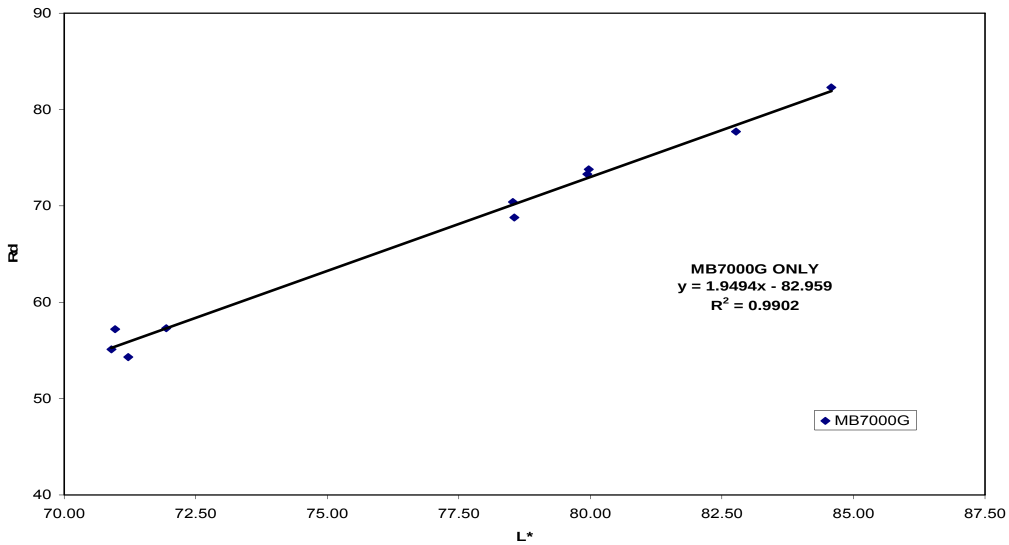

Figure 4. Validation of L*↔Rd for the MacBeth CE7000A bench-top spectrophotometer, AMS tiles, with glass.

The strength of the L*↔Rd and b*↔+b relationships were determined by comparing L*↔Rd and b*↔+b for each unit, both with and without glass. Very good color unit agreement between the bench-top units and moderate agreement for the portable units were obtained for L*, b*, and DE* with the color tiles and AMS tiles when glass is not used. The L*↔Rd relationship yielded a slope of near 2.0 and a large offset, while the b*↔+b relationship yielded a slope of near 1.0 and a small offset for all units. These results validated the use of L*a*b* for relating globally recognized color parameters from a color spectrophotometer to the HVI's Rd and +b color parameters.

In addition, figures 5 and 6 indicate the impact of glass on the color results of tiles, which impacted primarily the L* and DE* results. Distinct differences were observed between the different spectrophotometers for L*↔Rd when glass is used in front of the spectrophotometer measurement port, but the L*↔Rd differences for each tile were small when no glass is used.

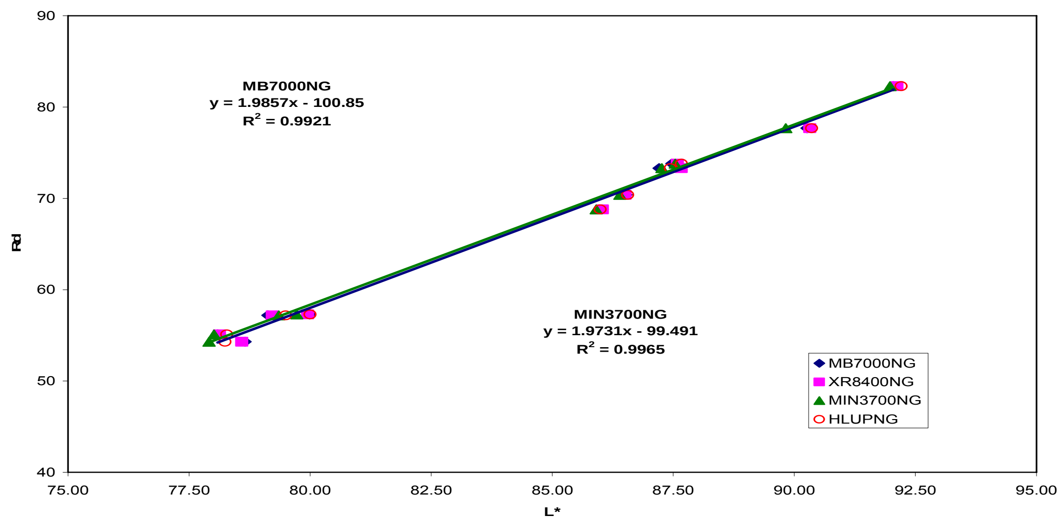

Figure 5. L*↔Rd for relationships for bench-top spectrophotometer, AMS tiles, without glass.

