Determination of Peanut Maturity Using a Hunter Colorimeter

C. C. Grimm[1*], E. T. Champagne[1], and T. H. Sanders[2]

ABSTRACT

Peanut maturity has previously been correlated with the color of the mesocarp of the peanut hull going from light to dark as the peanut matures. In this study, peanuts were sorted into maturity classes of yellow, orange A, orange B, brown and black based on the hull scrape method of Williams and Drexler. The Hunter L*, a*, and b* values were also measured on the dry pods for each class. The color of the mesocarp of freshly harvested peanuts was determined using a Hunter colorimeter. Hunter L*, a*, and b* values on individual peanuts, representative of each class using wet and dry hulls, were reproducibly determined with standard deviations of less than 0.8%. Yellow peanut pods had a median L* value of 70.0, while mature black peanut pods had a median L* value of 51.7 and median values for orange A, orange B and brown pods were, 68.0, 63.7, 57.0, respectively. A similar inverse relationship was observed for the b* value and maturity, while the a* value reached a maximum at orange A. No correlation was observed between the peanut maturity and L*, a*, and b* values acquired with the exocarp intact. Hunter L* and b* values of mesocarps show potential for determining physiological maturity of peanuts.

Key Words: *Arachis hypogaea* L., groundnut, marketability.

Determination of peanut maturity is important at several stages in the course of bringing peanuts to market. The first stage occurs prior to harvest and is used as the primary indicator of when to harvest the peanuts. The optimum time to harvest peanuts is considered to be at the point when 75% or more of the pods are physiologically mature (Sanders, 1989). However, under agricultural settings influenced by soil, water, planting date, and temperature, this maturity distribution may not always be obtainable. The second stage occurs during the processing of the peanut following curing. At the processing stage, peanuts are sorted based on size, which roughly correlates with the physiological state of the peanut. Mature peanuts have been shown to have better flavor and increased shelf life over immature peanuts (Sanders *et al.*, 1989). Over the past decade, separation of peanuts based on physiological maturity rather than size has been used in various studies by peanut researchers, but a rapid, large-scale method would be useful for industrial needs.

Methods for determining peanut crop maturity have been reviewed by Sanders (1982) and include the shell-out method, methanolic extract, arginine maturity index (Young and Mason, 1972), flavenoid development in the mesocarp (Daigle *et al.*, 1980), formation of the arachin polypeptide (Basha, 1989), or the lipid distribution in the peanut seed (Sanders, 1980). However, by far the most widely accepted method for determining when to harvest peanuts is the hull-scrape method (Williams and Drexler, 1981). The method involves removing the exocarp of the peanut to expose the mesocarp. Simple scraping is sufficient but an impact blaster can remove the exocarp from a large number of peanuts (Williams and Monroe, 1986). As the peanut matures, the mesocarp of the peanut hull changes from a white color in the immature peanut to a black color in the mature peanut. During the maturation process the mesocarp color progresses through yellow to orange to brown and finally to black. The color class determination is made by observing the attachment point of the apical seed on the dorsal side of the pod (Fig. 1). This is the

[1]USDA-ARS-SRRC, 1100 Robert E. Lee Blvd., New Orleans, LA 70124.
[2]USDA-ARS-MQHR, Box 7624, NC State University, Raleigh, NC 27695.
*Corresponding author (email: cgrimm@nola.srrc.usda.gov).

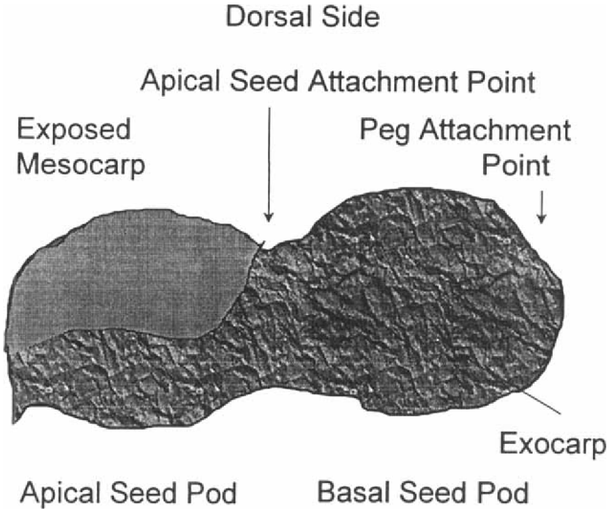

Fig. 1. Diagram and nomenclature associated with a peanut.

same side as the peg attachment point. The maturity distribution is determined by developing histograms based on the number of peanuts in each of the different maturity classes from a sample of the peanut crop.

