A Laboratory Colorimeter Method to Measure Pod Brightness in Virginia-Type Peanuts

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ABSTRACT

Pod brightness is an important characteristic that influences consumers to purchase in-shell peanuts. A method is needed to quantitate pod brightness. Studies were conducted to determine whether pod color measurements were related to visual aesthetics rated by a panel representing seven virginia peanut shelling companies and to determine the effect of the optical aperture of the colorimeter on the measurements obtained. Forty-eight virginia-type pod lots were separated into fancy and jumbo fractions using a standard Federal-State Inspection Service grading peanut sizer. Pod color was measured for three subsamples of each fraction using a Hunterlab D25-PC2 colorimeter equipped with the D25-2RAL Reduced Area Viewing for L optical sensor (51-mm diameter sample area). The 96 samples also were rated by 11 Virginia-Carolina area shellers for pod color and size. Sheller ratings for the two traits were highly correlated ($r > 0.6$, $P \leq 0.01$). Hunter L and b scores were strongly correlated with sheller color ratings. The colorimeter is a useful tool for measuring pod brightness as an adjunct to breeding for improved pod brightness. Use of a 95 mm aperture resulted in greater average Hunter L, a, and b scores and significantly reduced the variance among subsamples. The larger aperture should be used when the quantity of pods available for measurement permits.

Key Words: *Arachis hypogaea* L., Hunter L, pod color.

In recent years, sales of in-shell products have dominated the virginia-type peanut (*Arachis hypogaea* L.) market. Peanut shellers in the Virginia-Carolina production area indicate that pod brightness is a key factor in the consumer's decision to purchase in-shell peanut products. Shellers have expressed their concern regarding the release of new virginia-type cultivars with pods that have a tendency to be darker, reducing the visual aesthetics or "eye appeal" of in-shell products (Virginia-Carolina Peanut Shellers Assoc., pers. commun., 1995). Shellers commonly use electronic color sorters in their pod sorting processes to eliminate darkened and defective pods from lots of in-shell products. Breeders need to incorporate measurements of visual aesthetics into their grading procedure to make sure that new cultivars will benefit not only growers through higher yields and better market grades, but that they also have bright pods that are acceptable to shellers and consumers of in-shell products.

Color is a key characteristic not only for peanut but also for most horticultural crops. Colorimetry has been used in many horticultural crop species to determine desirable and undesirable quality characteristics (Anon., 1990; Higashio *et al.*, 1992; Mabon, 1993; Floyd *et al.*, 1995). For strawberry (*Fragaria* spp.), colorimetry has been used as an adjunct to breeding programs (Shaw, 1991; Shaw and Sacks, 1995). In peanut, visual standards for pod color have been established by the USDA as part of the grading process for in-shell peanuts, but the standards are subjective (USDA, 1994). Colorimetry has been used to assess peanut pod disease, and Hunter L and b scores were found to be highly correlated with visual ratings of pod discoloration due to pod rot organisms (Parker *et al.*, 1989).

The objectives of this study were to determine whether (a) color data obtained with a laboratory colorimeter are significantly related to visual aesthetics as determined by a panel of experts, (b) data obtained using the 95 mm aperture on the Hunter Lab optic sensor are consistent with data obtained using the 51-mm aperture, and (c) differences exist between apertures in the precision of measurement.

Materials and Methods

Colorimeter Data and Sheller Preference Scores. Peanut pod lots were obtained from 48 cultivars and breeding lines grown at the N.C. Dept. of Agriculture Peanut Belt Res. Stn. at Lewiston, NC in 1995. The 48 entries were grown unreplicated in a field with heterogeneous soil in plots consisting of two 66-m rows spaced 91 cm apart with plants spaced 25 cm apart within rows. All plots were planted on 5 May 1995, dug on 3 Oct. 1995, and combined on 13 Oct. 1995. Pods were exposed to 78 mm of rain between digging and combining. Fancy and jumbo pods were separated from each lot using a Federal-State Inspection Service rolling grader following removal of foreign material, creating 96 individual samples. Samples were stored at room temperature (approx. 25 C) in plastic food storage bags following separation.

