Sample Size Effects on Measuring Grade and Dollar Value of Farmers' Stock Peanuts[1]

F. E. Dowell[2]

ABSTRACT

Multiple samples of two sizes from 40 trailers of farmers' stock peanuts were inspected to determine sample size effects on measuring grade factors and dollar value. Grade factors and dollar value were measured using the current sample size (1X) and in a sample double the current size (2X). The 2X sample variances for determining sound mature kernels, sound splits, other kernels, damaged kernels, foreign material, loose shelled kernels, and load value were significantly lower than the 1X sample variances in only 8 or less of the 40 trailers. Average dollar values indicate measurement errors caused by equipment and human errors when cleaning samples, determining kernel size, and determining damaged kernels may be increasing as sample size increases. At least 24% of the total error can be attributed to equipment and human error. The grade factors with the smallest percentage of total error attributable to equipment and human error will benefit most by increasing sample size. Thus, dollar value, sound mature kernel, foreign material and damaged kernel measurements will benefit most by increasing sample size; whereas, loose shelled kernels, sound split and other kernel measurements will benefit most by improving equipment and procedures.

Key Words: Peanuts, sample size, grading, quality.

The Federal State Inspection Service (FSIS) inspects samples from lots of farmers' stock peanuts to determine grade factors and dollar value. Grade factors are determined by measuring the percentage of edible kernels, inedible kernels, split kernels, foreign material, and moisture. Accurate measurement of these grade factors insures the seller receives a fair price for his product and insures the buyer pays a fair price and has accurate information about the quality of the product. The buyer will use this grade information to insure proper segregation, storage, and processing of the peanuts. Inaccurate evaluation of grade factors and subsequent over or under estimate of the load value can result from sampling errors or measurement errors made by equipment or by inspectors. Accurate evaluation of grade factors is paramount to insure only good quality peanuts reach the market place. The U. S. peanut industry has requested that the grading system be examined to determine if the system needs to be modified or updated to improve the precision and accuracy of measuring grade factors (3).

The grading procedure begins with obtaining a sample of at least 1500 g from a load of peanuts using a pneumatic sampler (Fig. 1). This sample consists of foreign material (FM), loose shelled peanut kernels (LSK), and peanut pods. LSK are kernels shelled from pods during the harvesting, handling, and sampling process and are mostly of poor quality. The FM and LSK are removed by a sample cleaner and by hand and the percentage (weight basis) of FM and LSK determined. Five hundred grams of pods from the cleaned sample are then sized to increase shelling efficiency and then shelled to determine the percentage of undamaged or sound mature kernels (SMK), sound split kernels (SS), damaged kernels (DK), small other kernels (OK), and moisture (MC). Shelling, kernel sizing, and splitting equipment is used to assist the inspector in the grade measurement process. All LSK, OK, and DK are inspected for the presence of a toxin producing mold, *Aspergillus flavus*. The inspectors are furnished color charts and trained to identify damaged kernels. The damage detection procedures include splitting and examining each kernel in the sample, except for the OK (9).

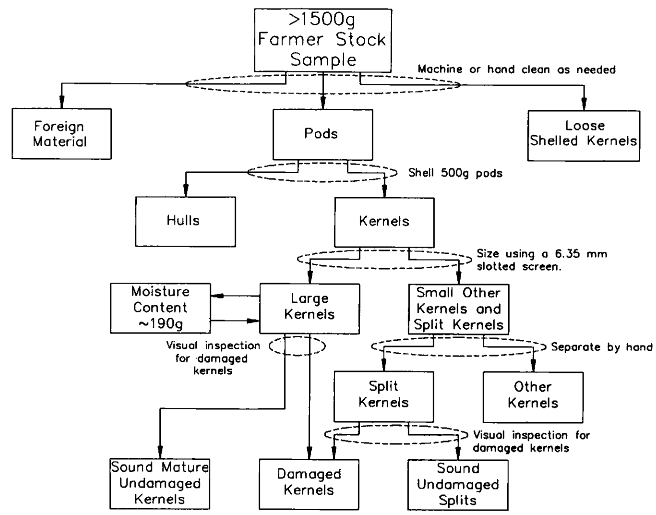

Fig. 1. Peanut grade sample inspection process.

The value of the load is determined from the grade factors measured in the inspected sample. Depending on the current market price, quota runner type SMK and SS receive about \$1.00 per kg while OK and LSK are worth about \$0.15 per kg. Financial penalties are assessed for excessive DK, FM, SS, and the presence of *A. flavus*. Penalties range from \$3.40 to \$10.00 per percent per 908 kg of DK over 1%, from \$1.00 to \$2.00 per percent per 908 kg of FM over 4%, and from \$0.80 to \$1.00 per percent per 908 kg of SS over 4%. If *A. flavus* is detected, the load is devalued by about 75% (10). Thus, small errors in measuring each grade factor can result in substantial differences in the value of the load.

