Variability Associated with Determining Grade Factors and Support Price of Farmers Stock Peanuts[1]

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ABSTRACT

Replicated grade samples were taken from runner, spanish, and virginia-type farmers stock peanut lots. Each sample was graded according to the procedures of the Federal State Inspection Service. The variability of % foreign material (%FM) and % loose shelled kernels (%LSK) associated with a 1800-g sample was measured. The variability of % sound mature kernels (%SMK), % sound splits (%SS), % other kernels (%OK), % damage (%DAM), and % extra large kernels (%ELK) associated with a 500-g sample was also measured. The variance was shown to be a function of the magnitude of the grade determination and was described by a relationship derived from binomial theory. From the measured grade factors, the support price per gross ton was calculated for each grade sample using the 1988 USDA loan schedule. The variance of the price per gross ton was also estimated and appeared to be independent of the price per gross ton. The coefficients of variation averaged across all lots tested were 21.1, 18.7, 2.6, 21.2, 14.0, 55.3, 7.8, and 2.4% for %FM, %LSK, %SMK, %SS, %OK, %DAM, %ELK, and price per gross ton, respectively. The computed price per gross ton of a farmers lot that has a true value of $600 was estimated to vary from $573 to $627 95% of the time when using the 500 and 1800 g grade sample to measure each grade factor.

Key Words: Peanuts, grading, errors, variability.

When farmers bring their inshell peanuts to a buying point, an 1800-g sample is removed and graded by the Federal State Inspection Service (FSIS) (1). The 1800-g sample is separated into foreign material (FM), loose shelled kernels (LSK), and pods. The percent by weight of foreign material (%FM) and loose shelled kernels (%LSK) in the 1800-g sample are determined. A 500-g sample of pods is removed from the inshell portion of the 1800-g sample. The 500-g sample of pods is shelled and the percent by weight of sound mature kernels (%SMK), sound splits (%SS), other kernels (%OK), damaged kernels (%DAM), extra large kernels (%ELK), and moisture content, % wet basis, (%M) are determined (2). (The grade factor %ELK only applies to virginia-type peanuts). The quota loan value (QLV) the farmer receives for his load of inshell peanuts is determined from a USDA loan schedule that uses the above grade factors to calculate the QLV (3).

Even if no selection biases are associated with physically taking samples, and if there are no human or equipment biases in grading samples, there will be variation among grade values determined from replicated samples taken from a lot of peanuts. Determinations for each grade factor will randomly vary about their mean. As a result, the QLV calculated from sample grade factors will also vary.

The objectives of this study were to (a) determine the variability associated with measuring % FM and % LSK when using the 1800-g AMS grade sample, (b) determine the variability associated with measuring %SMK, %SS, %OK, %DAM, and %ELK when using the 500-g AMS grade sample, (c) determine the variability associated with computing the QLV from the above grade factors when using 1800-g and 500-g AMS grade samples and(d) predict the effect of sample size on the variability of the above grade factors and computed QLV.

Materials and Methods

Three separate data sets were used to estimate the variability associated with determining grade factors and support price of farmers stock peanuts. Table 1 shows the number of lots, the number of replicated samples graded per lot, the crop year, and the type peanuts used in each of the three data sets. In all three studies, samples were graded by FSIS personnel. The grade factors %FM and %LSK were determined from the 1800-g sample. The grade factors %SMK, %SS, %OK, %DAM and %ELK were determined from a 500-g sample of pods. The grade factors were expressed in percent by weight and rounded to the nearest whole percent in accordance with FSIS procedures. The QLV per gross ton (QLV/GT) was computed for each grade sample result using the 1988 USDA loan schedule. The gross weight (GWT) is defined as pod weight (PODWT) plus loose shelled kernel weight (LSKWT) plus foreign material weight (FMWT). Since the gross weight of the lots graded in this study were not known, it was assumed that PODWT plus LSKWT equaled 2000 pounds. Therefore, a gross weight was calculated from equation 1,

$$GWT=2000/(1-\%FM/100). \qquad (1)$$

The moisture content of all grade samples was assumed to be seven percent, (no excess moisture) since moisture values were not available for all data.