Various means are available for determining colors in the visible region. One such system that has gained widespread use is the CIELAB or Hunter color system where color space is defined by the variables L*, a*, and b* (Hunter, 1952). The reflected light from a surface illuminated with a specified source is given by L* = lightness, a* = green to red (- to +), and b* = blue to yellow (- to +). Using these variables, a three-dimensional space is defined with the origin being achromatic. Instrumental measurement of these variables can then be transferred to the color space and vice versa. The use of Hunter colorimetry to determine maturity is broad based and has been successfully employed for tomatoes (Young *et al.*, 1993), muskmellon (Forbus *et al.*, 1991), and beef (Cramwell *et al.*, 1996).

Colorimetry is already employed for peanut roast color, which has been correlated with roasted peanut flavor (Chiou *et al.*, 1991; Pattee *et al.*, 1991). Although the peanut shell is rather rough and not conducive to reflectance spectroscopy, the gross color differences between maturity classes of peanuts should be readily discernible. The objective of this study was to determine if a Hunter colorimeter could be used to determine the color of the mesocarp of the peanut and correlate it to the physiological maturity of the peanut.

Materials and Methods

Peanuts. Peanuts used in this investigation were virginia-type (cv. NC 9), grown according to conventional practices and hand harvested from the North Carolina Dept. of Agriculture Peanut Belt Research Station at Lewiston, NC in Oct. 1996. The exocarp was removed from a sub sample of ca. 400 peanuts using the abrasive action of a slurry of small glass beads in water under pressure (Williams and Monroe, 1986). The color of the exposed mesocarp was examined and used to separate the peanuts into maturity classes of yellow, orange A, orange B, brown, and black. The white and yellow categories were combined. Each maturity group contained between 50 to 100 peanuts. The remainder of the sample peanuts were refrigerated for up to 3 mo. The mesocarp color determination was made in the region of the apical seed on the dorsal side of the peanut (Fig. 1). The color classified peanuts then were placed into five separate bags and the remainder of the peanuts (with exocarp intact) were packed on dry ice and sent to the Southern Regional Research Center in New Orleans. Peanuts were kept refrigerated until analysis.

Hunter Colorimeter. A 1/2-in. specimen port was used on a DP-9000, Hunter Colorimeter (Reston, VA) and the tunable lenses adjusted for the smaller sample aperture. The colorimeter was connected to a personal computer via the RS-232 serial port. The system was standardized using the black and white tiles provided with the instrument. Readings of the saddle region of the peanut hull resulted in large errors associated with the dispersive nature of the concave shape of the peanut. Therefore, readings were taken on the dorsal portion of the peanut hull containing the apical seed (Fig. 1). Single and double seed peanuts were measured similarly on the portion of the hull nearest the apical end and on the same side as the peg attachment point. Dry samples were presented "as is" to the specimen port. Wetted samples were dipped into water and excess moisture removed with a tissue prior to placement at the specimen port.

In order to determine the error in analyzing the color of peanut hulls with the Hunter colorimeter, replicate measurements were made. A representative peanut was

Table 1. Mean and standard deviation of 30 Hunter colorimeter readings of a peanut from each maturity class.

Hunter color parameter	Peanut maturity	Sample conditions: Dry Mean	Dry S.D.	Wet Mean	Wet S.D.
L*	Yellow	70.0	0.3	65.5	0.4
	Orange A	65.7	0.3	58.2	0.5
	Orange B	61.2	0.6	54.2	0.6
	Brown	58.2	0.1	47.8	0.8
	Black	50.7	0.5	37.7	0.5
a*	Yellow	-0.3	0.2	0.6	0.3
	Orange A	-0.3	0.5	2.2	0.3
	Orange B	1.4	0.3	3.4	0.4
	Brown	1.2	0.1	3.9	0.2
	Black	-0.3	0.3	2.4	0.4
b*	Yellow	19.9	0.1	26.4	0.4
	Orange A	16.1	0.4	19.9	0.3
	Orange B	12.2	0.2	16.2	0.5
	Brown	10.8	0.1	14.2	0.1
	Black	9.5	0.4	10.2	0.2

selected from each maturity class and repeatedly analyzed 30 times using the Hunter colorimeter. Although the same part of the peanut was presented to the instrument, the sample peanut was rotated approximately 90° between readings. The same peanut then was moistened and an additional 30 readings were taken. The instrument exposes the sample to a white light source and the intensity of the reflected light is monitored by optical sensors. The lightness and chromaticity of the reflected light is given by the L*, a*, and b* values.