Pod color was measured using a Hunterlab D25-PC2 colorimeter equipped with the D25-2RAL Reduced Area Viewing for L optical sensor (51-mm diameter sample area). Color was measured on fancy and jumbo samples from each of the 48 pod lots. The colorimeter registered three scores: the "Hunter L" score measured brightness with a score of 0 indicating complete blackness and 100 indicating perfect whiteness; the "Hunter a" score measured color on a red-green scale with positive scores indicating redness and negative scores indicating greenness; and the "Hunter b" score similarly measured color on a blue-yellow scale with positive scores of greater magnitude indicating more intense yellow color (Billmeyer and Saltzmann, 1981). For

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each sample, three subsamples were poured into three 2-L glass beakers for presentation to the optical sensor. The three beakers were used in a random rotation for each set of three subsamples. For each reading, the beaker was centered over the aperture beneath the beaker. A total of 288 readings included 48 lots each with two pod grades and three subsamples per grade.

Ratings of visual aesthetics were obtained in a session with 11 individuals representing seven shelling companies in the Virginia-Carolina area (Table 1). These individuals are hereafter called "shellers." The session was held at the Severn Peanut Co. headquarters at Severn, NC on 4 March 1996. Fancy and jumbo samples were presented separately to the shellers. Each set of samples was randomized. Shellers were asked to make a preference rating for each sample separately for color and size using a 1 to 10 scale with higher scores indicating better acceptability. Sheller ratings were subjected to analysis as a split plot design with shellers as replications as whole plots, and pod sizes as subplots.

Table 1. Individuals who participated in visual ratings of pod aesthetics.

Individual	Representing
Tom West	Birdsong Storage Co., Factory Street, Suffolk, VA 23434
Dawson Rascoe	Gillam Brothers Peanut Co., P.O. Box 284, Windsor, NC 27983
Billy Barrow	Golden Peanut Co., 303 S. Saratoga St., Suffolk, VA 23434
Graham O'Berry	Golden Peanut Co., P.O. Box 284, Ahoskie, NC 27910
Mark Hodges	Hancock Peanut Co., L.P., P.O. Box 100, Courtland, VA 23837
Hal Burns	Jimbo's Jumbos, P.O. Box 465, Edenton, NC 27932
Dallas Barnes	Severn Peanut Co., Inc., P.O. Box 710, Severn, NC 27877
Carl Gray	"
Lori Jones	"
Elbert J. Long	"
Leonard Stanton	"

Aperture Size Data. To compare colorimeter data for different size apertures, the jumbo samples previously used were remeasured. Three subsamples of each jumbo pod sample were poured into three 3-L glass beakers for presentation to the optical sensor. For each reading, the beaker was centered over the sensor aperture located beneath the beaker. All three subsamples were measured using both the 51- and the 95-mm apertures. For each aperture change, the sensor was recalibrated. To present the same overall pod surface to the sensor in each set of readings, particular care was given not to agitate subsamples between readings. A total of 288 readings included 48 jumbo samples with three subsamples each and two readings per subsample using different aperture sizes.

Hunter L, a, and b scores were subjected to two analyses of variance. The first analysis combined readings using both apertures and tested the significance of the effects of samples, subsamples, aperture, and sample-by-aperture interaction. The second analysis estimated variance among subsamples separately for data obtained using the large and small apertures. These variances were compared using a two-tailed F test. Analysis of covariance was performed and correlation coefficients estimated for the paired data on subsamples for the large and small apertures.

Results and Discussion

Comparison of Colorimeter Data and Sheller Ratings. Hunter L, a, and b scores for the 96 fancy and jumbo pod samples varied significantly (Table 2). Pod lots were a highly significant source of variation. Since it was not the purpose of this study to determine the source of variation among samples, whether the variation was due to genotypic or environmental factors is not relevant. Pod size had a highly significant effect on L and b scores with jumbo pods having higher L and b scores, i.e., brighter, yellower pods. Lot-by-pod-size interaction was significant ($P \leq 0.05$) for Hunter a and b scores and verged on significance for L scores ($P \leq 0.10$). Because this interaction appeared to be present, data from fancy and jumbo pods were kept separate for the calculation of correlations among traits.