Study 1 - A 30-kg minilot was removed from each of 20 farmers stock lots of runner type peanuts with a FSIS pneumatic sampler (2). Each minilot was subdivided with a riffle divider into 16 grade samples. The 320 grade samples were coded and graded in a random manner by FSIS personnel. The mean and variance of each grade factor and QLV/GT was determined for each of the 16 replicated grade samples for each of the 20 minilots.

Study 2 - The FSIS has a check sample program where duplicate 1800-g samples are graded from randomly selected farmers stock lots marketed during the crop year. One sample is the official grade sample while the second sample, called the check sample, is graded by a different FSIS

Table 1. Description of the three data sets used to measure the variance of grade factors for farmers stock peanuts.

DATA SET	NUMBER LOTS	NUMBER SAMPLES PER LOT	CROP YEAR	TYPE PEANUT
1	20	16	1980	RUNNER
2	979	2	1984	RUNNER
2	448	2	1985	RUNNER
2	2003	2	1988	RUNNER
2	899	2	1984	VIRGINIA
2	2076	2	1985	VIRGINIA
2	1720	2	1986	VIRGINIA
2	1243	2	1987	VIRGINIA
2	1713	2	1988	VIRGINIA
3	4	32	1987	RUNNER
3	4	32	1987	VIRGINIA
3	4	32	1987	SPANISH (IRRIGATED)
3	4	32	1987	SPANISH (DRY LAND)

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grader. Differences in grade results from the duplicate samples are used by FSIS for internal purposes to estimate the precision with which FSIS personnel determine grade factors of farmers stock peanuts. The mean and variance associated with each grade factor and QLV/GT were determined from the duplicate samples from each lot. Table 1 shows the number of lots and type peanut used in the check sample program each crop year. Since the number of lots was extremely large, varying from 448 to 2076 lots, a single mean and variance estimate for each grade factor was determined for each type peanut and each crop year by taking the average of all means and the average of all variance estimates.

Study 3 - Originally designed to study the effects of screening inshell peanut lots, the FSIS collected samples of farmers stock peanuts from each of the three production areas. Within each production area, the samples were combined to provide a large lot consisting of one type peanut. In the southwest production area, two spanish lots were created, one for dryland and one for irrigated spanish peanuts. Each lot was divided into four minilots weighing 64 kg each. Each minilot was subdivided into thirty-two 1800-g grade samples. The 32 replicated grade samples for each type peanut were used to determine mean and variance estimates for each grade factor and for QLV/GT.

Theoretical Considerations - The distribution and variation among replicated grade sample measurements of a grade factor from the same lot may be described by the binomial distribution (4). The binomial distribution is a decrete distribution where an outcome is either success or failure, for example, a kernel is damaged or not damaged.

The probability of obtaining k successes (k damaged kernels) in a sample of n kernels taken from a lot with a true proportion of damaged kernels p is described by equation 2.

$$p(X=k)=\binom{n}{k} p^k(1-p)^{n-k} \qquad (2)$$

The mean and variance relationships for the binomial case are defined by the following equations. The mean defectives in the a sample of n kernels is np and the variance among samples of n kernels in np (1-p). If the number of defectives is expressed as a percent of the total kernels in the sample, the mean m becomes

$$\mu = 100p \qquad (3)$$

and the variance σ^2 becomes

$$\sigma^2 =(100)^2 np (1-p)/n^2, \qquad (4)$$

or

$$\sigma^2 = (100)^2 p (1-p)/n. \qquad (5)$$

Substituting p from equation 3 into equation 5 gives

$$\sigma^2 = (100/n)\mu - (1/n)\mu^2, \qquad (6)$$

or

$$\sigma^2 = \alpha\mu - (\alpha/100)\mu^2 \qquad (7)$$

where $\alpha = 100/n$.

From equation 4 it can be seen that the variance is a function of the mean. As p increases from 0 to 50%, the variance increases. As p continues to increase from 50 to 100%, the variance decreases. At p=0 and 100%, the variance is zero and at p=50%, the variance is a maximum. The true mean μ and variance σ^2 are estimated by experimental measurements denoted by m and s^2, respectively.

Results

The measured mean m and variance s^2 among replicated grade sample determinations for each grade factor and for the QLV/GT are shown in Table 2. All three data sets in the Table 2 were analyzed as a single data set. For most grade factors, the variance of grade determinations appears to be a function of their mean. For example, s^2 and m for sound splits in Table 2 are shown in Fig. 1. The measured variance increases with an increase in the mean.