Penny *et al.* (5) studied the effect of predicting peanut grade factors and value using 100 g and 1000 g samples. Approximately 360 tons of runner and 100 tons of spanish farmers' stock peanuts were tested from crop year (CY) 1953. A reduction in the variability between samples as sample size increased illustrated the improvement in grading accuracy associated with larger samples. However, the actual increase in accuracy was not as large as theoretical predictions. Error associated with visually assessing damage in the large samples was identified as one of the main reasons more significant differences between sample sizes were not seen. Although a reduction in variability was shown as sample size increased, little quantitative data was reported

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[2]Agricultural Engineer, USDA, ARS, National Peanut Research Laboratory, 1011 Forrester Drive, S. E., Dawson, Georgia 31742.

and the inspection procedures were somewhat different than those used currently.

Whitaker *et al.* (12) determined the coefficient of variation averaged across 20 lots of runner farmers' stock peanuts from CY 1982. Sixteen samples of approximately 1800 g each were removed from each lot. The coefficients of variation averaged across all lots were 21.1, 15.7, 2.6, 21.2, 14.0, 55.3, and 2.4% for % FM, % LSK, % SMK, % SS, % OK, % DK, and quota price per ton, respectively. Davidson *et al.* (2) determined the variability between 3 replicated 1800 g samples removed from each of 14 loads of CY 1988 runner farmers' stock peanuts. The coefficients of variation averaged across all lots were 25.0, 28.8, 2.2, 23.1, 10.8, and 45.1% for % FM, % LSK, % SMK, % SS, % OK, and % DK, respectively.

The total variability (V_t) reported by previous researchers includes sampling variance (V_s) and measurement variance (V_m), thus $V_t = V_s + V_m$. V_s occurs since it is not practical to inspect the entire load and a sample must be obtained and inspected. V_m occurs when inspectors or equipment measure each grade factor (4). Reducing V_s or V_m will reduce the total variability. Increasing the sample size will reduce V_s by a proportional amount, assuming the quality factors are uniformly distributed throughout the load (8). However, increasing sample size should reduce V_s, but V_m may increase due to the larger sample that must be handled and inspected. Thus, if sample size is increased, V_t will change in proportion to the change in V_s and V_m. V_m can be reduced by eliminating or reducing inspector subjectivity and equipment variability.

Increasing sample size is the one component of error that can affect all quality factors. Whitaker (11) showed sampling errors were much larger than subsampling or analysis errors when testing for aflatoxin in peanuts. Thus, increasing sample size may significantly increase the accuracy of measuring other quality factors. Sample size effects on total error should be investigated first to see if further reductions in human or equipment errors are warranted.

The previous work by Davidson *et al.* (2) and Whitaker *et al.* (12), in which only one sample size was used, could be used to predict the improvement in grading accuracy by increasing sample size if all or a significant amount of error was due to sampling. However, the research by Penny *et al.* (5) shows that human and equipment errors should not be ignored. Thus, the objective of this research was to measure the effect of doubling the current sample size on the variability of determining grade factors and dollar value of farmers' stock peanuts.

Materials and Methods

Forty loads of farmers' stock peanuts weighing 3500 to 4500 kg were collected during the CY 1990 harvest season. Each load was riffle divided using a farmers' stock divider to obtain approximately 900 kg of farmers' stock peanuts (Fig. 2.). The 900 kg was repeatedly riffle divided until 64, 2200 g and 64, 4500 g samples were obtained. Ten of the 2200 g samples were cleaned and divided into 500 g and 1000 g pod samples and graded to determine the % SMK, SS, DK, OK, and MC. Ten of the 2200 g and 10 of the 4500 g samples were used to determine the percentage of FM and LSK. The remaining samples and all kernels from the grade samples were used to determine the variability associated with testing for aflatoxin as part of a separate study. The variability associated with determining the presence of *A. flavus* kernels was not determined since the related study for detecting levels of aflatoxin is underway.

