A Diffuse Reflectance Measuring Instrument to Determine Peanut Pod Brightness

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Abstract. *For Valencia peanuts, pod brightness is determined by inspectors during the peanut grading process when peanuts are sold by the grower. Presently, inspectors make visual observation of each peanut pod, from a sample drawn from a bigger lot, and determine the percentage of discolored pods present in the sample. The percent discolored pods is one of ten grade factors that determines the price at which the Valencia peanuts are sold. The visual method seems to be reliable, but it may not be consistent among inspectors nor over time due to the human element involved. An instrument may be more consistent and objective. The design and operation of an optical system for this purpose is described here. A narrow beam of white light was collimated onto the surface of a peanut pod at four consecutive positions spaced at 90° intervals around the circumference of the peanut pod. Diffuse reflectance from the peanut surface was measured at each position using a silicon detector with UV enhanced response. The average of these four values was a good indicator of the pod brightness and was used to detect discolored peanuts. Percent discolored pods determined using this instrument was highly correlated (r^2 = 0.98) with the visual evaluations made by inspectors.*

Keywords. *Detector, Discolored, Pod brightness, Reflectance, Valencia peanuts.*

Valencia type peanuts are well known for their sweeter taste than other peanut types and are grown almost exclusively in New Mexico. Valencia peanuts are consumer marketed by processors, mostly in shell, after farmer marketing. Shell brightness of the peanut pods is an important consumer factor for Valencia peanuts. During farmer marketing, the peanuts are graded based on pod discoloration. If the percent discolored pods from a lot is 25% or greater, the lot value is reduced (Blankenship et al., 2002). Trained inspectors visually inspect samples from a lot and subjectively determine the percentage of discolored pods in the lot. This method is prone to inconsistencies and can result in economic losses to the buyer or the seller. Presently, there are no simple or inexpensive instruments to make this determination objectively.

Early attempts were made to measure the reflected light using bidirectional geometries (Black, 1973) or diffuse geometry using integrating spheres (Hardy, 1938) as specified by the CIE (1986). However, the process of illumination or reflection of light from a peanutpod does not strictly fall into either of the above geometries. In the CIE geometries, the illumination is assumed to be either directional or diffuse. In reality, the illumination is a combination of both. In addition, the pod surface cannot be classified as totally glossy or completely diffuse. Using the above geometries, very little, if any, specular reflection from a peanut pod occurs. Therefore, the pod surface can be termed as more diffuse. For mostly diffuse materials, all geometries correlate closely with the visual determinations (Berns, 2000); therefore, the illumination system does not have to strictly conform to the CIE geometries. Ultimately, modifying the CIE geometries to give the best correlation between the instrument values and the visual values to suit the type of surface under study should produce the best results. Others have recently developed instrumentation for peanut pod brightness using two contrast sensors (Blankenship et al., 2002) and digital video imaging techniques (Bolder et al., 2002).

Objective

The goal of this project was to develop a relatively low-cost instrumentation system that:

- Objectively measures the hull brightness of whole peanut pods.
- Classifies peanut pods as acceptable or discolored.
- Accurately determines the percent of discolored pods in a sample when compared to experienced inspectors.

Materials and Methods

Description of the Instrument

The instrument consists of a collimator, a receiver, and a feed-tube into which the pods are dropped for brightness measurement (fig. 1). The collimator (1 in fig. 1) is a 250 mm long aluminum tube with a 50 mm external diameter. The light source is a 12 V, 25 W single-filament tungsten lamp sitting at the focal point of a 25 mm diameter convex lens of 50 mm focal length. Two iris diaphragms regulate the light into a 5 mm diameter beam that impinges on the peanut pod.

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Mention of company or trade names is for purpose of description only and does not imply endorsement by the USDA.