The binomial variance relationship given in equation 7 was fit to the mean and variance measurements for all grade factors in Table 2 using regression techniques to determine the coefficient α. As an example, the predicted variance among 500 g grade samples when measuring sound splits as a function of the true quantity of sound splits in the lot is also shown in Fig. 1. The coefficient α along with coefficient of determination (R^2) are shown in Table 3 for all grade factors. The coefficient of determination reflects forcing regression equation 7 to have an intercept of zero.

The coefficient of variation, CV, expressed as a percent can also be determined for each grade factor by taking the square root of equation 7 and dividing by m. The resulting equation for CV becomes

$$CV = (100/\mu) \sqrt{\alpha\mu - (\alpha/100)\mu^2}. \qquad (8)$$

As in the case of the variance estimates, the CV also varies with the magnitude of the grade determination m. A plot of the CV associated with %FM and %LSK when using a 1800-g sample are shown in Fig. 2; a plot of the CV associated with %SMK and %ELK when using a 500-g sample is shown in Fig. 3; and a plot of CV associated with %SS, %OK, and %DAM when using a 500-g sample are shown in Fig. 4. For all grade factors, the coefficient of variation decreases as the mean increases. The CV shown in Figures 2, 3, and 4 reflect α coefficients given in Table 3.

The variance of QLV/GT is shown in Table 2. Because the variance associated with each grade factor was a function of the mean grade determination, the variance of QLV/GT may also be a function of the mean QLV/GT. However, due to the variability associated with the QLV variance estimates, no functional relationship is detectable in the data shown in Table 2. As a result, the average variance for QLV/GT of 184.64 was considered to be the best estimate of the true variance in QLV/GT and was assumed to be constant over the range of prices computed in this study. From the average variance value of 184.64, the CV expressed as a percent for the QLV/GT is

$$CV = (13.5/\mu)\ 100. \qquad (9)$$

From equation 9, the CV associated with computing the QLV/GT for a μ of 555 dollars is 2.4%.

The variance and CV relationships developed in this study reflect the use of an 1800-g sample for %FM and %LSK and a 500-g sample for the remaining grade factors. Increasing sample size decreases both the variance and the CV. For example, assuming no additional human or equipment error are introduced, doubling sample size will cut the variance in half and the CV is reduced by the square root of 2. It is assumed that if only the 1800-g sample size was doubled, the variances associated with %FM and %LSK would both be cut in half but there would be no effect on the variance of % SMK, %SS, %OK, %DAM, and %ELK. It is also assumed that if only the 500-g sample size is doubled, the variance associated with %SMK, %SS, %OK, %DAM, and %ELK are all cut in half but there would be no effect on the variance of %FM and %LSK. As a result, if both the 1800-g and 500-g sample were doubled in size, the variance associated with the QLV/GT should also be cut in half since the variance of all grade factors used in the price equation are cut in half. The variance relationship shown in equation 7 can be used to predict the variation expected for to reflect any size sample.

$$\sigma^2_{\bar{x}} = (\alpha\mu - (\alpha/100)\mu^2)(1/N) \qquad (10)$$

Table 2. Mean and variance (var) associated with each grade factor and quota loan value per gross ton (QLV/GT) when using an 1800-g sample to measure percent foreign material (%FM) and loose shelled kernels (%LSK) and a 500-g sample to measure percent sound mature kernels (%SMK), sound splits (%SS), other kernels (%OK), damaged kernels (%DAM), and extra large kernels (%ELK).