Virginia peanuts harvested simultaneously with those in the previous experiment were analyzed with the exocarp intact. Approximately 100 peanuts with the exocarp intact were numbered and analyzed by the Hunter colorimeter. The analysis was repeated twice for a total of three runs. The replicates for each peanut were averaged for the L*, a*, and b* values. The exocarp was removed to expose the mesocarp and the peanut was analyzed three times. A two-sample t-test was used to compare the Hunter values taken of the peanuts with and without the exocarp. No correlation was observed for either the L*, a*, or b* values of the peanuts analyzed with and without the exocarp ($P < 0.20$).

Results and Discussion

Table 1 shows the average and standard deviations of the replicate sampling for the dry and wet readings for each of the five maturity classes. Standard deviations ranged from 0.1 to 0.6 for the L* value for dry peanuts and were slightly greater for wet peanuts. Standard deviations were lower for the a* and b* values, and as with the L* values a slight increase was observed in the standard deviations of the wet values relative to the dry values. This amount of error is elevated relative to a sample with a smooth surface, but is acceptable for a sample with a rough surface. For the L* value, the effect of wetting the peanut hull was greatest on the mature peanuts and least on the immature peanuts. The opposite relationship was observed for the b* value, where the immature peanuts gave the largest difference between the wet and dry readings. For the a* value, the maximum difference occurred for the brown peanut class.

The data in Table 2 indicate an inverse correlation of the L* and b* values with increasing maturity, while the a* value first increased with maturity reached a maximum between the orange B and brown peanut classes and then decreased. The dry values cover a smaller range than the wet values, i.e., the L* value ranges from 70.0 ± 0.3 for the immature peanut to 50.7 ± 0.5 for the mature peanut. The L* value for the same peanuts with a wetted surface resulted in values of 65.5 ± 0.4 and 37.7 ± 0.5 for the for the immature and mature peanut, respectively.

Figure 2 shows the comparison of analyzing peanuts with the hull in the dry state and in the wet state. The exocarp was scraped off and the residual powder removed with a bristle brush from 100 peanuts selected at random. Readings of the mesocarp were taken with the peanut in the dry state for each of the 100 peanuts and then the process was repeated twice more and the values averaged. The peanuts were then wetted and

Table 2. Hand-sorted vs. Hunter colorimeter data.

Hunter color parameter	Peanut maturity	No. samples	Mean	S.D.	Median	Min.	Max.
L*	Yellow	94	69.4	2.3	70.0	63.7	73.5
	Orange A	83	67.9	2.2	68.0	61.4	73.4
	Orange B	69	62.8	4.0	63.7	51.7	69.6
	Brown	79	57.0	4.1	57.0	49.0	67.6
	Black	57	51.9	4.4	51.7	42.0	58.9
a*	Yellow	94	-2.2	1.4	-2.1	-6.0	1.7
	Orange A	83	-0.7	0.9	-0.6	-3.0	1.9
	Orange B	69	1.0	1.0	0.9	-2.1	3.2
	Brown	79	0.1	1.3	0.0	-2.8	3.3
	Black	57	0.5	1.2	0.5	-2.3	2.3
b*	Yellow	94	21.5	1.8	21.3	17.6	26.3
	Orange A	83	20.0	1.5	20.2	15.2	23.7
	Orange B	69	17.2	2.1	17.7	12.3	21.3
	Brown	79	13.5	2.2	13.2	9.8	20.0
	Black	57	10.7	1.4	10.7	7.6	13.5

readings taken. In order to obtain reproducible readings of the wetted hulls, rewetting of the samples was required between analyses. The peanuts hulls with the wetted surface gave a larger range for the L*, a*, and b* values with only a slight increase in error relative to the dry samples; however, analysis of wet samples presented some problems. To obtain repeatable measurements on the wetted samples, they were immersed into water immediately before analysis and then excess water removed with a tissue. Hunter L*, a*, and b* readings changed in a matter of minutes as the hulls began to dry.

Hunter L*, a*, and b* values for the wet and dry readings are plotted in Fig. 2. Correlation between the wet and dry readings were observed for the Hunter L* and b*, with linear correlation coefficients of 0.856 and 0.887, respectively. No correlation was observed between the wet and dry readings for the Hunter a* values, with a correlation coefficient of 0.029 (Fig. 2B). A correlation between the wet and dry values would not be expected for the Hunter a* value because it is bimodal, with a maximum value observed at the orange B maturity class.

