In-Shell Bulk Density as an Estimator of Farmers Stock Grade Factors

C.L. Butts[1]*, C.V.K. Kandala[1], R.B. Sorensen[2], and M.C. Lamb[3]

ABSTRACT

The objective of this research was to determine if bulk density of in-shell peanuts, called pod bulk density can be used to accurately estimate farmer stock grade factors such as total sound mature kernels and other kernels. Physical properties including pod or in-shell bulk density, pod size, and kernel size distributions are measured as part of the cooperative Uniform Peanut Performance Tests (UPPT). Using physical property data from three years (2002–2004) of UPPT, analysis of variance were performed to determine the effect of bulk density, location, year, peanut type, and cultivar on percent total sound mature kernels (TSMK), other kernels (OK), and farmer stock value (FSV). Results indicated that all effects in the model were significant in predicting both TSMK and FSV and accounted for most of the variation (R^2=0.80). Linear regressions of the UPPT (2002–2004) data (with pod bulk density as a single factor) showed that TSMK and FSV increased as pod bulk density increased with poor R^2 values (R^2=0.2). A second set of data collected during the 2005 peanut harvest by Federal State Inspection Service (FSIS) had similar results. Location and peanut type were highly significant factors in the variation of TSMK, OK, and FSV. Overall correlation of grade factors with pod bulk density, location, and type was poor (R^2<0.5). Based on these data, pod bulk density cannot be used to accurately estimate TSMK and OK for marketing farmer stock peanuts. Observed pod bulk density averaged for UPPT (all years) and FSIS was 316 kg/m^3 for runner, 427 kg/m^3 for spanish, 491 kg/m^3 for valencia, and 258 kg/m^3 for virginia peanuts.

Key Words: grading, peanut, value, physical properties, bulk density.

The farmer stock grading system was developed and implemented during the 1960's (USDA, 1963) to establish value of peanut (*Arachis hypogaea* L.) at farmer marketing. Equipment and procedures to extract a representative sample (Dickens, 1964), to separate that sample into foreign material, loose shelled kernels (LSK), and pods, to shell the pods (Dickens, 1962), and to determine the amount of edible peanuts in the sample have remained relatively unchanged since their inception. In an effort to automate the sample processing, Dowell (1993) developed equipment to clean, size and shell pods, and size kernels in a single pass. This equipment used air to separate foreign material and recirculate unshelled peanuts based on density. Air velocities in the machine were based on flotation velocities of individual pods and foreign material from previous research (Blankenship and Williams, 1977).

Research by Rucker et al. (1994) showed that pod density is highly correlated to kernel maturity and seed size distribution. As pod density increased, the maturity of the seed inside the pod increased. Also, as pod density increased, the percent of jumbo- and medium-sized kernels tended to increase, while the percent number one-sized kernels decreased. Based on this research, it is assumed that as the average pod density increases as pod bulk density increases. Therefore, as pod bulk density of a sample increases, the percent of edible kernels in that pod sample should also increase.

Small grains are typically marketed based solely on bulk density or test weight, moisture content, and dockage or foreign material. Siemens and Long (2005) separated wheat on a gravity table into several density fractions with the more dense fractions having higher quality.

The objective of this research was to determine if pod bulk density can be used to accurately estimate farmer stock grade factors such as total sound mature kernels (TSMK), other kernels (OK), total kernels (TK=TSMK+OK), and farmer stock value (FSV) for the purpose of marketing.

Materials and methods

Pod Bulk Density Measurements.

A known mass of cleaned pods were poured into an acrylic box with inside dimensions measuring 22.9 cm wide, 22.9 cm long, and 30.5 cm tall and equipped with a vibrator motor (Model 3M564, Dayton Electrical Mfg., Niles, IL). The surface of the pods was manually leveled, and then an acrylic plate was lowered into the box until it rested on the peanut surface. Using the bottom edge of the plate, the peanut depth was recorded from the scales mounted on each side of the box. The average depth was used to calculate the total volume occupied by the peanuts including void space. The pod bulk density was calculated by dividing the sample mass by the bulk volume.

[1]Agricultural Engineer, [2]Research Agronomist, and, [3]Research Leader, USDA, ARS, National Peanut Research Laboratory, Dawson, Georgia 39842.

*Corresponding author.