DATA SET	%FM		%LSK		%SMK		%SS		%OK		%DAM		%ELK		QLV/GT	
	MEAN	VAR	MEAN	VAR	MEAN	VAR	MEAN	VAR	MEAN	VAR	MEAN	VAR	MEAN	VAR	MEAN	VAR
1	8.10	1.18	5.70	.36	58.10	1.26	5.60	1.33	13.00	1.60	1.00	.27			499.56	75.49
1	1.90	.25	4.60	.38	63.40	1.60	2.20	.43	10.40	1.33	1.00	.00			557.38	102.79
1	6.60	2.11	3.70	.63	53.80	4.03	5.40	1.85	13.80	2.60	1.10	.06			484.78	191.33
1	2.90	.27	8.30	.47	65.10	.92	3.60	.40	7.50	1.47	1.40	.40			554.09	63.13
1	2.60	.25	5.20	.30	65.90	.65	4.40	1.06	7.40	.66	1.40	.40			584.62	69.45
1	6.60	1.58	4.00	.29	69.00	2.53	5.90	.65	5.30	1.03	.94	.20			593.37	275.62
1	2.60	.26	2.50	.27	58.00	2.47	4.80	.60	13.00	1.47	1.10	.12			546.35	48.00
1	2.90	.33	4.00	.27	61.60	1.46	4.00	.93	11.00	.80	2.00	.67			552.18	61.41
1	3.30	.23	2.70	.23	60.90	3.53	3.40	.65	12.60	1.32	1.20	.16			550.56	172.85
1	4.90	1.13	3.90	.20	59.30	2.23	6.30	1.00	7.90	1.05	1.80	.64			539.27	146.85
1	2.10	.33	3.30	.20	65.10	2.33	6.10	1.00	8.70	1.03	1.30	.23			603.64	50.52
1	2.70	.36	3.10	.20	60.80	4.83	3.40	.25	14.30	3.03	1.20	.16			553.17	131.85
1	5.60	1.06	3.60	.25	66.20	3.10	4.90	1.66	6.20	1.76	1.60	.65			575.26	124.96
1	9.30	1.00	7.30	.50	61.40	2.78	5.00	1.20	9.80	2.38	2.10	.86			499.80	193.44
1	9.20	1.36	7.20	.60	55.10	5.31	4.80	1.63	14.20	2.88	2.40	1.98			458.74	290.71
1	4.90	.38	4.90	.33	61.40	4.38	6.80	.73	8.50	2.13	2.20	.83			550.11	260.34
1	6.30	1.70	4.00	.27	62.90	1.18	3.90	.86	11.20	.96	1.80	.96			541.02	248.23
1	8.30	1.13	4.70	.23	43.50	3.47	4.60	.53	22.20	3.36	1.80	.47			393.69	142.47
1	9.10	.60	3.80	.16	61.40	3.05	4.30	.87	11.00	1.47	1.60	.52			513.60	182.27
1	9.20	.30	8.00	.53	67.80	1.93	5.00	.67	5.50	.80	2.10	.50			537.66	105.79
2	4.10	.81	5.00	.78	70.50	1.96	3.30	.83	4.00	.53	.64	.18			587.41	144.84
2	4.30	.69	4.50	.73	68.40	2.09	3.40	.97	5.80	.80	.43	.21			576.52	154.86
2	4.30	.37	5.20	.57	66.00	1.14	3.40	.51	7.10	.56	.74	.14			556.00	91.43
2	4.50	.76	3.50	.50	67.80	1.74	1.70	.49	2.40	.31	.50	.20	37.70	5.79	557.98	158.73
2	3.80	.61	4.70	.72	70.20	1.55	2.20	.65	1.70	.25	.36	.19	41.45	6.77	579.37	115.34
2	4.30	.76	3.90	.53	67.30	1.87	2.40	.70	2.40	.37	.27	.14	38.49	6.30	560.27	126.93
2	3.30	.59	8.30	.86	61.40	3.39	3.30	1.20	4.00	.59	.58	.27	38.46	9.62	516.47	154.38
2	4.90	.85	3.90	.56	63.60	3.08	3.50	1.24	3.50	.52	.83	.29	38.62	7.28	536.87	203.28
3	3.50	.67	4.00	2.79	67.20	1.76	3.40	.38	5.70	.67	.78	.18			585.61	352.41
3	1.00	.03	.78	.18	69.50	1.87	2.80	.65	4.80	.50	.88	.11			629.85	72.78
3	1.30	.56	.03	.03	69.50	1.42	2.80	.39	4.70	.47	.63	.24			631.36	129.52
3	.80	.45	.03	.03	70.30	2.30	2.70	.33	4.30	.45	.53	.26			642.56	93.25
3	4.10	1.78	2.80	1.03	62.80	6.11	4.80	1.85	5.50	1.29	.19	.16			563.94	473.81
3	.81	.35	.00	.00	60.30	1.83	5.60	1.03	6.40	.56	.53	.32			579.50	158.05
3	.69	.48	.00	.00	63.60	4.06	7.50	2.13	4.20	1.40	.50	.26			621.09	457.41
3	.81	.29	.00	.00	64.70	3.24	7.20	1.61	3.10	.64	.56	.25			626.85	351.07
3	5.10	1.60	2.90	1.02	55.80	5.23	5.40	.50	8.80	2.09	.75	.19			508.80	581.87
3	.74	.33	.03	.03	56.90	4.05	5.30	.68	7.90	.85	.84	.34			549.75	324.69
3	.31	.22	.00	.00	58.90	2.31	5.50	.77	7.20	.67	.78	.18			570.59	100.76
3	.41	.38	.00	.00	60.80	.63	5.60	.65	5.50	.58	.66	.23			585.90	63.19
3	4.80	.31	3.80	.18	57.40	1.93	5.70	1.14	4.50	.39	.84	.20	33.53	4.90	524.47	115.11
3	1.50	.32	.69	.22	55.80	2.78	5.50	1.22	5.00	.58	1.19	.42	29.16	7.43	541.33	224.71
3	1.20	.22	.00	.00	55.80	2.77	6.20	1.21	5.00	.42	.94	.19	29.31	9.11	551.13	183.85
3	1.00	.07	.00	.00	57.10	4.56	5.80	1.02	4.70	.62	.94	.19	32.13	11.71	560.86	354.21
AVG.	3.88	.67	3.38	.40	62.33	2.65	4.53	.92	7.54	1.12	1.07	.35	35.43	7.66	555.30	184.64