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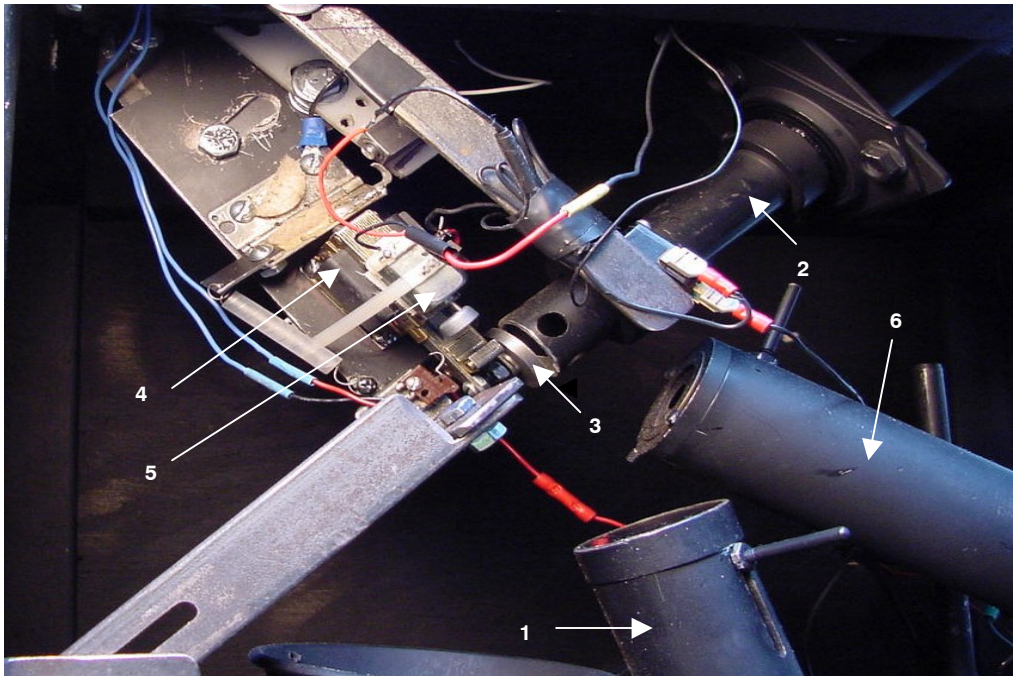

Figure 1. Instrument assembly: (1) collimator, (2) feed tube, (3) plastic plate, (4) solenoid, (5) vibrator, and (6) receiver.

The feed tube is a 350 mm long aluminum tube of 25 mm inner diameter with four 9 mm holes drilled on its circumference, 3 mm from the near end. The feed tube is fixed at an angle of 45° to the base of the instrument. A 20 mm diameter plastic plate is attached to the plunger of a solenoid, as shown in figure 1, and hangs close to the near end without touching the tube. When a peanut is dropped into the tube from the top, or feeding end, it rests on this plate. The laminated, type 16 solenoid (Guardian Electric Manufacturing Co., Woodstock, Ill.) operates on 110 VAC and has a lift of about 20 mm. A 6 VDC vibrator (model AKME-C, Panasonic) is mounted on the solenoid. A microswitch mounted on a supporting rod to the left of the plunger controls the movement of the plunger. The feed tube goes through a shaft at the feeding end and is fitted with a gear wheel that meshes with that of a drive motor. A proximity switch senses four stopper pins positioned on the circumference of the feed tube and stops the motor in these four positions. Each stop corresponds to one of the four hole positions on the near end with the hole in alignment with the light beam. The drive motor (model NSH 11 D4, Bodine Electric Co., Chicago, Ill.), in conjunction with a programmable multifunction time delay relay/counter (model CNT-35-96, Siemens), ensures that each hole in the feeder tube aligns correctly with the light beam for a set time period. At the end of the fourth time period, the solenoid is activated, pulling the plastic plate up, and the peanut drops into a tray below the near end of the feeding tube.

The receiver has similar dimensions to the collimator and is fitted with an iris diaphragm at the top. A 25 mm diameter convex lens with a 50 mm focal length gathers the light reflected from the sample and focuses it through a 12 mm tunnel drilled centrally along the length of the receiver to a silicon detector at the other end of the receiver. The wall of the tunnel is polished to minimize light absorption. The aperture of the iris diaphragm was adjusted to collect most of the light reflected from the sample by the receiver lens. A 15 mm opening was adequate, considering the incident beam size (5 mm), the distance between the sample surface and the receiver, and the average curvature of the surface of the pods. The silicon detector is a 12 mm diameter, unbiased, UV enhanced-response type (Edmund Industrial Optics, Barrington, N.J.) with an active area of 20 mm^2. This detector has a response of about 0.16 A/W at 400 nm and 0.47 A/W at 700 nm, which is suitable for the visible range. An electronic circuit amplifies the output from the detector and feeds it to a data acquisition module (model 232SDA12, B&B Electronics, Ottawa, Ill.). A laptop computer logs and analyzes the data.