The peanuts with the exocarp removed and previously sorted into different maturity classes were then analyzed in triplicate. The exposed mesocarp was presented to the colorimeter in the dry state. The averaged L*, a*, and b* values, standard deviations, and median, minimum and maximum values from each maturity class are given in Table 2 and the data are plotted in Figure 3. The L* values range from the high 40s for mature peanuts to the low 70s for immature peanuts (Fig. 3A). The ranges of the Hunter values overlap from one maturity group to another. This can be attributed to color variation within a pod. The colorimeter sees only a small portion of the total pod and makes its reading based on that one area. Peanuts with maturities that lie midway between two

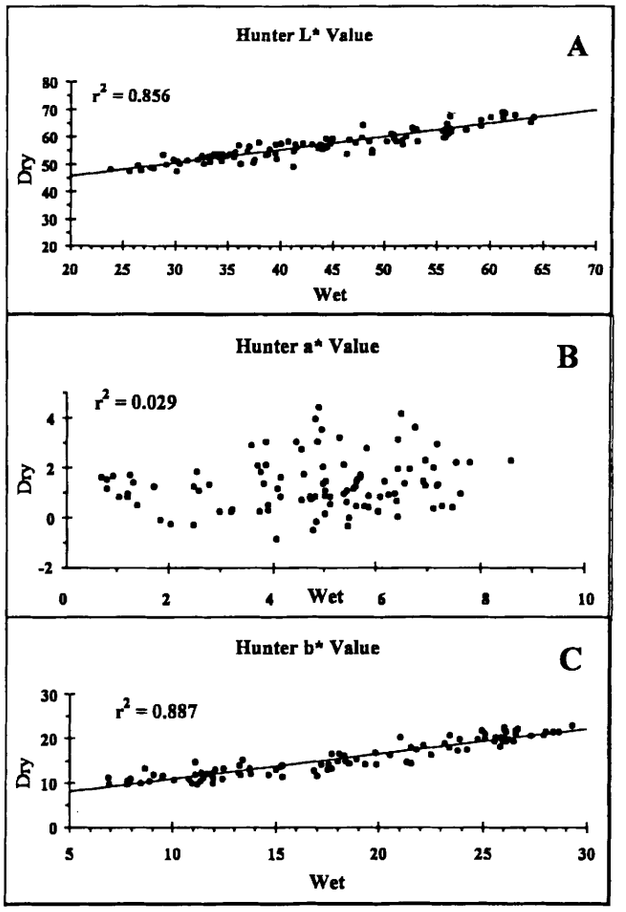

Fig. 2. Analysis of the mesocarp of 100 peanuts with a dry hull and a wet hull. [A] L* value. [B] a* value. [C] b* value.

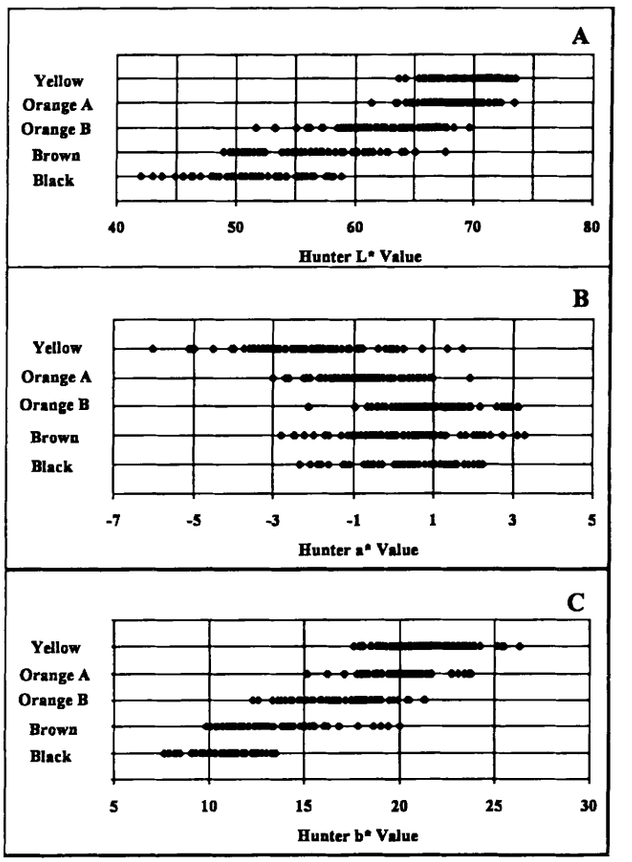

Fig. 3. Comparison of maturity classified manually vs. the Hunter colorimeter. [A] L* value. [B] a* value. [C] b* value.

classifications could easily be classified differently. Additionally, the areas of the peanut used for the manual classification and the instrumental were different. The original error in classifying the peanuts by hand is unknown and an objective method for determining that error is not available.

