COMPARISON OF REFLECTANCE MEASURES FOR CHARACTERIZING GROUND BEEF COLOR

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Background

Visual color evaluation best represents consumer perception and is the standard for determining consumer preference. However, the disadvantages associated with conducting visual panels (AMSA, 1991) have caused many researchers to follow meat discoloration with rapid, non-invasive instrumental measures, such as reflectance spectrophotometry. Researchers have used these methods to measure discoloration by calculating percentage changes in one or more of the myoglobin forms. However, these detailed measurements may not always be needed since discoloration may be adequately assessed by instrumentation that evaluates color changes rather than myoglobin forms. Since estimating myoglobin forms is time consuming, other reflectance measures of color, such as L*, a*, b*, chroma, and hue angle may be useful for evaluating meat discoloration. However, these variables often exhibit collinearity and thus, analyzing each one may not provide new useful results. If color data are available that indicate the best color traits to evaluate a given product, researchers could eliminate various parameters. If these data are lacking, it is generally necessary to collect all color parameters to determine those best for detecting color differences due to treatment.

Objectives

This investigation was initiated to determine if commonly used reflectance measurements adequately demonstrate changes in ground beef visual color during display. Considering the concept of parsimony, this project also evaluated the likelihood of assessing meat discoloration with only one reflectance variable.

Methods

To produce a wide range of discoloration, which would enhance correlation and regression accuracy, ground beef chubs (12 per replication) containing 19% fat were allocated to 1 of 36 storage and display combinations over 3 replications. Following each storage treatment, each chub was ground through a 0.32 cm plate, and 454 g was placed on a 2S Styrofoam® tray with a Dry-Loc pad. Trays were overwrapped in polyvinyl chloride film (oxygen transmission rate of 23,250 cc/m^3/24h @ 23°C and 0% RH). One tray per chub per replication was displayed continuously for 48 hours in 2.44 meter open top display cases under 1614 lux of Ultra-Lume fluorescent light (3000K).
Ground beef surface color was analyzed at 0, 24, and 48 hours of display. Initial color (0 hour) was evaluated 30 minutes after the meat was packaged. Visual color was appraised by seven trained panelists (AMSA, 1991), all of whom passed the Farnsworth-Munsell 100-Hue Test. A color scale of 1=very bright cherry red, 3=slightly dark red to tannish red, and 5=tan to brown was used. Reflectance measurements included CIE L*, a*, and b* values (CIE, 1976) for Illuminant A and spectrophotometric measurements (400-700nm) using a HunterLab MiniScan™ with a 3.18 cm diameter aperture. Hue angle (arc tangent b*/a*), saturation index $(a^{*2} + b^{*2})^{1/2}$, a*/b*, %R 630 ÷ %R 580, and %R 630 - %R 580 were calculated. Percent DMb and MMb were determined according to AMSA (1991) using K/S 474 ÷ K/S 525 and K/S 572 ÷ K/S 525, respectively. Oxymyoglobin was calculated by difference according to the equation: OMb= 100% - (%DMb + %MMb). Correlation and regression analyses were performed using SAS (2000).