The quota loan value for the current sample size (1X) was calculated by assigning a 2200 g FM and LSK sample to a 500 g cleaned sample and calculating the value for 908 kg (1 ton) of farmers' stock peanuts. This is the sample size currently used in the inspection process. The quota loan value for double the current sample size (2X) was calculated by assigning a 4500 g FM and LSK sample to a 1000 g cleaned sample and calculating the value for 908 kg (1 ton) of farmers' stock peanuts. Thus the quota loan value variability between 10-1X and 10-2X samples was determined. SAS (6) was used to test whether the quality factor and loan value means and variances between the 1X and 2X sample sizes for each trailer were significantly different using procedures defined by Steele and Torrie (7). Whitaker *et al.* (12) demonstrated that the variances can be predicted using binomial theory.

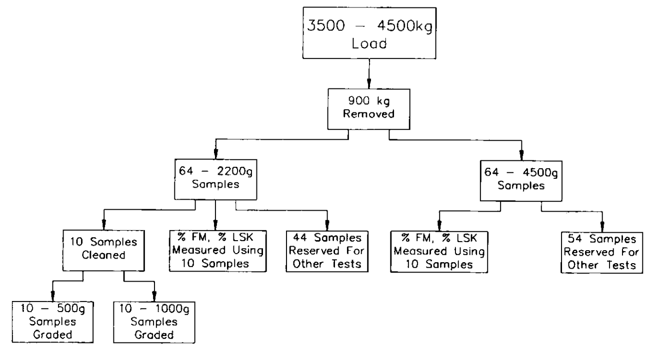

Fig. 2. Flow chart of tests to measure the effect of doubling sample size on the accuracy of grading peanuts. Forty 3500-4500 kg loads were sampled.

Two FSIS licensed inspectors and six aides graded all samples. Approximately 20 of the trailers were graded by inspectors alternately grading 1X and 2X samples. The remaining trailers were inspected by grading all 1X samples and then grading all 2X samples. The inspector aides determined only FM and LSK while the inspectors performed the remaining grading process. The two inspectors exchanged jobs periodically and the aides exchanged jobs with other aides periodically and were routinely monitored by FSIS area supervisors. Inspectors and aides set their own pace, and thus extra time was allowed as needed when inspecting the 2X samples.

Results and Discussion

Mean and Total Variance Results

Table 1 shows the mean and total variance for all grade factors and dollar value per 908 kg for each of the 40 lots. Few of the 2X variances were significantly lower statistically than the 1X variances indicating that increasing sample size does not necessarily increase the precision associated with measuring quality factors and load value. This implies that the measurement error is sizeable, particularly for some grade factors. The dollar value per 908 kg is a measure of all quality factors and the variability of dollar value should decrease as sample size increases. Only 3 of the 2X dollar value variances from the 40 trailers were significantly lower than the 1X variances (Table 2). Thus a significant advantage of doubling sample size for the purpose of improving the prediction of load value was not realized for most trailers. In addition, the dollar value of the 2X sample size for 11 trailers was significantly higher than the 1X sample indicating that equipment or human error inflated the load value derived by the 2X sample. The 2X average for all trailers was \$4.51 higher then the 1X sample.

Approximately 98% of the load value is determined by the percentage of SMK in the sample. Thus, for the purposes of determining value, accurate measurement of the amount of SMK is more important than for the other quality factors. This is reinforced by noting that in 10 of the 11 instances when the value measured using the 2X sample was significantly higher the 1X sample value, the percentage of SMK in the 2X sample was significantly higher than in the 1X

Table 1. Effect of sample size on grade factor percentage means (x) and total variances (V_t) for 10 samples from each of forty farmers stock peanut lots.