The vibrator was operated for 60 s and the peanut depth was recorded again from each side of the box. The pod bulk density was calculated in the same manner as described above. The pod bulk density computed from measurements recorded before vibration was called the "loose-filled" pod bulk density. The "settled" pod bulk density refers to the bulk density calculated from measurements recorded after vibration.

Uniform Peanut Performance Tests.

Peanut breeders collaborate in testing advanced breeding line peanut cultivars through the Uniform Peanut Performance Tests (UPPT). Standard cultivars of each peanut market type along with advanced selections from the various peanut breeding programs are planted and grown at nine locations across the United States (Branch, 2000). Samples are harvested and sent to the USDA, ARS National Peanut Research Laboratory in Dawson, Georgia to determine physical properties. Measured physical properties include whole pod and kernel size distribution, loose-fill pod bulk density, kernel moisture content, and seed count per unit mass (Lamb et al., 2005). After physical analysis, samples are sent to the USDA, ARS Market Quality and Handling Research Unit to determine several chemical and flavor attributes (Sanders et al., 2005). Farmer stock grade factors of percent sound mature kernels (SMK), sound splits (SS), total sound mature kernels (TSMK=SMK+SS), and other kernels (OK) were calculated from the kernel size distribution data. Farmer stock values (FSV) were calculated from the TSMK and OK with no deductions for excessive splits, foreign material, or damage. UPPT data from 2002, 2003, and 2004 crop years were analyzed using analysis of variance to determine the correlation of loose-fill pod bulk density, peanut type, cultivar, year, and location to TSMK, OK, and FSV. The degrees of freedom associated with each factor are shown in Table 2.

2005 Field Tests.

During farmer stock marketing of the 2005 peanut crop, the Federal-State Inspection Service (FSIS) in Alabama, Georgia, North Carolina, and Texas collected pod bulk densities data on all four peanut market types (runner, spanish, valencia, and virginia). Peanuts were offered for official inspection and grading to the FSIS. The official farmer stock sample (foreign material sample) was weighed and recorded according to the normal grading procedure. The foreign material sample was cleaned using the approved FSIS foreign material machine. In addition to measuring TSMK, total kernels (TK=TSMK+OK) were also measured for the 2005 study. Data were sent to the state office, error checked at the state office then forwarded to the USDA, ARS, National Peanut Research Laboratory in Dawson, Georgia. FSIS data from the 2005 crop years were analyzed using a paired t-test to determine any difference between loose-fill and settled pod bulk densities. Analysis of variance was used to determine the effects of peanut type, moisture, location, and pod bulk density on TSMK, OK, TK, and FSV. The degrees of freedom associated with each factor are shown in Table 3.

Results and Discussion

Uniform Peanut Performance Tests.

Data from 393 UPPT samples harvested during the 2002–2004 crop years were analyzed and are summarized in Table 1. Grade factors spanned the

Table 1. Summary of loose-fill pod bulk density, grade factors and farmer stock value obtained from the 2002, 2003, and 2004 Uniform Peanut Performance Tests (UPPT).

Peanut Type		Bulk Density (kg/m^3)	TSMK (%)	OK (%)	Farmer Stock Value ($/t)
Runner	Average	290	72	4.9	230.57
	Maximum	348	81	15.8	254.65
	Minimum	240	55	1.0	194.00
	Std. Dev.	18.5	4	2.4	10.49
	N	231	230	230	230
Spanish	Average	307	68	7	223.72
	Maximum	322	74	10	235.52
	Minimum	289	63	3	210.33
	Std. Dev.	11.3	3	2	8.07
	N	9	9	9	9
Virginia	Average	256	71	4	226.40
	Maximum	312	79	9	250.11
	Minimum	213	57	1	182.09
	Std. Dev.	20	4	2	10.56
	N	153	153	153	153

Table 2. Analysis of variance (P > F) of factors to estimate total sound mature kernels (TSMK), other kernels (OK), and farmer stock value (FSV) for 2002, 2003, and 2004 UPPT data.

