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Use of digital images to estimate CIE color coordinates of beef ☆

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Abstract

The objective of this study was to evaluate the use of digital images (DI) to estimate CIE $L^*a^*b^*$, hue angle and chroma of beef, as compared to a colorimeter (CM). Loin samples from 21 steers finished with high-grain diets were displayed under retail-simulated conditions. Color readings were obtained from 63 cores covering the full spectrum of discoloration in beef. CIE L^*, a^*, and b^* were measured with a surface-reflectance CM. Red, green and blue (RGB) values were obtained from DI and sequentially transformed to XYZ and CIE $L^*a^*b^*$ color space. Hue angle and chroma were calculated from a^* and b^* values. Regressions of CM on DI for a^*, hue angle and chroma had R^2 values of 0.93 and above. Average color difference (ΔE^*_{ab}) between the predicted and the actual CM L^*, a^*, and b^* values for 13 samples that were not included in the regressions was 1.57, below reported thresholds of detection for 50% of observers. Color readings from DI could be used to accurately predict color coordinates measured by CM, especially a^*, hue angle and chroma. Use of digital imaging could become a practical tool to detect changes in beef color and other muscle foods.

Keywords: Beef color; Digital images; RGB; Colorimeter; CIE $L^*a^*b^*$

1. Introduction

Consumers have ranked freshness as the most important factor for buying meat (Maguire, 1994). When evaluating beef, consumers associated "red" and "bright red" lean with freshness of the raw product and expressed dislike for brownish color which was perceived to be an indicator of stale or spoiled beef (Forbes, Vaisey, Diamant, & Cliplef, 1974). Objective color measurements are better correlated to visual color than pigment concentrations (Jeremiah, Carpenter, & Smith, 1972) and numerous researchers have successfully used various CIE color expressions [Lightness (L^*), redness (a^*), yellowness (b^*), hue angle, and chroma] for detection of fresh meat color differences (Hunt, Sorheim, & Slinde, 1999; Liu, Scheller, Arp, Schaefer, & Frigg, 1996; Von Seggern, Calkins, Johnson, Brickler, & Gwartney, 2005). However, instruments used for this purpose usually have the limitation of scanning a small surface area (Hunt et al., 1991) which can reduce repeatability of measurements if sample location is not carefully controlled.

Computer imaging is a promising method for predicting visual color (Mancini & Hunt, 2005). Digital image analysis has detected color changes during cooking of beef ribeye steaks (Unklesbay, Unklesbay, & Keller, 1986). These authors observed that the mean and standard deviation of the red, green and blue colors were sufficient to differentiate between 8 of 10 classes of steak doneness. Other researchers have observed that instrumental color measurements taken from digital images (DI) of pork samples were more highly correlated to sensory-panelist evaluations than color values measured with a colorimeter (CM) (O'Sullivan et al., 2003). Rapid advances in hardware and software for DI acquisition and processing and significant reduction in equipment costs during recent years have made this technology accessible and cost-effective.

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Leon, Mery, Pedreschi, and Leon (2006) compared different models to convert red, green and blue (RGB) values from digital images to the CIE $L^*a^*b^*$ color space. They used an array of 32 color charts and observed that the regressions between CIE $L^*a^*b^*$ color coordinates from DI and CM had a coefficient of determination (R^2) higher than 0.99 when a quadratic model and a neural network were used. However, it is not known if such high R^2 would be observed when regressing CM on DI color coordinates within the narrow range of colors possible in raw beef. Our hypothesis was that, within the limited range of colors possible in beef, CIE L^*, a^*, b^*, hue angle, and chroma obtained from DI would be highly correlated with values obtained from CM and thus, they could be used to study color changes in beef. The objective of this study was to evaluate the use of DI to estimate CIE color coordinates of beef as compared to a CM, thus anticipating a technology that would be inexpensive and widely available.

2. Materials and methods

2.1. Experimental design and sampling

Meat samples from 21 Angus crossbred steers finished with high-grain diets (Larraín, Schaefer, Richards, & Reed, 2008) were used in this study. All experimental procedures were approved by the Institutional Animal Care and Use Committee of the University of Wisconsin, Madison. Animals were individually penned and feed was offered once daily. After 123 days on feed, cattle were transported 160 km and slaughtered at Packerland Packing (Green Bay, WI, United States).