Trailer	Size[2]	Sound mature kernels (SMK) x	Sound mature kernels (SMK) V_t	Sound splits (SS) x	Sound splits (SS) V_t	Other kernels (OK) x	Other kernels (OK) V_t	Total damage (DK) x	Total damage (DK) V_t	Foreign material (FM) x	Foreign material (FM) V_t	Loose shelled kernels (LSK) x	Loose shelled kernels (LSK) V_t	Value $/908 kg x	Value $/908 kg V_t
1	1X	70.04	1.53	1.82	0.13	4.48	0.61	1.49[1]	0.07	1.06	0.02	0.97	0.04	640.79	89.52
	2X	70.34	0.84	1.67	0.14	4.28	0.16	1.16[1]	0.12	1.08	0.03	1.17	0.07	641.74	61.37
2	1X	71.05	1.30	1.12	0.32[1]	4.35	0.40	1.31	0.13	6.82	3.45	2.99	0.28	593.82	321.59
	2X	71.72	0.44	0.73	0.03[1]	4.29	0.30	1.01	0.07	6.76	0.85	2.95	0.38	596.99	133.77
3	1X	59.99[1]	2.83	0.98	0.18	14.76[1]	1.53	0.74	0.08[1]	2.88	0.17	6.02	0.99	528.25	163.73
	2X	58.42[1]	1.67	0.93	0.06	16.23[1]	1.47	0.58	0.01[1]	3.00	0.35	5.47	2.22	518.40	92.53
4	1X	68.93	1.20	1.23	0.08	5.07	0.56	1.31[1]	0.10	6.38	0.89	7.05[1]	1.62	552.48	158.36
	2X	69.08	0.67	1.43	0.08	5.42	0.21	0.98[1]	0.11	7.07	0.57	8.52[1]	1.31	543.44	187.19
5	1X	68.76	0.63	1.61	0.13	4.43	0.19	1.76	0.17	5.43	0.20	4.09	0.52	582.18	38.71
	2X	68.64	0.25	1.54	0.12	4.78	0.11	1.64	0.07	5.33	0.62	4.24	0.97	580.71	72.72
6	1X	63.63[1]	1.83	1.76[1]	0.29[1]	8.46[1]	0.54	1.31	0.21	0.82	0.02	1.13	0.09	588.63[1]	93.00
	2X	65.19[1]	0.64	1.21[1]	0.06[1]	7.83[1]	0.32	1.22	0.06	0.81	0.01	1.03	0.05	599.03[1]	37.67
7	1X	61.78	2.33	1.64	0.41[1]	7.69	0.23	5.23	1.20	2.26[1]	0.21	4.24[1]	0.44	519.52	830.13[1]
	2X	62.03	0.68	1.34	0.06[1]	7.60	0.37	5.25	0.54	2.72[1]	0.18	4.78[1]	0.61	512.81	167.59[1]
8	1X	72.28	1.20[1]	2.91	0.39	2.70	0.25	0.86	0.15	1.06	0.02	1.36	0.11	667.01	72.41[1]
	2X	72.21	0.08[1]	2.85	0.20	3.06	0.13	0.89	0.06	1.14	0.07	1.28	0.08	666.55	14.90[1]
9	1X	66.75[1]	0.97	1.83	0.33	7.38	0.29	1.01[1]	0.05	0.93	0.02	1.05	0.12	618.01	65.01
	2X	67.64[1]	0.44	1.51	0.58	7.12	0.43	0.75[1]	0.09	0.90	0.01	0.86	0.03	623.71	50.01
10	1X	65.11	2.51	1.63	0.72	6.67	0.39	4.50	0.87	4.85[1]	0.50	4.49[1]	0.83	540.74	477.13
	2X	66.04	1.88	1.73	1.69	6.38	0.58	4.14	1.12	4.87[1]	0.19	5.33[1]	0.43	547.01	346.31
11	1X	67.70[1]	1.66[1]	1.92	0.37[1]	7.59	0.67[1]	1.39[1]	0.07	2.93	0.13	4.60	0.85	595.53[1]	73.27
	2X	69.01[1]	0.21[1]	1.89	0.06[1]	7.12	0.17[1]	0.96[1]	0.08	2.95	0.24	4.91	1.24	604.87[1]	52.69
12	1X	69.71[1]	0.56	1.75	0.15	5.98[1]	0.44	1.04	0.07	3.49	0.13	3.59[1]	0.40	611.20	60.31
	2X	70.84[1]	0.22	1.44	0.07	5.33[1]	0.15	0.85	0.03	3.48	0.39	4.15[1]	0.50	614.77	42.30
13	1X	72.32	0.68	1.48	0.13	4.63	0.63[1]	0.70	0.05	5.49	1.15	2.52[1]	0.10	614.83	169.37
	2X	72.23	0.57	1.52	0.09	4.95	0.15[1]	0.58	0.03	6.11	0.97	3.28[1]	0.24	606.65	96.65
14	1X	68.03[1]	1.34	3.44	0.86[1]	3.79	0.27	1.06	0.03[1]	1.47	0.06	2.98	0.39	625.06	13.05
