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# Comparison of Peanut Butter Color Determination by CIELAB $L^*a^*b^*$ and Hunter Color-Difference Methods and the Relationship of Roasted Peanut Color to Roasted Peanut Flavor Response[†]

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Information concerning an optimum roasted peanut color to which peanut samples should be roasted for optimum roasted peanut attribute response is incomplete. Comparison of the Minolta Chroma Meter II CR-100 and Model 96 Spectrogard color systems indicates that the CR–100 system can be used for the measurements needed. However, it only gives CIELAB color values directly. A simple equation, Hunter $L$ = CIELAB $L^* - 7$, can be used to convert $L^*$ values to $L$ values in the $L^*$ range 52–65. By use of four data sets from a 3-year period, an optimum $L^*$ value was found to which peanuts should be roasted to obtain optimum roasted peanut attribute response. Across these data sets optimum $L^*$ varied from 58.2 to 59.5, suggesting that samples should be roasted to $L^*$ values of 58–59 or $L$ values of 51–52 when optimum roasted peanut attribute is of primary interest. Analysis of the data has shown that adjusting for overroast and/or underroast attributes when present reduces the correlation to zero between the roasted peanut attribute and roast color.

## INTRODUCTION

The color to which peanuts are roasted has important quality implications. This is due to an association between color and the flavor and aroma which develops during roasting (Morris et al., 1953). The characteristic color results from sugar–amino acid reactions that produce melanin (Hodge, 1953). The golden brown color of melanin intensifies with increasing temperature of roast and lengthened roasting time. A secondary source of color in roasted peanuts is caramelization of sugars (Mason et al., 1966). Measurement of peanut butter color in establishment of the U.S. peanut butter grade is done by visual comparison to the U.S. Department of Agriculture Color Standards (licensed supplier: Magnuson Engineers, Inc., 1010 Timothy Drive, San Jose, CA 95133) (USDA, 1972). Many commercial peanut butter producers also use Hunter color-difference values for their quality assurance standards. Recently CIELAB $L^*a^*b^*$ color values have been used to describe degree of roast in peanut paste samples used for sensory evaluation (Pattee et al., 1989, 1990) and inner and outer surface color of oil roasted peanuts (Erickson et al., 1988). However, a simple conversion equation giving the relationship between Hunter color-difference values and CIELAB $L^*a^*b^*$ values is not readily available to or known by those working with peanut butter color. While this work was in progress Baardseth et al. (1988) published a paper on the relationship between CIELAB $L^*a^*b^*$ from two different instruments and calculated $L^*a^*b^*$ values from a Hunter Labscan II instrument for several different commodities. Their objective was to compare the $L^*a^*b^*$ relationship on the basis of different sources. Our objective was to compare the $L^*$ and Hunter $L$ value relationship by using peanut butter since to date the predominant color measurement value for peanut butter has been the Hunter $L$ value and presentation of other color parameter values would carry little meaningful without a readily available, documented means of comparison. Degree of roast, color intensity, and intensity of the roasted peanut sensory attribute in roasted peanuts are logically interrelated, but limited research data are available on this interrelationship. The lack of uniform methods to evaluate "degree of roast" and lack of a documented color optimum at which the roasted peanut attribute should be evaluated make comparison difficult. Peanut-roasting studies usually give a time–temperature protocol or refer to degree of roast as "light", "medium", or "dark" (Buckholz et al., 1980; Oupadissakoon and Young, 1984). Pattee and co-workers (Pattee et al., 1982a,b), studying changes in roasted peanut flavor as affected by seed size, storage time, and seed moisture content, used Hunter $L$ values to indicate the degree of roast in their studies and indicated that an $L$ value of 49 was equivalent to a medium roast. Sanders and co-workers (Landsen et al., 1988; Sanders et al., 1989a,b) have also used Hunter $L$ values to measure degree of roast in studying the effect of maturity on roast color and descriptive flavor, maturity and curing-temperature effects on descriptive flavor, and degree of roast effects on alkylpyrazine production. Although the Hunter $L$ value was used as a definitive measure of degree of roast, no optimum value for color intensity was given.