Factor	df	TSMK (%)	OK (%)	FSV ($/t)
All Types (n=429)				
Density (kg/m^3)	1	<0.0001	<0.0001	<0.0001
Location	8	<0.0001	<0.0001	<0.0001
Year	2	<0.0001	<0.0001	<0.0001
Type	2	<0.0001	<0.0001	<0.0001
Cultivar	29	<0.0001	<0.0001	<0.0001
R^2		0.761	0.599	0.809
Runner type (n=231)				
Density (kg/m^3)	1	<0.0001	0.0072	<0.0001
Location	8	<0.0001	<0.0001	<0.0001
Year	2	<0.0001	<0.0001	<0.0001
Cultivar	17	<0.0001	<0.0001	<0.0001
R^2		0.740	0.579	0.792
Virginia type (n=153)				
Density (kg/m^3)	1	<0.0001	<0.0001	<0.0001
Location	8	<0.0001	<0.0001	<0.0001
Year	2	<0.0001	<0.0001	<0.0001
Cultivar	12	<0.0001	<0.0001	<0.0001
R^2		0.796	0.715	0.818

range from 55 to 81% TSMK and 1 to 16% OK. Runner peanuts averaged 72% TSMK and 5% OK with an average FSV of $230.57 per metric ton. The pod bulk density of runner peanuts averaged 290 kg/m^3 and ranged from 240 to 348 kg/m^3. This is slightly lower than the average of 327 kg/m^3 published for Florunner peanuts by Davidson et al. (1982). Similarly, the average pod bulk density for the spanish (307 kg/m^3) and virginia (256 kg/m^3) type peanuts were lower than published values of 316 and 272 kg/m^3 for spanish and virginia peanuts, respectively. However, it should be noted that the published bulk densities are for a single cultivar of each market type (Davidson et al., 1982), whereas the UPPT data contains data from a total of 32 cultivars. Under the UPPT protocol, the pod densities are loose-fill bulk density.

Results of analysis of variance using location, year, peanut type, cultivar, and bulk density to model TSMK, OK and FSV are shown in Table 2. When analyzed across all types, all variables had a significant effect on TSMK, OK, and FSV. The R^2 values for TSMK, OK, and FSV were 0.76, 0.60 and 0.81, respectively indicating that a model may be developed to estimate grade and value. However, the strong effect of location may indicate that different models may be necessary for each production region and peanut market type. Similar results were obtained when analyses were conducted for each market type.

The analysis of variance for spanish type peanuts is not shown because there was only one cultivar included in the UPPT. In general, the TSMK (Fig. 1) and FSV (Fig. 2) of runner peanuts increased linearly as bulk density increased. The low R^2 values indicated that bulk density alone only accounted for 19% of the variation in TSMK and 24% in the FSV.

2005 Field Tests.

Tests were conducted during 2005 on a total of 480 samples of runner type peanuts in Alabama, Georgia, and Texas. Both loose-filled and settled pod bulk density were measured on 496 runner lots, but the grades were not completed on 16 samples in which the moisture content exceeded 10% wet basis. Data were collected on 25 lots of spanish type peanuts in Texas, and 132 virginia type lots in North Carolina and Texas. Twenty-two lots of valencia type peanuts were tested in Texas. The

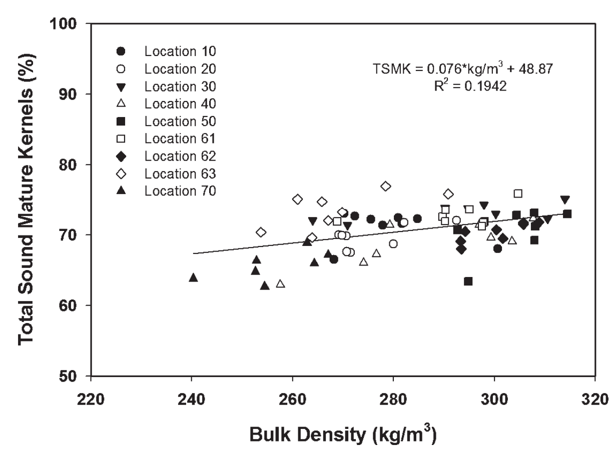

Fig. 1. Total sound mature kernels versus loose-filled pod bulk density for runner peanuts obtained from the 2003 UPPT.