	2X	69.02[1]	0.73	2.90	0.09[1]	3.36	0.22	1.29	0.12[1]	1.42	0.06	2.82	0.28	628.35	38.69
15	1X	70.36	1.19	1.13	0.10	5.19[1]	0.46	1.50[1]	0.16	1.05	0.02	1.63	0.08	630.07	53.27
	2X	70.81	0.42	0.99	0.07	5.77[1]	0.28	1.08[1]	0.08	1.01	0.01	1.67	0.08	634.65	35.03
16	1X	71.80[1]	0.25	1.15	0.08	4.92[1]	0.25	0.80	0.10	1.03	0.04	1.70	0.09	643.09[1]	29.87
	2X	72.88[1]	0.45	1.05	0.16	4.26[1]	0.08	0.70	0.08	0.99	0.05	1.57	0.18	652.48[1]	35.04
17	1X	66.27	0.50	0.77	0.05	9.15	0.27	1.22	0.16	1.64[1]	0.05	1.34	0.18	599.84	49.75
	2X	66.53	0.85	0.88	0.06	8.87	0.38	1.21	0.08	1.91[1]	0.05	1.47	0.06	600.73	59.86
18	1X	67.73	0.88	1.21	0.21	6.86[1]	0.28	0.79	0.06	3.11[1]	0.24	1.33[1]	0.06	605.30[1]	42.01
	2X	68.11	0.69	1.39	0.50	6.18[1]	0.16	0.85	0.09	2.75[1]	0.06	1.08[1]	0.02	612.48[1]	37.61
19	1X	71.28	1.94	2.01	0.22	4.01	1.03[1]	0.79[1]	0.05	1.71	0.11	1.36	0.09	644.54	103.66
	2X	71.83	0.74	1.85	0.21	3.89	0.21[1]	0.51[1]	0.02	1.82	0.05	1.28	0.15	647.19	44.42
20	1X	60.79[1]	0.83	4.50[1]	0.79	7.64	0.20[1]	1.58[1]	0.26[1]	1.45[1]	0.20	2.01[1]	0.27	579.76	20.56[1]
	2X	62.76[1]	3.05	2.52[1]	0.23	8.35	1.18[1]	1.01[1]	0.05[1]	1.83[1]	0.14	2.31[1]	0.06	578.80	123.64[1]
21	1X	68.68[1]	1.68	1.13	0.20[1]	5.45[1]	0.50	2.01[1]	0.30	4.65	0.75	1.59	0.07	595.67[1]	117.44
	2X	70.57[1]	0.62	0.95	0.03[1]	4.78[1]	0.21	1.50[1]	0.19	4.34	0.18	1.70	0.06	612.99[1]	48.21
22	1X	53.49[1]	1.94	1.03	0.08	15.00[1]	1.46	2.12	0.45	4.63	0.37	2.39[1]	0.33	468.18[1]	137.23
	2X	55.64[1]	3.33	1.14	0.16	13.75[1]	1.38	1.71	0.11	5.01	0.63	2.61[1]	0.18	483.27[1]	323.30
23	1X	57.61	2.06	0.84	0.18[1]	14.28	1.40	1.33	0.05	1.61[1]	0.07	1.59	0.13[1]	530.62	211.96
	2X	58.22	0.82	0.93	0.04[1]	13.82	0.61	1.30	0.18	1.78[1]	0.05	1.51	0.08[1]	535.77	60.05
24	1X	57.79	3.33[1]	1.69[1]	0.35	12.54	1.16	1.48[1]	0.04	5.06	0.42	2.49	0.16	509.72	185.54
	2X	58.99	0.72[1]	1.22[1]	0.10	11.89	0.43	1.13[1]	0.16	5.35	0.47	2.23	0.12	514.27	68.79
25	1X	60.41	1.33	3.26[1]	0.47	8.44	1.07	1.22	0.10	3.02[1]	0.22	1.82	0.09	555.82	69.88
	2X	61.38	0.99	2.44[1]	0.18	8.26	0.33	1.18	0.13	4.14[1]	0.24	1.57	0.08	550.73	109.55
26	1X	67.28[1]	0.76	3.46[1]	0.93	4.84	0.47	0.89	0.09	1.08	0.01	1.33	0.05	631.00	40.01
	2X	68.54[1]	0.53	2.37[1]	0.61	4.89	0.70	0.92	0.05	1.21	0.03	1.49	0.19	631.08	63.46
27	1X	67.13	2.09	2.71	0.34	5.16	0.46[1]	0.88[1]	0.03	0.55	0.02[1]	0.57	0.01	629.92	166.83
	2X	67.46	4.13	2.84	0.55	5.47	3.32[1]	0.58[1]	0.03	0.54	0.01[1]	0.52	0.02	634.75	165.44
28	1X	68.64	1.18	1.42	0.33[1]	4.31	0.18	1.59	0.23	0.84[1]	0.01	0.77	0.06	621.34	120.60
	2X	68.93	0.79	1.07	0.05[1]	4.35	0.20	1.54	0.29	0.77[1]	0.02	0.77	0.05	621.40	76.08
29	1X	69.70	3.79	0.60	0.06	4.20	0.64[1]	2.54[1]	0.87	0.71	0.03	0.54	0.01	618.62	356.75
	2X	70.91	0.99	0.64	0.04	3.94	0.10[1]	1.82[1]	0.27	0.72	0.02	0.56	0.01	629.79	98.81