The objectives of this study are (1) to determine a mathematical relationship between Hunter $L$ and CIELAB $L^*$ values in the subjective degree of roast range light to medium-dark to provide a quick comparison between Hunter $L$ and CIELAB $L^*$ values, (2) to compare the CIELAB $L^*$ values from two different instruments using the same sample and sample holder to determine if the instrument with greater flexibility and ease of usage for this application will provide statistically equivalent values, (3) to determine if there is an optimum CIELAB $L^*$ value for the roasted peanut attribute intensity, and (4) to describe the sensory attributes that influence the

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roasted peanut attribute in relation to the CIELAB $L^*$ color values.

## MATERIALS AND METHODS

The individual peanut samples used in this study were obtained from the peanut-breeding programs in Florida, Georgia, Oklahoma, North Carolina, Texas, and Virginia and represent nearly all commercial peanut cultivars and all market types grown in the United States. The selected cultivars and breeding lines for the 1986 crop year (study 1) were obtained from the above represented states. Selected cultivars and breeding lines for studies 2–4 were grown in Georgia and Virginia during 1987 and 1988 (documentation detail for the 399 samples in this study is available upon request to H.E.P.). All samples were obtained from plants grown and harvested under standard recommended procedures for the specific location. After shelling, the sound mature kernel (SMK) fraction was obtained by screening over the screen size appropriate for the given market type. An approximate 1000-g SMK fraction was shipped to Raleigh, NC, during February following harvest and placed in controlled storage at 5 °C and 60% relative humidity until roasted and evaluated.

Peanut samples were roasted during June and July of the year following harvest by using a Blue M Power-O-Matic 60 laboratory oven. A 400-g roasting sample was equally divided among eight compartments within the oven. Roasting time varied from sample to sample, but the roasting temperature was held constant at 160 °C. Immediately following cooling using forced room temperature air, the peanuts were blanched (Hoover, 1979) and then ground into peanut paste by using an Olde Tyme peanut butter mill (Olde Tyme Food Products, 143 Shaker Road, E. Long Meadow, MA 01028). Two random subsamples of the peanut paste were placed into Falcon 1007, 60 × 15 mm, disposable Petri dishes, the covers replaced to retard any oxidative processes, and the CIELAB $L^*a^*b^*$ values determined immediately. The remainder of each ground peanut paste sample was placed into a glass jar, sealed, and frozen at −20 °C until needed for sensory evaluation.

The three color-reflectance values, CIELAB $L^*,a^*,b^*$, were obtained for each subsample with a Minolta Chroma Meter II CR-100 (Minolta Camera Co., Ltd., Osaka, Japan). The reflectance port size was 8 mm, and a d/O illuminating system used. The illumination was supplied by a D6500 K light source, and the spectra responses approximate the CIE colorimetric standard observer. Each subsample was read once at two different locations on the sample container by using the Minolta Chroma Meter. CIELAB $L^*,a^*,b^*$ and Hunter $L,a,b$ values were obtained for all samples on a Model 96 Spectrogard color system (Pacific Scientific, Silver Springs, MD 20910) at the end of the day. The illumination was supplied by a tungsten halogen light source with a 22-mm reflectance port. The observer angle was 10°, and the specular component was included. CIE $XYZ$ values were calculated by using the weighted-ordinate method at 10-nm intervals in the wavelength range 380–720 nm. The desired chromaticity values were calculated from the $XYZ$ values. Two output observations for each reflectance value were obtained on each subsample. The output observations are the average of two scans by the instrument. The standard white tile supplied with the Minolta Chroma Meter II CR-100 was used to standardize both instruments.

CIE $XYZ$ values were calculated from Minolta Meter II Meter CIELAB $L^*a^*b^*$ values (illuminant D6500) by using the color scale conversion equations given in Billmayer and Saltzman (1981):

$$Y^{1/3} = (L^* + 16)/24.99 \text{ (illuminant C)} \quad (1)$$

$$X\%^{1/3} = (a^*/107.72) + Y^{1/3} \quad (2)$$

$$Z\%^{1/3} = Y^{1/3} = Y^{1/3} - (b^*/43.09) \quad (3)$$

Corresponding Hunter $L,a,b$ values were then calculated by using the color scale conversion equations:

$$L = 10^*\sqrt{(Y)}\text{(illuminant C)} \quad (4)$$

$$a = 17.5^*(X\% - Y)/\sqrt{(Y)} \quad (5)$$

$$b = 7.0^*(Y - Z\%)/\sqrt{(Y)} \quad (6)$$

Validation for using illumination C equations for illuminant D6500 conversion is given under Results and Discussion, and calculation of CIE coordinates is discussed in Billmeyer and Saltzman (1981).