As observed with the wet and dry experiments, there was a readily discernible relationship between peanut maturity and the Hunter L* and b* values (Fig. 3A,C). The Hunter a* value is bimodal (Fig. 3B) and may provide a secondary confirmation. Using either the L* or b* value, peanuts can be classified as yellow, orange A, orange B, brown or black by using the average value of the two medians between classes as the separation criteria. For instance the classification of yellow would apply to all peanuts with a mesocarp giving an L* value of greater than 69 where [(68 + 70)/2] is the average value of the medians of the yellow and orange A classes. The b* value could be used as a check to insure that the proper classification had been made.

The use of numerical data allows for the easier implementation of new criteria. Rather than the five color classifications for maturity used here, additional sub-classifications are possible or just the opposite, the number of classes can be reduced. Depending upon the application, an L° value of 55 may be used to separate mature from immature peanuts. Additionally, statistical information from a representative aliquot of samples could be used to gauge the maturity distribution of the crop and consequently assist in gauging the economic value of the crop.

Conclusions

An instrumental approach for refining and enhancing the hull scrape method of Williams and Drexler (1981) for the determination of peanut maturity has been examined. The Hunter colorimeter has been shown capable of determining the physiological maturity of a peanut based upon the color of the mesocarp. Reproducible readings can be obtained for either wet or dry samples in a totally objective manner. The ultimate result is a more accurate assessment of the maturity distribution for a given crop of peanuts. Classification of maturity on peanuts with the hull intact using the colorimeter was not possible.

Acknowledgments

We thank Kimberley Jackson for the initial work on the Hunter Colorimeter, and Bryan Vinyard for suggestions on statistical analysis.

Literature Cited

Basha, S. M. 1990. Protein as an indicator of peanut seed maturity. J. Ag. Food Chem. 32:373-376.

Chiou, R. Y. Y., Y. S. Chang, T. T. Tsai, and S. Ho. 1991. Variation of flavor-related characteristics of peanuts during roasting as affected by initial moisture contents. J. Ag. Food Chem. 39:1155-1158.

Cranwell, C. D., J. A. Unruh, J. R. Brethour, and D. D. Simms. 1996. Influence of steroid implants and concentrate feeding on carcass and longissimus muscle sensory and collagen characteristics of cull beef cows. J. Anim. Sci. 74:1777-1783.

Daigle, D. J., E.J. Conkerton, T. H. Sanders, and A. C. Mixon. 1988. A. C. peanut hull flavonoids: Their relationship with peanut maturity. J. Ag. Food Chem. 36:1179-1181.

Forbus, W. R. Jr., G. G. Dull, and D. Smittle. 1991. Measuring netted muskmelon maturity by delayed light emission. J. Food Sci. 56:981-984.

Hunter, R. S. 1952. Photoelectric tristimulus colorimetry with three filters. U.S. Dept. Comm. Nat. Bur. Std. (U.S.) Circ. C, p. 429.

Pattee, H. E., F. G. Giesbrecht, and C. T. Young. 1991. 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. J. Ag. Food Chem. 39:519-523.

Sanders, T. H. 1980. Fatty acid composition of lipid classes in oils form peanuts in variety and maturity. J. Amer. Oil Chem. Soc. 57:12-15.

Sanders, T. H. 1989. Maturity distribution in commercially sized Florunner peanuts. Peanut Sci. 16:91-95.

Sanders, T. H, A. M. Schubert, and H. E. Pattee. 1982. Postharvest physiology and methodologies for estimating maturity, pp 624-654. *In* H. E. Pattee and C. T. Young (eds.) Peanut Science and Technology. Amer. Peanut Res. Educ. Soc., Youkum TX.

Williams, E. J. and J. S. Drexler. 1981. Hull scrape method - A nondestructive method for determining peanut pod maturity. Peanut Sci. 2:134-141.

Williams, E. J., and G. E. Monroe. 1986. Impact blaster for peanut pod maturity distribution. Trans. Amer. Soc. Agric. Eng. 29:263-266.

Young, C. T., and M. E. Mason. 1972. Free arginine content of peanuts (*Arachis hypogaea* L.) as a measure of seed maturity. J. Food Sci. 37:72-725.

Young, T.E., J. A. Juvik, and J. G. Sullivan. 1993. Accumulation of the components of total solids in ripening fruits of tomato. J. Amer. Soc. Hort. Sci. 118:286-292.