Table 2. Percent of total sum of squares (SSTo) and mean squares from analysis of variance of Hunter L, a, and b scores on fancy and jumbo pods from 48 virginia-type peanut cultivars and breeding lines.

		L Score		a Score		b Score	
Source	df	SSTo	MS	SSTo	MS	SSTo	MS
		%		%		%	
Total	287						
Pod lot	47	54.3	11.56**	38.0	0.26**	71.7	5.50**
Pod size	1	4.9	48.92**	0.0	0.01	2.8	10.24**
Pod lot × Pod size	47	10.1	2.15†	16.6	0.11*	6.7	0.52*
Error	192	30.7	1.60	45.3	0.08	18.7	0.35

†,*,**Denote mean squares significant at $P \leq 0.10$, $P \leq 0.05$, and $P \leq 0.01$, respectively.

Sheller ratings of color and size also varied significantly. Shellers were a significant source of variation (Table 3), indicating that different shellers had somewhat different opinions as to the relative aesthetics of the overall pod sample. However, sheller-by-sample interaction [Error (a)] was not significant for either of the two ratings indicating that the pod samples maintained their relative ratings regardless of which sheller was assigning the ratings. As was found for the colorimeter scores (Table 2), pod size was a significant factor in sheller ratings with jumbo pods receiving generally superior ratings for both characteristics. There was significant sheller-by-pod-size interaction for size ratings indicating that there was variation among shellers in the differential between ratings they gave to fancy and jumbo pods. However, there was no significant sheller-by-pod-size interaction for pod color.

Table 3. Percent of total sum of squares (SSTo) and mean squares from analysis of variance of sheller ratings on fancy and jumbo pods from 48 virginia-type peanut cultivars and breeding lines.

Source	df	Color SSTo	Color MS	Size SSTo	Size MS
		%		%	
Total	1055		2.37		1.88
Shellers	10	16.9	42.17**	27.0	53.54**
Pod lot	47	41.6	22.12**	10.8	4.55**
Error(a)	470	19.5	1.04	25.6	1.08
Pod size	1	5.1	127.55**	2.4	47.52**
Pod lot x pod size	47	4.4	2.34*	5.4	2.29
Error(b)	480	29.4	1.53	55.8	2.30
Sheller × pod size	10	0.9	2.25	8.8	17.50**
Sheller x pod lot × pod size	470	28.5	1.51	47.0	1.98

*,**Denote mean squares significant at P ≤ 0.05 and P ≤ 0.01, respectively.

Correlations among the characteristics were generally greater than zero with a few exceptions (Table 4). Correlations between fancy and jumbo pods for Hunter L and b scores (r ≥ 0.70) were highly significant (P ≤ 0.01). Correlations between L and b scores for a given pod size were highly significant and stronger (r ≥ 0.80). Correlations among the sheller ratings of color and size were significantly greater than zero. This may have occurred because the ratings for color and size were made in a single viewing, providing an opportunity for nonindependence of ratings. The correlations of shellers' color ratings with Hunter L and b scores were highly significant and ranged from 0.65 to 0.86. Measurement of color and brightness by colorimeter appears to be more objective than shellers' ratings of color and were still well correlated with those ratings.

Comparison of Aperture Size Data. During the collection of color data, the presence of a single discolored pod within the area presented to the colorimeter's optic sensor caused marked changes in the Hunter L, a, and b values obtained. Because the aperture of the instrument was only 51 mm, a single pod could occupy a large proportion of the total aperture area. A larger viewing aperture may lessen the effect of random discolored hulls on the values by including more pods within the viewing area and thereby reducing the impact of a single hull on the readings.

In the combined analysis of variance of data collected on jumbo pods using the small and large (95 mm) apertures, aperture was a highly significant source of variation for all three aspects of pod color (Table 5). Measurement using the larger aperture resulted in higher average Hunter L, a, and b scores (Table 6) due to greater saturation of the colorimeter sensor. There was no significant sample-by-aperture interaction for any color trait, indicating that the relative values for samples were essentially unchanged by the aperture. The correlation between sample means using the large and small apertures was 0.96 (P ≤ 0.01) for the L score, 0.77 (P ≤ 0.01) for the a score, and 0.98 (P ≤ 0.01) for the b score. Data collected using the large aperture exhibited significantly lower variation among subsamples for L and b scores (Table 6). The subsample variation for a score collected with the larger aperture was not significantly lower than that obtained with the smaller aperture. The combination of greater means and reduced subsample variance for all three traits resulted in substantial decreases in the coefficient of variation obtained using the larger aperture (Table 6).