**Sensory Evaluation.** An eight-member trained roasted peanut flavor profile panel at the Food Science Department, North Carolina State University, evaluated 399 peanut paste samples using 14-point intensity scales. An orientation session was conducted at the beginning of each peanut crop year evaluation in which the panel reviewed the definition of the following roasted peanut sensory attributes: painty, stale, roasted peanut, overroast, underroast, sweet, fruity, mold, petroleum, bitter, astringent, and throat/tongue burn; the panel then compared selected experimental peanut paste samples to a peanut butter control sample. A handout containing the defined roasted peanut sensory attributes and the control sample with ratings was presented to the panel at each session. The definitions of the sensory attributes which are interactive with peanut butter color are given in Table I. Two sessions were conducted weekly. Panelists evaluated six samples per session the first year and five samples per session in subsequent years presented in a randomized order. Statistical analyses were performed on averages of individual panelists' scores by using SAS procedures (SAS Institute Inc., 1985).

## RESULTS AND DISCUSSION

Statistical validation for application of the color scale conversion equations based on use of illuminant C to color values obtained from illuminant D6500 is presented in Figure 1. The correlation between CIELAB $L^*$ values obtained for illuminate D6500 ($L^*$D65) and illuminate C ($L^*$C) on the Spectrogard color system (Figure 1A) was 0.999, an expected result because the values are internally calculated and based on single position readings. Comparison of CIELAB $L^*$ values from the Minolta system (M$L^*$) has a correlation coefficient of $r = 0.92$. This lower $r$ value results from the reading of the sample at slightly different sampling points in obtaining the illuminant C (M$L^*$C) and illuminant D6500 (M$L^*$D65) values. This sampling point variance is established by comparing $L^*$C and M$L^*$C values and $L^*$D65 and M$L^*$D65 values where random sampling point differences also occur and the correlation coefficient $r$ is 0.96 and 0.93, respectively, between the two instruments. The above comparisons thus show that the equations can appropriately be used to calculate Hunter $L$ values from illuminant D6500 CIELAB $L^*$ values. Applying the same comparisons to CIELAB $a^*$ and $b^*$ values (Figures 1B and 1C) indicates that with our product and instruments calculation of Hunter $a$ values would be appropriate and calculation of $b$ values would not be appropriate.

In our laboratory the Minolta Chroma Meter II CR-100 system has been found to be a rapid and simple method for estimating the lightness values of roasted peanut paste. The correlation coefficient of the CIELAB $L^*$ values obtained from the Spectrogard color system and the Minolta Chroma Meter across the 3 years of this study was $r = 0.96$, and the standard deviations for the CIELAB $L^*$ means from the respective systems were 1.63 and 1.89. These data indicate that we are not giving up accuracy in the data to decrease measurement time. However, the Minolta Chroma Meter system only provides the lightness values as CIELAB $L^*$, and a need exists to relate these values to the appropriate Hunter $L$ values in a quick and simple manner since Hunter $L$ values are the primary

**Table I. Definition of Sensory Attributes Interactive with Peanut Butter Color**

| | |
|---|---|
| roasted peanut | nutty flavor associated with medium-roast peanuts |
| overroast | flavor associated with dark-roast of charred peanuts |
| underroast | flavor associated with light-roasted peanuts and having legumelike character |