Table 1 con't

30	1X	71.00[1]	1.03	0.95	0.25	3.72	0.64[1]	1.29[1]	0.09	0.70[1]	0.01	0.38[1]	0.02	642.64[1]	64.29
	2X	72.11[1]	1.59	1.41	0.91	3.21	0.11[1]	0.69[1]	0.03	0.82[1]	0.02	0.66[1]	0.01	654.33[1]	32.65
31	1X	69.78	1.51	3.09	1.81	3.13[1]	0.19	0.56	0.07	1.84	0.29	2.18[1]	0.09	637.87	31.66[1]
	2X	70.27	0.86	2.55	1.30	3.58[1]	0.11	0.46	0.02	1.75	0.13	2.34[1]	0.23	637.82	5.99[1]
32	1X	66.20	2.59	2.43	1.30	5.04	0.42	0.76[1]	0.10	1.83	0.03[1]	2.44	0.11	579.67	98.18
	2X	67.18	1.05	2.54	1.38	4.95	0.51	0.31[1]	0.02	1.95	0.01[1]	2.71	0.30	587.22	48.17
33	1X	67.76[1]	0.97	3.11	0.28	3.70	0.33	2.23[1]	0.31	2.86	0.15[1]	2.37	0.05	607.75[1]	55.54
	2X	69.44[1]	1.02	2.84	0.19	3.40	0.34	1.46[1]	0.09	3.17	0.04[1]	2.41	0.07	621.16[1]	67.83
34	1X	64.21[1]	1.60	4.09[1]	0.44	3.52[1]	0.08	2.33[1]	0.16	5.46[1]	0.30	1.61[1]	0.09	572.02[1]	69.04
	2X	67.49[1]	1.54	3.36[1]	0.36	2.61[1]	0.10	1.47[1]	0.12	6.13[1]	1.30	1.92[1]	0.13	586.87[1]	53.27
35	1X	62.33[1]	1.72	0.51	0.09	8.48[1]	0.61	1.80	0.32[1]	3.57[1]	0.21	2.53	0.10	529.69[1]	141.58
	2X	64.62[1]	2.35	0.58	0.08	7.00[1]	0.40	1.67	0.07[1]	3.23[1]	0.08	2.25	0.24	550.73[1]	238.04
36	1X	62.59[1]	3.41	1.19	0.39	8.01	1.77	1.84[1]	0.39	3.91	0.43	3.37[1]	0.35	545.86[1]	311.07
	2X	64.37[1]	1.44	0.98	0.29	7.26	0.54	1.20[1]	0.11	3.44	0.25	3.66[1]	0.13	561.26[1]	99.30
37	1X	70.12[1]	1.78	5.59[1]	0.27	1.83	0.42[1]	1.59[1]	0.13	1.46	0.04	3.95[1]	0.23	650.31	60.37
	2X	71.48[1]	0.53	4.53[1]	0.33	1.65	0.05[1]	1.21[1]	0.10	1.51	0.09	4.56[1]	0.36	651.07	82.43
38	1X	60.17	1.39	2.68[1]	0.17	8.89	0.54	1.04	0.15	4.77	0.86	2.85[1]	0.04	534.33	217.86
	2X	61.11	2.05	2.10[1]	0.16	8.68	0.63	0.87	0.04	5.06	0.60	3.41[1]	0.17	535.01	73.92
39	1X	71.45[1]	0.56	1.67	0.18	2.56[1]	0.12	1.20	0.09	2.80[1]	0.15	1.70	0.14	635.41	39.82
	2X	72.42[1]	0.76	1.44	0.17	2.01[1]	0.12	1.06	0.10	2.71[1]	0.19	1.88	0.19	641.03	46.77
40	1X	65.53[1]	0.54[1]	5.99[1]	1.19	3.93[1]	0.37	1.87	0.36	2.65	0.10	3.36	0.93	608.91	44.02
	2X	68.58[1]	2.69[1]	3.76[1]	1.34	3.20[1]	0.11	1.63	0.09	2.81	0.10	3.55	0.51	614.45	51.36
Average	1X	66.40	1.54	2.08	0.38	6.32	0.56	1.52	0.21	2.75	0.30	2.41	0.27	592.15	136.60
Average	2X	67.38	1.11	1.78	0.32	6.09	0.43	1.26	0.13	2.86	0.23	2.56	0.30	596.66	88.59
C.V. (%)	1X	1.82		31.56		12.80		28.18		15.97		19.71		1.83	
C.V. (%)	2X	1.48		29.12		10.47		27.21		14.52		18.83		1.51	

[1] Means or variances for this trailer are significantly different.