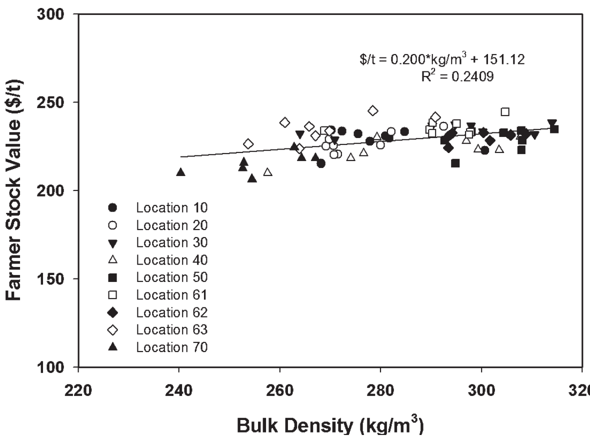

Fig. 2. Farmer stock value versus loose-filled pod bulk density for runner peanuts from the 2003 UPPT.

loose-fill bulk density ranged from 240.5 to 697.6 kg/m^3 for runner type peanuts (Table 3). As expected, paired t-tests showed that the settled bulk density was significantly greater than the loose-filled bulk density for all peanut market types.

As expected, market type had a significant effect on peanut pod bulk density. Davidson et al. (1982) showed the loose-fill bulk densities for runner (Florunner), spanish (Starr), and virginia (Florigiant) type peanuts as 327, 316, and 272 kg/m^3, respectively. These compare to the loose fill bulk densities of 328, 470, and 262 kg/m^3 for the runner, spanish, and virginia type peanuts. There are no published data for valencia type peanuts (Davidson et al., 1982). Bulk densities, both loose-fill and settled, varied with market type as expected. Spanish and valencia types had the highest pod bulk density, while the virginia type were the least dense.

The grade factors observed for each market type tested are shown in Table 3. Runner TSMK ranged from 56 to 82%; OK ranged from 1 to 15%; and TK ranged from 64 to 82%. A total of 480 samples were graded during the 2005 harvest. The grades for the other market types all fell within the ranges seen in the runner type peanuts. However, the range was not nearly as large.

As in the data from the 2002–2004 UPPT, analysis of variance indicated for the 2005 data significant effects of market type and location (Table 4). When analyzed over all market types, the R^2 value was higher for TSMK model than for either the SMK or SS. When analyzed by market type, only the runner peanuts exhibited the same trend. Moisture content could be eliminated from the model when trying to estimate TSMK for each market type. However, it was a significant factor in the model for the other grade factors. The relationships between settled pod bulk density and the various grade factors for runner peanuts are shown in Figures 3 to 5. There was no clear and predict-

Table 3. Summary of pod bulk density, total sound mature kernels (TSMK), other kernels (OK), total kernels (TK), and farmer stock value (FSV) obtained during the study conducted during the 2005 peanut crop harvest.

Peanut Type		Bulk Density (kg/m^3) Loose Fill	Bulk Density (kg/m^3) Settled	TSMK (%)	OK (%)	TK (%)	FSV ($/t)
Runner	Average	328.1 a[1]A[2]	347.6 bA[2]	72.1	4.9	77.3	388.06
	Maximum	697.6	739.8	82.0	15.0	84.0	434.59
	Minimum	240.5	251.4	56.0	1.0	64.0	311.63
	Std. Dev.	81.2	87.7	4.9	2.5	2.8	21.33
	N	496	493	480	480	480	480
Spanish	Average	470.4 aB	500.6 bB	75.9	2.0	77.9	392.29
	Maximum	789.7	845.2	79.0	3.0	80.0	418.65
	Minimum	269.2	291.1	71.0	1.0	74.0	323.19
	Std. Dev.	125.9	136.5	2.2	0.7	1.7	27.95
	N	25	25	25	25	25	25
Valencia	Average	490.8 aC	621.2 bC	70.5	3.1	74.0	407.73
	Maximum	580.1	715.7	74.0	4.0	77.0	427.25
	Minimum	335.8	343.6	67.0	2.0	70.0	383.16
	Std. Dev.	60.9	82.5	2.2	0.8	1.7	12.57
	N	22	22	22	22	22	22
Virginia	Average	261.0 aD	273.7 bD	70.3	1.7	72.7	397.72
	Maximum	494.1	541.2	77.0	4.0	79.0	433.46
	Minimum	149.3	150.8	62.0	0.0	66.0	348.28
	Std. Dev.	56.4	61.0	2.9	0.7	2.5	16.99
	N	131	128	132	132	132	132

[1]Average loose fill and settled bulk densities for each peanut market type are not significantly different ($P \geq 0.05$) if followed by the same lower case letter.

[2]Average bulk density in the same column followed by the same upper case letter are not significantly different (($P \geq 0.05$).

Table 4. Analysis of variance (P > F) of factors affecting the farmer stock grade and value determined during the 2005 harvest season conducted by Federal-State Inspection Service.