Results and discussion

Pearson coefficients for all reflectance measures except L* were highly correlated to ground beef visual color scores (Table 1). This was expected since L* values measure surface lightness rather than red color intensity and the percentage fat was essentially the same amongst samples. Saturation index and a* had the highest correlations (r = -0.97) to visual panel scores, and thus were most representative of the red color that panelists saw on the surface of ground beef. Spearman correlation coefficients (data not shown) indicated that a* and saturation index had a high monotonic association (r = -0.96) with ground beef color changes. Thus, the inverse relationship of these variables indicated that larger values characterized bright red color and a numerical decrease represented discoloration from desirable red color to brown. These results support Liu et al. (1991), who reported that Hunter ‘a’ values were moderately correlated (r = 0.83) to ground beef visual color scores. Other mathematical manipulations of color variables (a*/b* and hue angle) were the least related among reflectance measurements to visual color, although they were still highly correlated (r = -0.89 and 0.85, respectively). For spectral data, the difference of %R 630 - %R 580 (r = -0.93) and ratio %R 630 ÷ %R 580 (r = -0.89) were correlated highly to visual color scores. Strange et al. (1974) found that %R 630 - %R 580 was highly correlated (r = 0.86) to consumer acceptability and Harrison et al. (1980) also found a correlation of – 0.82 between %R 630 - %R 580 and visual color.
The high degree of collinearity among instrumental variables is shown in Table 1. Both a* and saturation index were similarly related to visual color (r = 0.97), however, the two measures also were highly correlated to one another (r = 1.0). Similar trends occurred for a* to b* (r = 0.97), b* to saturation index (0.99), and a*/b* to hue angle (-1.0). Thus, when the project goal is to evaluate discoloration as a decrease in desirable red color, analysis of more than one of these variables may not provide additional benefits over a* alone.
Saturation index (R^2 = 0.94) and a* (R^2 = 0.95) accounted for the most variability in visual scores (R^2 values not shown in table). Of the spectral variables, %R 630 - %R 580 accounted for a relatively large amount of variability (R^2 = 0.87), whereas %R 630 ÷ %R 580 accounted for 80%. When predicting visual color attributes (i.e. adjectives such as bright red, dull red, or brown) with reflectance measures, one and two variable regression models were most practical and parsimonious. Multivariate models for these predictions did not provide additional predicting power compared to using a* alone (R^2 = 0.95). According to regression analyses, a* values (Illuminant A) less than 25.4 corresponded to ground beef surface color that trained panelists assessed as unacceptable for purchase. For Illuminant C and D65, a* values associated with panel rejection were 17.1 and 16.5, respectively. Panelists considered ground beef color unacceptable for purchase when approximately 37% of the surface was MMb and 60.5% OMb. Similarly, Greene (1971) suggested that ground beef purchasing decisions were influenced when MMb accounted for more than 40% of the surface.
Since a* was highly correlated to visual scores, %OMb (r = 0.94), and %MMb (r = -0.93), a* appeared to be the most logical choice for following ground beef color stability during display. The degree of collinearity amongst reflectance variables suggests a* may be the only variable necessary to evaluate decreases in desirable red color. High a* values were indicative of large amounts of OMb, whereas low values characterized oxidized meat pigment. In addition, a* will allow researchers to transform instrumental color measures into actual color descriptors (bright, dull, and dark red to brown) for ground beef with a reasonable degree of accuracy (R^2 = 0.95).

Conclusions

a* and saturation index should accurately characterize ground beef surface color when a visual panel is not necessary or available. However, a* may be the only instrumental variable necessary to evaluate ground beef color when myoglobin derivative quantities are not of interest, thus eliminating the need to calculate myoglobin concentrations, a*/b*, hue angle, and saturation index. Although these reflectance variables may not be necessary to assess ground beef visual color, they may prove valuable when determining color stability of other products. Trained panelists consider ground beef unacceptable for purchase when OMb content decreases to 60% and a* values are 25.4 or less.

Pertinent literature

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Contribution No. 02-369-A from the Kansas Agricultural Experiment Station, USA.

Table 1
Pearson correlation coefficients[a] for visual color scores, reflectance measurements, and myoglobin forms on ground beef.

Variables	Visual	a*	b*	SI	a*/b*	HA	630-580	630÷580	%OMb	%MMb
L*	-0.80									
a*	-0.97									
b*	-0.94	0.97								
SI	-0.97	1.00	0.99							
a/b	-0.89	0.91	0.77	0.86						
HA	0.85	-0.87	-0.72	-0.82	-1.00					
630 - 580	-0.93	0.92	0.93	0.94	0.79	-0.75				
630 ÷ 580	-0.89	0.90	0.87	0.90	0.78	-0.74	0.90			
%OMb	-0.93	0.94	0.88	0.92	0.92	-0.90	0.95	0.92		
%MMb	0.90	-0.94	-0.85	-0.90	-0.92	0.90	-0.94	-0.94	-0.97	
%DMb	0.15	-0.08	-0.23	-0.14	0.17	-0.21	-0.22	-0.12	-0.06	-0.05

[a] Coefficients less than 0.1 were not significant ($P > 0.05$).