[2] 1X samples use a 2200 g sample to determine foreign material (FM) and loose shelled kernels (LSK) while 500 g of pods are shelled to determine the remaining grade factors. 2X samples use 4500 g for FM and LSK and 1000 g of pods for remaining factors.

sample. In all, 18 of the SMK 2X sample means were significantly higher than the 1X means while only 3 of the 2X sample variances were significantly lower than the 1X variances.

The higher SMK means in the 2X samples indicate that either the screen sizer is overloaded and not allowing some small kernels in the 2X samples to fall through the screen, or that all of the DK are not removed from the 2X samples. Possible improper sizing is supported by the fact that ten of the 2X sample OK means were significantly lower than the 1X sample means and, in all cases, the significantly lower OK means occurred when the 2X sample SMK means were significantly higher. Improper sizing may be caused by the larger sample overloading the screen and not allowing all small kernels to fall through the slotted screen. Possible improper damage removal is supported by noting that nine of the 2X sample DK means were significantly lower than the 1X means when the 2X sample SMK means were significantly higher indicating that a smaller percentage of DK were removed from the larger sample size. In all, 17 DK 2X sample means were significantly lower than the smaller sample DK means indicating that the inspectors were probably not inspecting the 2X sample size as well as the 1X sample.

Table 2. Number of current size (1X) grade sample quality factor means (x) and total variances (V_t) that are significantly different from quality factors calculated from a sample twice the size (2X). Calculations were made on 10 samples from each of 40 trailers.

Quality factor	2X x signif. higher than 1X x	2X x signif. lower than 1X x	2X V_t signif. higher than 1X V_t	2X V_t signif. lower than 1X V_t
Sound mature kernels (SMK)	18	1	1	3
Sound splits (SS)	0	9	0	8
Other kernels (OK)	3	10	2	6
Damaged kernels (DK)	0	17	1	3
Foreign material (FM)	8	4	0	3
Loose shelled kernels (LSK)	13	1	0	1
Dollar value	11	0	1	3

The 2X sample appeared to not have been cleaned as well as the 1X sample since 13 LSK means and 8 FM means were significantly higher in the 2X sample than in the 1X sample. Hand picking is required to assist the sample cleaner in removing pods from the FM and LSK and the size of the 2X sample may not have allowed the sample to be properly cleaned.

These results indicate that measurement error may be a significant portion of the total error. Thus, further investigation into the relative amounts of measurement and sampling errors are warranted.

Measurement and Sampling Variance Results

An estimate of the measurement and sampling variance can be obtained by assuming that measurement error is constant for both sample sizes and by assuming that sampling variance is cut in half when the sample size is doubled. The total error, or variance, associated with sampling and measuring each sample size can be expressed by the equations

$$V_{t1X} = V_{s,1X} + V_{m,1X} \qquad (1)$$

$$V_{t,2X} = V_{s,2X} + V_{m,2X} \qquad (2)$$

where total error (V_t), sampling error (V_s), and measurement error (V_m) are estimated from the respective sample variances. Only V_t was measured in this study; however, if V_m is assumed to be constant for the 1X and 2X sample size, an estimate of V_m and V_s for each sample size can be obtained. Since doubling sample size reduces the sampling error in half, the sampling variances are related by the equation:

$$V_{s,1X} = 2 * V_{s,2X} \qquad (3)$$

If measurement errors are assumed to be constant then:

$$V_{m,1X} = V_{m,2X} \qquad (4)$$

Substituting equations 3 and 4 into equations 1 and 2 results in

$$V_{t,1X} - V_{t,2X} = V_{s,2X} \qquad (5)$$

The comparison of sample means discussed in the previous section indicated that V_m may not be constant for both sample sizes; however, assuming $V_{m,1X} = V_{m,2X}$ allows some estimate of V_m and V_s to be obtained. Table 3 shows the variance estimates using these assumptions. V_m was least for damaged kernels with 24% and 38% of the total error attributed to measurement error for the 1X and 2X sample sizes, respectively. V_m was greatest for LSK with 122% and 110% of the total error attributable to the measurement error for the 1X and 2X sample size, respectively. Although the values above 100% are not realistic, given the assumptions made, they do indicate that the LSK V_m is large.

The variances in Table 1 appear to be a function of the mean, thus V_t can also be calculated by regressing the variance against the mean and comparing predicted values from the 1X and 2X regression equations. A binomial distribution (1) was fit to each sample size and the regression coefficients and coefficient of determination (R^2) are listed in Table 4. The regression was restricted to pass through the origin and this inflates the R^2 value. Table 5 shows the calculated variances when the average grade values are used in the regression equations. All measurement errors were at least 30% of the total error with LSK measurement errors being the largest.