		Grade Factor[1]					
Factor	df	SMK	SS	TSMK	OK	TK	FSV
All Types (n= 659)							
Density (settled)	1	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Moisture	1	<0.0001	<0.0001	0.1838	<0.0001	0.0054	0.0035
Type	3	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Location	3	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
R^2		0.312	0.482	0.665	0.704	0.678	0.540
Runner (n=480)							
Density (settled)	1	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Moisture	1	<0.0001	<0.0001	0.6023	0.0069	0.7260	0.0360
Location	2	0.0947	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
R^2		0.338	0.446	0.691	0.614	0.584	0.588
Spanish (n=25)							
Density (settled)	1	0.1539	0.5519	0.0163	0.0054	0.0575	0.0033
Moisture	1	0.0016	0.0004	0.4494	0.1940	0.6681	0.9347
Location	0	—	—	—	—	—	—
R^2		0.408	0.444	0.257	0.340	0.161	0.331
Valencia (n=22)							
Density (settled)	1	0.0242	0.2383	0.0384	0.5521	0.0125	0.0251
Moisture	1	0.0171	0.0080	0.1331	0.0505	0.6026	0.1294
Location	0	—	—	—	—	—	—
R^2		0.403	0.351	0.281	0.199	0.293	0.307
Virginia (n=132)							
Density (settled)	1	0.9148	<0.0001	<0.0001	0.1455	<0.0001	<0.0001
Moisture	1	0.4334	0.0228	0.3773	0.2088	0.9113	0.5880
Location[2]	1	0.0009	<0.0001	0.7453	0.0105	0.8450	—
R^2		0.090	0.420	0.234	0.077	0.258	0.422

[1]Sound Mature Kernels (SMK), Sound Splits (SS), Total Sound Mature Kernels (TSMK), Other Kernels (OK), Total Kernels (TK)

[2]Only 1 location provided Extra Large Kernel (ELK) percentage to calculate ELK premium for the FSV of virginia type peanuts

able relationship between pod bulk density and SMK or SS as shown in Figure 3. There was a general trend for the SMK, SS, and TSMK to increase as pod bulk density increased. However, the scatter in the data would probably make pod bulk density an unacceptable predictor of these grade factors. For instance, a pod bulk density of 300 kg/m^3 had TSMK ranging from about 53 to 74% (Figure 4). Alternatively, peanuts with a 70% TSMK ranged in density from less than 200 to about 700 kg/m^3. There was a non-linear relationship that may be used to predict other kernels (OK). As pod bulk density increased the percent OK decreased approaching a minimum value

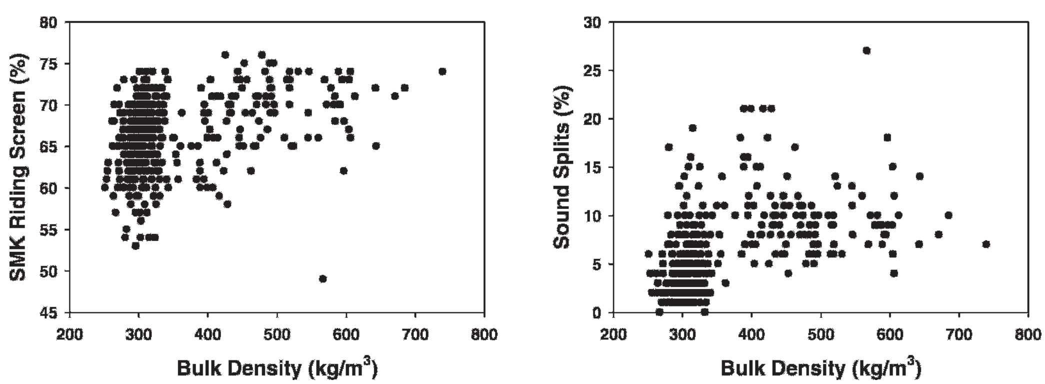

Fig. 3. Relationship of settled pod bulk density to sound mature kernels (SMK) riding 16/64″ screen (left) and sound splits (right) for runner peanuts graded during the 2005 harvest.