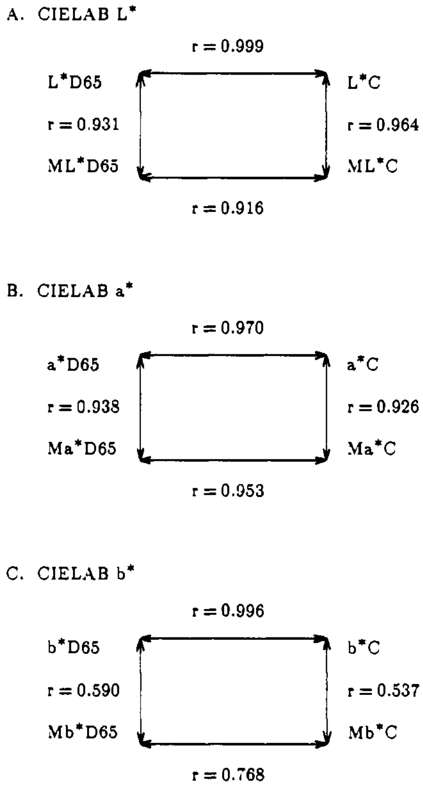


**Figure 1.** Correlation analysis of CIELAB $L^*a^*b^*$ values obtained by using illuminant C (C) and illuminant D6500 (D65) on a Minolta Chroma Meter II CR-100 (M) and a Model 96 Spectrogard color system.

parameter for peanut butter color in the peanut industry. Combining eqs 1 and 4 into a single equation

$$\text{Hunter } L = 10((\text{CIELAB } L^* + 16)/24.99)^{3/2} \quad (7)$$

one can calculate the Hunter $L$ value directly from CIELAB $L^*$ values. This equation can be satisfactorily approximated by

$$\text{Hunter } L = \text{CIELAB } L^* - 7 \quad (8)$$

for CIELAB $L^*$ values in the range 52–65.

The primary objective of this study was to determine if there exists an optimum degree of lightness (CIELAB $L^*$) for roasted peanut paste in the evaluation for the sensory attribute roasted peanut as defined by Pattee et al. (1990). An optimum CIELAB $L^*$ value is extremely important in the evaluation of the intensity of the roasted peanut attribute for the purpose of determining the variation which exists in this attribute across the germplasm sources currently used in U.S. peanut-breeding programs. Data sets from four different studies (three peanut-growing seasons) were used in determining if there was an optimum CIELAB $L^*$ value for obtaining the maximum value for the roasted peanut attribute. The 1986 growing season data had 120 germplasm entry observations (study 1) and showed an optimum CIELAB $L^*$ at 58.7 when analyzed by the SAS general linear models procedure using intensity of the roasted peanut attribute as the dependent variable (Figure 2). A germplasm entry

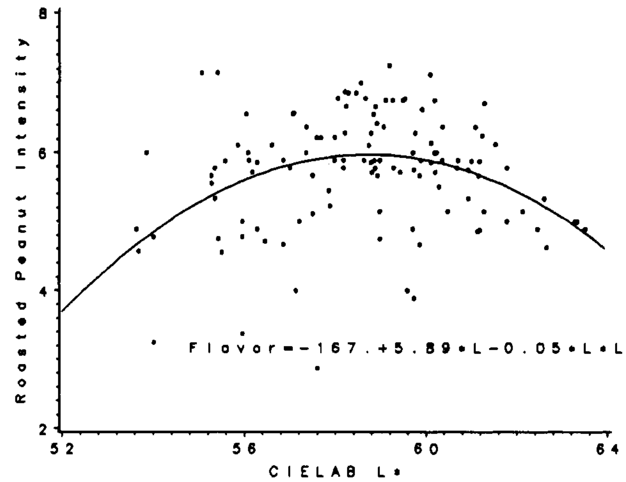


**Figure 2.** Interrelationship between roasted peanut attribute intensity and CIELAB $L^*$ values using 1986 germplasm data set (study 1). Observations = 120.

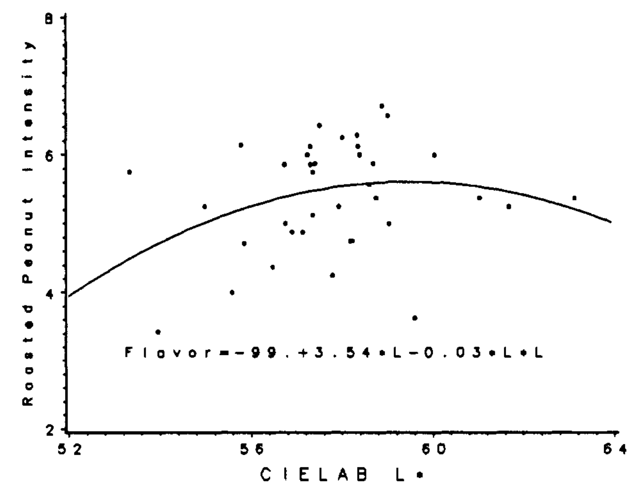


**Figure 3.** Interrelationship between roasted peanut attribute intensity and CIELAB $L^*$ values using 1987 germplasm data set (study 2). Observations = 39.