Summary and Conclusions

The data presented show that the colorimeter can be used to evaluate pod brightness objectively. The quantitative values measured by the colorimeter were highly correlated with subjective ratings of pod brightness made by industry experts. Thus, this method provides the breeder with a quantitative rather than a subjective measurement of pod brightness. Use of the colorimeter obviates the necessity of convening panels of experts to evaluate pod brightness. Based on comparison of large and small viewing apertures, the larger aperture should be used whenever the pod sample is adequate.

Table 4. Correlations among Hunter L, a, and b values measured by colorimeter and characteristics rated by a panel of shellers.[a]

		Color		Size		L score		a score		b score	
		Fancy	Jumbo	Fancy	Jumbo	Fancy	Jumbo	Fancy	Jumbo	Fancy	Jumbo
Color	Fancy	--	0.83**	0.61**	0.58**	0.65**	0.74**	0.60**	0.36*	0.79**	0.74**
	Jumbo	0.83**	--	0.42**	0.81**	0.60**	0.77**	0.57**	0.26	0.81**	0.86**
Size	Fancy	-0.61**	0.42**	--	0.34*	0.24	0.32*	0.30*	0.06	0.32*	0.28
	Jumbo	0.58**	0.81**	0.34*	--	0.38**	0.60**	0.51**	0.00	0.63**	0.73**
L score	Fancy	0.65**	0.60**	-0.24	0.38**	--	0.70**	0.29*	0.08	0.83**	0.55**
	Jumbo	0.74**	0.77**	0.32*	0.60**	0.70**	--	0.41**	0.33*	0.79**	0.86**
a score	Fancy	0.60**	0.57**	0.30*	0.51**	0.29*	0.41**	--	0.39**	0.62**	0.65**
	Jumbo	0.36*	0.26	0.06	0.00	0.08	0.33*	0.39**	--	0.23	0.41**
b score	Fancy	0.79**	0.81**	0.32*	0.63**	0.83**	0.79**	0.62**	0.23	--	0.83**
	Jumbo	0.74**	0.86**	0.28	0.73**	0.55**	0.86**	0.65**	0.41**	0.83**	--

[a]Critical values of r with 46 df are 0.2850 at P ≤ 0.05 and 0.3684 at P ≤ 0.01.

*,**Denote mean squares significant at P ≤ 0.05 and P ≤ 0.01, respectively.

Table 5. Mean squares from combined analysis of variance of Hunter L, a, and b scores collected using small (51 mm) and large (95 mm) apertures.

Source	df	L score	a score	b score
Total	287	4.1784	0.1417	1.5818
Sample	47	13.4340**	0.3073**	6.7881**
Subsample in sample	96	2.5923**	0.0937**	0.8054**
Aperture	1	275.1467**	12.5835**	45.0459**
Sample × aperture	47	0.2786ns	0.0397ns	0.0843ns
Error	96	0.3198	0.0290	0.0897

ns,*,**Denote mean squares that are not significant, significant at $P \leq 0.05$ and significant at $P \leq 0.01$, respectively.

Table 6. Estimates of population parameters from Hunter L, a, and b scores recorded using small and large apertures.

Estimate	Aperture	L score	a score	b score
Mean	Small	41.40	3.00	13.53
	Large	43.36	3.42	14.32
Subsample mean square	Small	1.9272	0.0667	0.5665
	Large	0.9849	0.0560	0.3285
F test with 96 and 96 df		1.957 **	1.191 ns	1.724*
CV (%)	Small	3.4	8.6	5.6
	Large	2.3	6.9	4.0

ns,*,**Denote F ratios that are not significant, significant at $P \leq 0.05$ and significant at $P \leq 0.01$, respectively.

Acknowledgmnts

The authors gratefully acknowledge the technical assistance of Keith W. Hendrix of the USDA-ARS Market Quality and Handling Research group, Raleigh, NC.

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Accepted 16 July 1997