Table 3. Total (V_t), measurement (V_m), and sampling (V_s) variance estimates from the average variances from 40 loads of farmers stock peanuts. V_m was assumed equal for the current sample size (1X) and for double the sample size (2X).

Grade Factor	$V_{t,1X}$	$V_{t,2X}$	V_m	$V_{s,1X}$	$V_{s,2X}$	$\frac{V_{m,1X}}{V_{t,1X}}$ (%)	$\frac{V_{m,2X}}{V_{t,2X}}$ (%)
Sound mature kernels (SMK)	1.54	1.11	0.68	0.86	0.43	44	61
Sound splits (SS)	0.38	0.32	0.26	0.12	0.06	68	81
Other kernels (OK)	0.56	0.43	0.30	0.26	0.13	54	70
Damaged kernels (DK)	0.21	0.13	0.05	0.16	0.08	24	38
Foreign material (FM)	0.30	0.23	0.16	0.14	0.07	53	70
Loose shelled kernels (LSK)	0.27	0.30	0.33	-0.06	-0.03	122	110
Dollar value	136.60	88.59	40.58	96.02	48.01	30	46

Table 4. Regression coefficients and coefficients of determination (R^2) for a binomial distribution used to estimate variances from sample means.

Grade factor	Regression coefficients 1X[a]	2X[a]	R^2 1X	2X
Sound mature kernels (SMK)	0.070	0.052	0.793	0.629
Sound splits (SS)	0.185	0.187	0.668	0.475
Other kernels (OK)	0.097	0.080	0.814	0.483
Damaged kernels (DK)	0.170	0.128	0.820	0.730
Foreign material (FM)	0.147	0.102	0.506	0.769
Loose shelled kernels (LSK)	0.140	0.149	0.776	0.675
Dollar value	0.699	0.456	0.484	0.627

[a]Sample variances were regressed against sample means for the current sample size (1X) and for double the sample size (2X) using the equation $y = ax-ax^2/100$ where a is the regression coefficient.

Table 5. Total (V_t) variance estimates predicted from a binomial distribution using the average grade (x) from 40 trailers. Measurement error (V_m) and sampling error (Vs) were calculated by assuming V_m was equal for the current (1X) sample size and for double the sample size (2X).

Grade factor	x	$V_{t,1X}$	$V_{t,2X}$	V_m	$V_{s,1X}$	$V_{s,2X}$	$\frac{V_{m,1X}}{V_{t,1X}}$ (%)	$\frac{V_{m,2X}}{V_{t,2X}}$ (%)
Sound mature kernels (SMK)	66.4	1.56	1.16	0.76	0.80	0.40	48.7	65.5
Sound splits (SS)	2.08	0.377	0.381	0.385	-0.008	-0.004	102	101
Other kernels (OK)	6.32	0.574	0.474	0.373	0.20	0.10	65	78.7
Damaged kernels (DK)	1.52	0.254	0.192	0.13	0.124	0.062	51.2	67.7
Foreign material (FM)	2.75	0.393	0.273	0.153	0.24	0.12	38.9	56.0
Loose shelled kernels (LSK)	2.41	0.329	0.350	0.372	-0.04	-0.02	113	106
Dollar value	592.15	142.19	92.76	43.32	98.86	49.43	30.5	47

The grade factor with the smallest percentage of total error attributable to measurement error will benefit most by increasing sample size. Thus dollar value, SMK, FM, and DK measurements will benefit most whereas LSK, SS, and OK measurements will benefit least if sample size is increased.

When examining individual trailers, doubling the current sample size resulted in significantly lower SMK, SS, OK, DK, FM, LSK, and the dollar value variances in the 2X samples in 3, 8, 6, 3, 3, 1, and 3 of the 40 trailers, respectively. Significantly higher load values calculated from the 2X samples were seen in 11 of the trailers and reflect significantly higher SMK and LSK percentages in 18 and 13 of the trailers, respectively. Significantly lower OK and DK percentages in the 2X samples from 10 and 17 of the trailers, respectively, contributed to the higher SMK values. V_m for dollar value, SMK, FM, and DK had the smallest component of V_t whereas V_m for LSK, SS, and OK had the largest component of V_t. However, estimates of V_m and V_s indicate that V_m accounts for at least 24% of V_t. Thus, improving equipment and procedures will be more effective in increasing the precision of measuring LSK, SS, and OK and increasing sample size would be more effective in increasing the precision of measuring dollar value, SMK, FM, and DK.

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