observation is defined as a single independent sample grown or processed uniquely. The 1987 (study 2) and two 1988 growing season data sets (studies 3 and 4) had 39, 60, and 180 germplasm entry observations, respectively. In these data sets the optimum roasted peanut attribute intensities were observed at CIELAB $L^*$ values equal to 59.5, 59.0, and 58.2, respectively (Figures 3–5). The analyses of variance given in Table II show that there is a statistically significant quadratic relationship between CIELAB $L^*$ values and roasted peanut attribute intensity. The intensities of the roasted peanut attribute near the maximum levels vary across years but these variations, whatever may be their source, have no effect on the optimum CIELAB $L^*$ values. To further examine the interrelationship between CIELAB $L^*$ values and roasted peanut attribute intensities, a multiple regression analysis (GLM) was used to obtain adjustments for overroast and underroast attributes on roasted peanut attribute intensity. This adjustment is needed because roasted peanut attribute intensity is depressed when peanuts are underroasted (high CIELAB $L^*$ values) or overroasted (low CIELAB $L^*$ values). No consistent relationship between CIELAB $L^*$ values and adjusted roasted peanut attribute intensity remained after adjustments to common underroast and overroast attributes. This comparison confirms the nature of the relationship between optimum CIELAB $L^*$ values and optimum roasted peanut attribute intensities. The lack of roasted peanut attribute intensity in

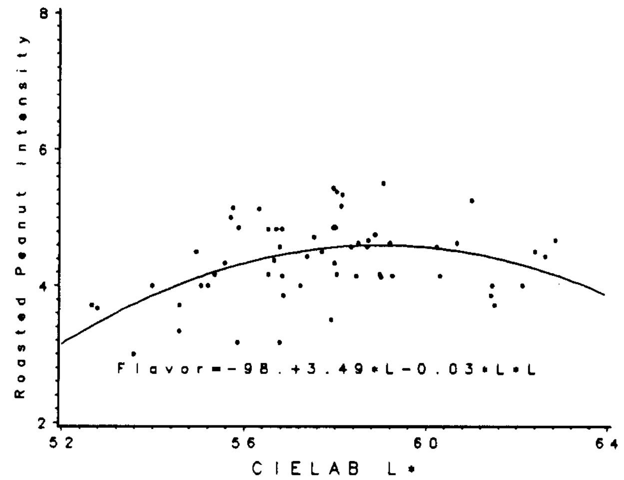


**Figure 4.** Interrelationship between roasted peanut attribute intensity and CIELAB $L^*$ values using 1988 germplasm data set (study 3). Observations = 60.

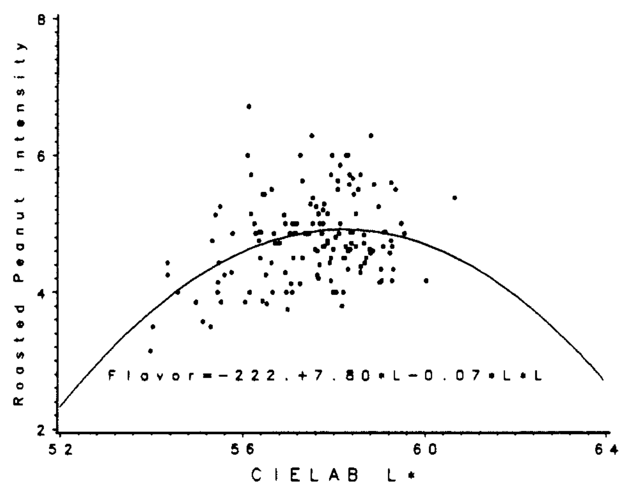


**Figure 5.** Interrelationship between roasted peanut attribute intensity and CIELAB $L^*$ values using 1988 germplasm data set (study 4). Observations = 180.