Forty eight hours after killing, right strip loins were removed from each carcass and transported to the Meat Science and Muscle Biology Laboratory of the University of Wisconsin-Madison. Cuts were vacuum packaged (Prime Source 3 mil vacuum pouches, Bunzl Distribution, St. Louis, MO, United States) and aged 14 days at 4 °C. After the desired ageing period, 1.27 cm thick steaks were made from the *longissimus lumborum* muscle and round cores (12 cm^2) were cut from them. Three cores from each steer were randomly selected for the study and placed on styrofoam trays, wrapped with oxygen-permeable fresh meat film (22.475 mL $O_2 \times m^{-2} \times d^{-1}$ at 23 °C, E-Z Wrap crystal clear PVC film, KOCH Supplies LLC, North Kansas City, MO, United States) and displayed under simulated retail conditions consisting of 4 °C with 1000 lx of continuous, deluxe cool white fluorescent illumination.

2.2. Color measurements

Color readings were obtained from 63 cores covering the full spectrum of discoloration in beef: from fresh samples having a bright-red color to stale samples with a green-brownish tint. Readings were taken near the center of each core using a CM (Minolta Chromameter CR-300, Osaka, Japan; Fig. 1a) with a 1 cm aperture, illuminant C and a 2° viewing angle. Before data collection, the instrument was calibrated with a white calibration plate ($L^* = 97.06$, $a^* = -0.14$, $b^* = 1.93$) covered in the same film wrapping the beef samples. Data were collected in CIE $L^*a^*b^*$ color space through the meat film. Lightness (L^*), redness (a^*), yellowness (b^*), chroma [or color saturation, $(a^{*2} + b^{*2})^{0.5}$], and hue angle [arctangent $(b^*/a^*) \times 360°/(2 \times 3.14)$] were evaluated. Digital pictures were taken immediately after the CM reading using a Canon PowerShot A70 digital camera (Fig. 1b). White balance was set using the custom option and the plate used to calibrate

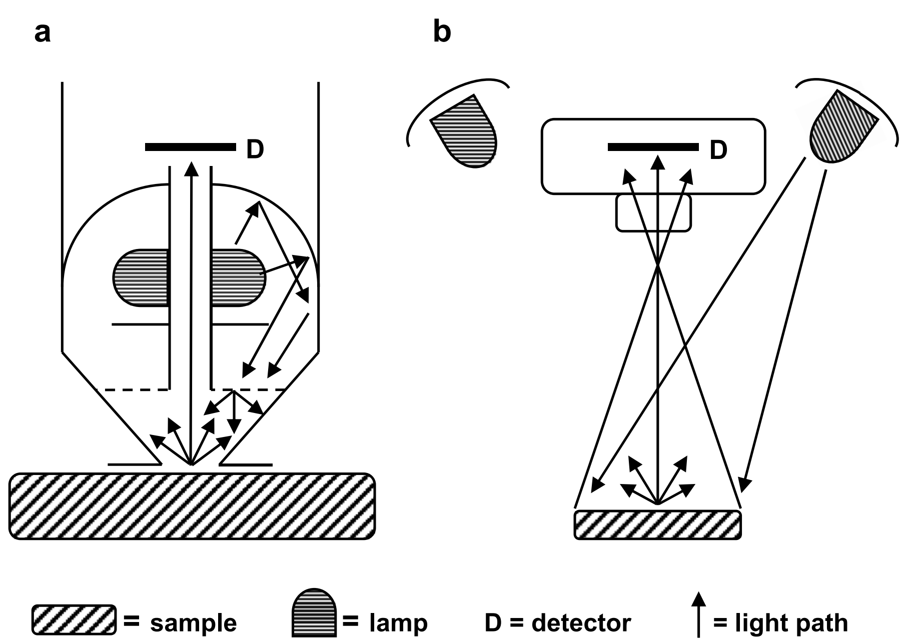

Fig. 1. Diagrammatic representation of the image acquisition systems. (a) Colorimeter, (b) Digital camera.