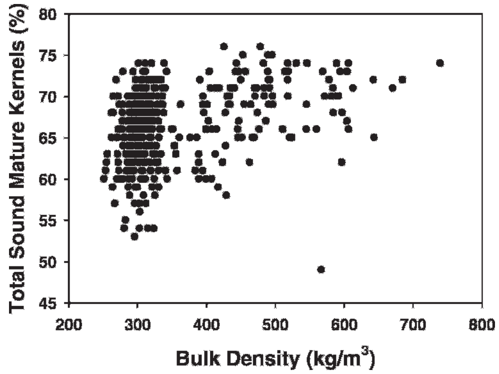

Fig. 4. Relationship of settled pod bulk density to total sound mature kernels (TSMK) for runner peanuts graded during the 2005 harvest.

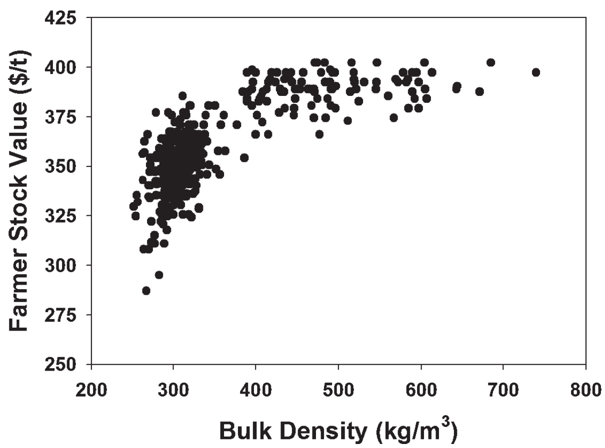

Fig. 5. Farmer stock value versus settled pod bulk density of runner peanuts graded during the 2005 harvest.

between 1 and 3 percent (Figure 5). Percent total kernels (TK=TSMK+OK) showed an increase with increasing settled pod bulk density.

Even where a predictable mathematical relationship could be developed, the large uncertainty associated with the prediction would be unacceptable for the buying and selling of peanuts. The FSV showed a nonlinear increase with settled pod bulk density (Figure 6) and reached a plateau of approximately $400/t. The uncertainty associated with predicting FSV is approximately ±$50/t and would be unacceptable for marketing farmer stock peanuts. The trends for virginia, spanish, and valencia peanuts were similar, with similar problems associated with large uncertainty.

Analysis of the 2002 to 2004 UPPT and 2005 FSIS data yielded similar results. Pod bulk density alone would not adequately predict grade factors or value for marketing. This is apparently contrary to results obtained by Rucker et al. (1994). However, in their research, individual pods were separated using a moving air stream. Using this method, separations were achieved based on the density of each peanut pod. The density of an individual peanut pod is primarily a function of how much the kernel fills the space within the shell. For example, a fully mature peanut in which the seeds fill the shell would have a higher density than a peanut with a completely formed shell with only one seed. This principal is used in various handling processes throughout the peanut industry. Density separations are used in the peanut combine to separate "pops" from filled pods. Gravity tables are used in the shelling industry to separate shelled from unshelled peanuts.

In contrast, bulk density is determined by the total volume occupied by a mass of peanuts, including void space between pods. The void space among peanut pods is affected by the shape and size of the pods and the manner in which they settle. This can be seen in the differences in bulk density between market types. Spanish peanuts tend to be small pods with many single seeded pods. A virginia type peanut usually has a very large pod with a thick hull. Virginia type peanuts are also very long relative to the smaller diameter of the seed. As seen in Tables 1 and 3, the bulk density of spanish peanuts is significantly higher than that of virginia type peanuts. This property is important in many engineering calculations such as warehouse storage capacities, sizing holding bins, and structural loads.

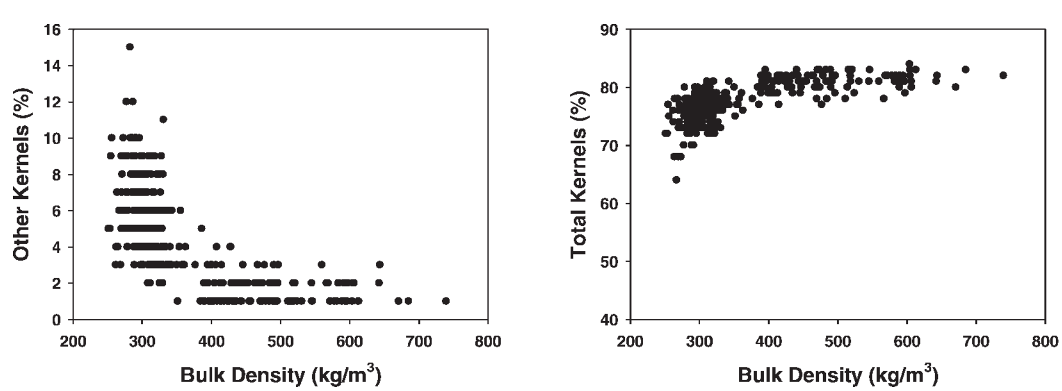

Fig. 6. Relationship of settled pod bulk density to other kernels (left) and total kernels (right) for runner peanuts graded during the 2005 harvest.