Experimental Procedure

Two cylindrical references, one white and one black, were constructed from Teflon. Each reference was 25 mm long and 12.5 mm in diameter. The collimator initially was set 45° from the normal to the feed tube, while the receiver was along the normal. The white reference was dropped into the feed tube, and the system was switched on. At the start of the measurement process, the vibrator motor vibrates for 3 s. The test piece settles across the first hole in the feed tube along the length of the tube during this time. The light beam emerging out of the collimator falls on the test piece through the hole, and the reflected light is collected and focused on the silicon detector. The current signals from the detector are amplified and measured. After the measurement is registered by the computer, the feed tube rotates 90° and stops with the test piece at the second hole. The vibrator starts again to facilitate proper alignment of the test piece as before, and the measurement process starts again. This is repeated for the third and fourth holes. The feed tube stays at each hole position for 7 s before returning to the initial (first hole) position. After the measurements are done on the fourth hole, the solenoid is energized, the plunger moves up, and the test piece drops down by gravity into a tray.

These measurements were repeated with the black reference, and the average value of the four measurements

was recorded on the computer. The difference of these two averages represents the range in the reflectivity between a white and a black surface. Maximizing the range improves the ability to detect smaller variations in the reflected light. This was achieved by slightly tilting the collimator and the receiver with reference to the normal, and taking care that the surface of the detector is always fully illuminated. The maximum range value was obtained when the collimator was set at 25° below the normal and the receiver at 20° above the normal (fig. 1). The collimator and receiver were fixed in this position, and the reflectivity value with the black reference was taken as the instrument zero value. The zero drift of the instrument was checked periodically by measuring the black reference reflectivity and comparing it with the zero value.

The peanut samples used in this test were of the Valencia type, harvested during 2001, and were graded by New Mexico inspectors in Portales, New Mexico. The graded samples, consisting of about 60 to 80 pods per sample, were packed into paper bags, and the percentage by weight determined as discolored by the inspectors was marked on the bags.

Twenty samples were randomly selected from the total grade samples to form a calibration sample set. Measurements were made on each pod of the calibration samples. These data were analyzed to determine the threshold reflectance value, below which the pod would be considered discolored. All the measured values were found to be within the range determined earlier. Initially, the measured value corresponding to 50% brightness value was considered as the cutoff value, and the pods from each sample whose reflectivity was less than this value were removed, weighed, and their percentage by weight was compared with the inspectors' visual values. A threshold value of 36.5% reflectance resulted in the best correlation between percent discolored pods as determined by the instrument and by the inspectors.

Measurements were made on about 60 pods in each of 217 samples. At the start of every measurement session and at periodic intervals, the zero value was checked using the black reference. Reduced zero values indicated that the exposed surfaces of the optics were covered with dust and needed cleaning.

Results and Discussion

Measurements were made on over 11,500 peanut pods contained in 217 samples. Each measurement required 28 s from the time the pod was dropped into the feed tube. Table 1 shows a comparison of the percent discolored pods determined by the inspectors to that determined by the instrument. Of the five groups shown, groups 1 and 2 were graded at the same buying point (BP), No. 35401, graded by the same group of inspectors, but for different peanut companies and on different dates. Groups 3 and 4 were graded at different buying points, with BP numbers 35404 and 35407. The samples from group 5 could not be identified as from a particular BP and are believed to be samples re-graded from one or all of the above buying points.

The columns in table 1 represent the average, maximum, and minimum number of pods graded as discolored in a single sample by the visual method and by the reflectance instrument. The highest difference observed was 4% by weight between the visual grading and the grading done by reflectance measurement. The last column shows the standard deviation of the differences between the visual and instrument values for all samples. Over all samples, the average percent discolored pods obtained by the two methods differed only by 0.3% by weight.

In figure 2, the inspectors' visual values for all the samples in each of five groups are plotted against the values determined by the instrument. Also shown are the relative distributions along the 1:1 line. The visual values for each group compare well with the instrument values. The slope, intercept, and R^2 values for each group were computed (table 2). Also shown in table 2 are the Hotelling's T^2 values and the corresponding F-distribution values.

Group 1 and group 4 showed slightly higher intercept values than the other groups, while the slope values for all the groups were very near to unity. The coefficient of determination (R^2) for all the groups was 0.91 or better, indicating a good correlation between the visual values and the instrument values.