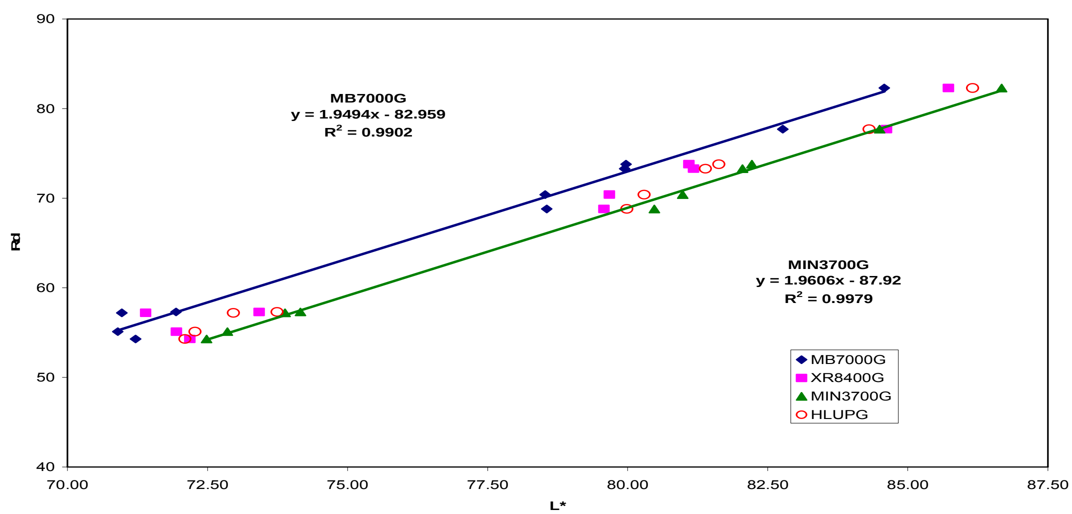

Figure 6. L*↔Rd for relationships for bench-top spectrophotometer, AMS tiles, with glass.

Conclusions

The strong L*↔Rd and b*↔+b correlations observed on one color unit in the preliminary investigation were verified and validated on all color units. Very good color unit agreement between the bench-top units and moderate agreement for the portable units were obtained for L*, b*, and DE* with the color tiles and AMS tiles when glass is not used. Very similar linear relationships were obtained for L*↔Rd and b*↔+b for all bench-top units. The primary variable that impacted the color agreement between units—for tiles and cottons—was the use of glass in the measurement. The use of glass often resulted in large DE* differences in color results between the different color instruments. L* was the color parameter that was most impacted by the use of glass in the color measurements. Distinct differences were observed between the different spectrophotometers for L* and L*↔Rd correlation agreements when glass is used, but the differences were usually small when no glass is used.

References

Billmeyer, F., and Hammond, H., Color and Light, ASTM Manual 17, ASTM, PA, 1996.

Billmeyer, F., and Saltzman, M., Principles of Color Technology, 3rd Ed., John Wiley & Sons, NY, 2000.

Harold, R., Industrial Finishing, Sept 1992.

Hunter, R., The Measurement of Appearance, John Wiley & Sons, NY, 1975.

HunterLab Application Note, “What is Color and How is Measured?”, 12 (5), May, 2000.

Rodgers, J, Thibodeaux, D, Campbell, J., Kimmel, L., “Cotton Color Measurements—The Possibility for “Traceable” HVI Color Standards,” 2006 Beltwide Cotton Conference, New Orleans, LA, 2006.

Thibodeaux, D, Campbell, J., Knowlton, J., “Development of NIST-Traceable HVI Color Measurements,” 2005 Beltwide Cotton Conference, New Orleans, LA, 2005.

Acknowledgements

The authors wish to gratefully acknowledge the support of the color instrument vendors for the use of their color units and Mr. James Knowlton and his staff of the Agricultural Marketing Service (AMS) in Memphis, TN, for the use of AMS ceramic tiles and cotton batts. We also wish to acknowledge the outstanding work by Ms. Sharon King, Jeannine Moriatis, and JaVon Gray for their

outstanding work in preparing and 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.