**Table II. Summary of Statistical Analyses Relating Roasted Peanut Attribute Intensity and CIELAB $L^*$ Values**

| source | MS | $d_f$ | prob |
|---|---|---|---|
| | Study 1 (1986 Germplasm Data Set) | | |
| linear | 0.49 | 1 | 0.38 |
| quadratic | 11.19 | 1 | <0.01 |
| error | 0.62 | 117 | |
| | Study 2 (1987 Germplasm Data Set) | | |
| linear | 0.95 | 1 | 0.22 |
| quadratic | 1.28 | 1 | 0.15 |
| error | 0.60 | 36 | |
| | Study 3 (1988 Germplasm Data Set) | | |
| linear | 1.33 | 1 | 0.03 |
| quadratic | 2.83 | 1 | <0.01 |
| error | 0.23 | 57 | |
| | Study 4 (1988 Germplasm Data Set) | | |
| linear | 4.70 | 1 | <0.01 |
| quadratic | 3.08 | 1 | <0.01 |
| error | 0.35 | 146 | |

underroasted peanuts is obviously a failure to reach the optimum roasted potential level. The relationship with the overroast attribute is not so obvious since the reduction in roasted peanut attribute intensity can be either or both roasted peanut attribute suppression or destruction of the roasted peanut attribute precursors.

Sanders and co-workers (Sanders et al., 1989a,b) have recently indicated that "color differences of 4.1 Hunter $L$ units did not elicit significant differences in roasted peanutty, raw beany or dark roasted flavor descriptors" and thus concluded "generally small differences in roast color among samples should not be considered as a major contributor to noted flavor differences". Our results imply a slightly more complex situation. The curves illustrated in Figures 2–5 show that changes in roasted peanut intensity due to deviations in CIELAB $L^*$ values which are less than 2 units in either direction from optimum will be difficult to detect. Sanders et al. (1989a,b) report Hunter $L$ values in the 45.2–48.9 range, which translates to CIELAB $L^*$ values in the 52.2–55.9 range. This deviates somewhat from the optimum. Our curves show that the difference in roasted peanut intensity between roasting to CIELAB $L^*$ equal to 52 and CIELAB $L^*$ equal to 56 should be approximately 1 unit. To know the number of observations needed to measure a statistical difference of 1 unit at the 5% level of significance, one must first determine the session to session variance of the panel. Our panel session to session variance is given for each year by the error MS in Table II. Combining the four analyses shown in Table II gives us a pooled estimate of the inherent session to session variance across the entire study. The pooled estimate for error MS was 0.45. Using the formulas on page 119 of Steel and Torrie (1980), one sees that two sets of six samples should be adequate to give at least an 80% chance of detecting a difference as small as 1 unit on the roasted peanut intensity scale when using a 5% level of significance. These calculations are conservative in the sense that the residual variance of 0.45 is probably an overestimate. There are no adjustments in the data for differences due to varieties and growing locations of the peanuts.

## SUMMARY

Comparison of the Minolta Chroma Meter II CR-100 system to the Model 96 Spectrogard color system for color analysis of roasted peanut paste samples indicates that the Minolta Chroma Meter II CR-100 system can be used for the rapid measurement needed. Since the Minolta Chroma Meter II CR-100 system only gives directly the CIELAB color values, we have shown that a rapid comparison of CIELAB $L^*$ to Hunter $L$ values can be made by subtracting 7 color units from the CIELAB $L^*$ values. By use of four different data sets across a 3-year period it has been shown that there is an optimum CIELAB $L^*$ value to which peanut should be roasted to obtain the optimum roasted peanut attribute response. Across these data sets the optimum CIELAB $L^*$ varied from 58.2 to 59.5, suggesting that peanut samples should be roasted to a CIELAB $L^*$ of 58–59 or a Hunter $L$ of 51–52 when optimum roasted peanut attribute is of primary interest. Statistical analysis has shown that adjusting for overroast and/or underroast attributes when present reduces the correlation to zero between the roasted peanut attribute and roast color.

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