While in-shell bulk density is an important physical property, these data indicate that it is not an acceptable method of determining peanut value at farmer marketing. A method that measures individual pod density similar to the density separations by Rucker et al. (1994) may be an acceptable predictor of marketable quality factors.

Summary

Previous research had indicated that pod density could be used to estimate grade factors for marketing farmer stock peanuts. Therefore, data were collected from two different sources during the 2002 to 2005 harvests to determine the feasibility of using pod bulk density to estimate marketable peanut quality and value. General trends showed that as pod bulk density increased SMK, SS, TSMK, and TK, FSV increased. Percent OK decreased as pod bulk density increased. However, uncertainty associated with the grade value predictions based on pod bulk density was unacceptable. Based on these data, pod bulk density determined by measuring the bulk volume of a known weight of in-shell peanuts, will not suitably replace the grade factors determined in the current grading system. A system to measure individual pod density may result in better and acceptable estimates of the amount of edible peanuts in a farmer stock load.

Acknowledgements

The authors gratefully acknowledge the cooperation of the peanut breeders from the land grant universities and USDA, ARS and allowing use of the UPPT data for these studies. We give thanks to the state offices of the Federal-State Inspection Service including Wayne Bryant (NC), Donald Dozier (AL), Sonny Hooks (GA), Jerry Shugart (TX), and Ron Wood (GA). Invaluable technical support was provided by Hank Sheppard and Dan Todd of the National Peanut Research Laboratory.

Literature Cited

Blankenship, P.D. and E.J. Williams. 1977. Air flotation velocities and physical properties of peanuts and foreign material. Peanut Sci. 4:57-62.

Branch, W.D. 2000. Uniform Peanut Performance Tests. Research Progress Report 4-00, University of Georiga, Coastal Plains Experiment Station, Dept. Education, Communication, and Technology, Tifton, GA.

Davidson, J.I. Jr., T.B. Whitaker, and J.W. Dickens. 1982. Grading, cleaning, storage, shelling, and marketing of peanuts in the United States. *In* H.E. Pattee and C.T. Young (eds.). Peanut Science and Technology. Am. Peanut Res. Educ. Soc., Inc., Yoakum, TX.

Dickens, J.W. 1962. Shelling equipment for samples of peanuts. Marketing Research Report No. 528. U. S. Government Printing Office, Washington, DC.

Dickens, J.W. 1964. Development of a pneumatic sampler for peanuts. Trans. ASAE. 7:384.

Dowell, F.E. 1993. An automated grading system for farmers' stock peanuts. Proc. Am. Peanut Res. Educ. Soc. 25:52.

Lamb, M.C., C.L. Butts, and T.H. Sanders. 2005. Uniform peanut performance tests (UPPT) 2004: Shelling and physical properties. USDA, ARS, National Peanut Research Laboratory, Dawson, GA. http://www.ars.usda.gov/Services/docs.htm?docid=12479.

Rucker, K.S., C.K. Kvien, K. Calhoun, R.J. Henning, P.E. Koehler, S.R. Ghate, and C.C. Holbrook. 1994. Sorting peanut by pod density to improve quality, kernel maturity distribution, and reduce aflatoxin. Peanut Sci. 21:147-152.

Sanders, T.H., L.L. Dean, and C.L. Butts. 2005. Uniform peanut performance tests (UPPT) 2004: chemical, sensory and shelf-life properties. USDA, ARS, Miscellaneous Publishing Information Bulletin.

Siemens, M.C. and D.A. Long. 2005. Improving Wheat quality consistency by density segregation. ASAE Paper No. 051028, St. Joseph, MI: ASAE.

United States Department of Agriculture. 1963. Inspection instructions for farmers stock peanuts (revised). U. S. Department of Agriculture, Agricultural Marketing Service, Washington, DC 20250.