Hotelling's T^2 test (Khattree and Naik, 2003) was applied for each group to detect any non-correlations between the instrument determination and the visual determination at any of the buying points. The T^2 values were computed and are shown in table 2. The F distribution values for each group, $F_{1,\,n-1,\,0.01}$ (Ott, 1993, table 6, A8-A19), are shown in the last column. None of the Hotelling's T^2 values are greater than the corresponding F-distribution values at the 0.01 confidence level, indicating that none of the observed differences between the instrument determinations and the inspector's visual determinations are significant.

Table 1. Comparison of percentage of pods graded as discolored by visual method and by reflectance-instrument measurement.

Group No.	Buying Point No.[a]	Samples Tested	Graded as Discolored						SD of Difference[b]
			Visual (%)			Instrument (%)			
			Avg.	Max.	Min.	Avg.	Max.	Min.	
1	35401	77	24.9	77	1	25.4	75	2	2.08
2	35401	43	21.0	60	4	20.7	60	3	2.88
3	35404	51	18.7	70	0	19.2	69	1	1.86
4	35407	16	12.8	22	1	13.3	24	3	1.84
5	Unknown	30	17.2	48	1	17.2	50	1	2.52
All groups		217	18.9			19.2			

[a] Groups 1 and 2 were graded at the same buying point but for different buyers. The unknown group could be re-grades from any or all of the above buying points.

[b] Standard deviation of % difference between visual and instrument grading.

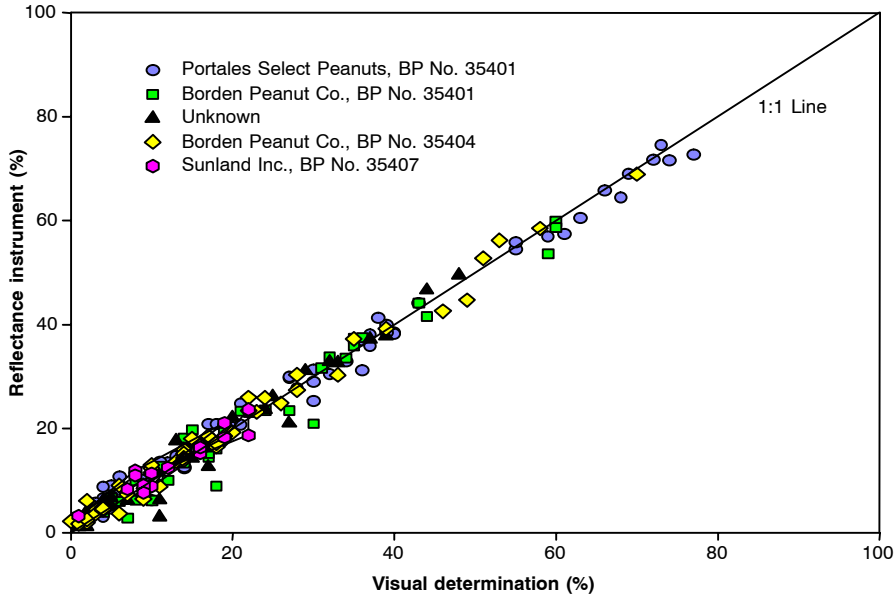

Figure 2. Comparison of percentage of pods graded as discolored by visual method and by reflectance instrument measurement. Samples obtained were from three buying points.

Table 2. Regression data for the pods graded as discolored: visual vs. reflectance determinations for the five groups.

Group No.	Buying Point No.	Intercept	Slope	R^2	Hotelling's T^2	F Distribution ($F_{1, n-1, 0.01}$)
1	35401	1.66	0.95	0.99	4.32	7.05
2	35401	0.40	0.97	0.96	0.50	7.30
3	35404	0.90	0.98	0.99	0.00	7.56
4	35407	2.27	0.87	0.91	3.39	7.19
5	Unknown	−0.07	1.00	0.96	1.49	8.68
All groups		0.98	0.97	0.98	3.02	6.83

Conclusions

Discoloration in Valencia type peanuts can be more objectively determined using a diffuse reflectance measuring instrument. The performance of such an instrument was very well correlated with the visual method presently used. The prototype instrument eliminates variations due to lighting conditions or perceptional variations among inspecting personnel. No special training is needed to operate such an instrument, and a commercial instrument developed on these principles has the potential to accelerate the grading process.

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