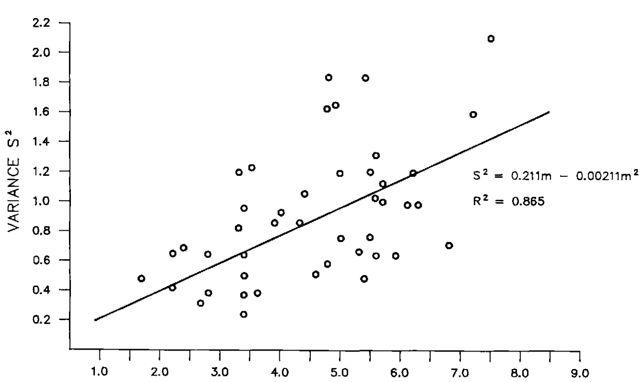

Fig. 1. Mean and variance among replicated 500-g grade sample measurements for sound splits along with the predicted variance relationship determined by regression techniques.

where N is the number of sampling units. A sampling unit is defined to be one 1800-g sample for %FM and %LSK and one 500-g sample for the remaining grade factors.

The effect of sample size or number of sampling units on the precision with which a grade factor can be determined can be estimated with equation 10, 11, and 12. The upper limit H and the lower limit L for 95% of the sample grade determinations taken from a lot with mean m can be estimated from normal approximations.

$$H = \mu + \sigma_{\bar{x}} (z_{a/2}) \qquad (11)$$

and

$$L = \mu - \sigma_{\bar{x}} (z_{a/2}) \qquad (12)$$

where $z_{a/2}$ is 1.96 for 95% confidence limits and $\sigma_{\bar{x}}$ is determined from equation 10. Figure 5 shows the upper and lower limits expected when using two different sample sizes (two different number of sampling units) to determine %FM from lots with various levels of %FM. Similar confidence limits can be developed for all grade factors using equation 11 and 12.

Similar relationships can be developed to estimate the effect of sample size or number of sampling units on the precision of determining the QLV/GT. The variance of QLV/GT for any size sample is

$$\sigma^2_{\bar{x}} = 184.64\ (1/N) \qquad (13)$$

Table 3. Regression coefficient α and the coefficient of determination R^2 relating the variance $S^2_{\bar{x}}$ to the mean m for each grade factor[1].

GRADE FACTOR	REGRESSION COEFFICIENT α	R^2
FOREIGN MATERIAL	0.166	0.758
LOOSE SHELLED KERNELS	0.098	0.754
SOUND MATURE KERNELS	0.115	0.822
SOUND SPLIT	0.211	0.865
OTHER KERNELS	0.170	0.884
DAMAGED KERNELS	0.363	0.791
EXTRA LARGE KERNELS	0.335	0.923

1. $s^2_{\bar{x}} = \alpha m - (\alpha/100)m^2$

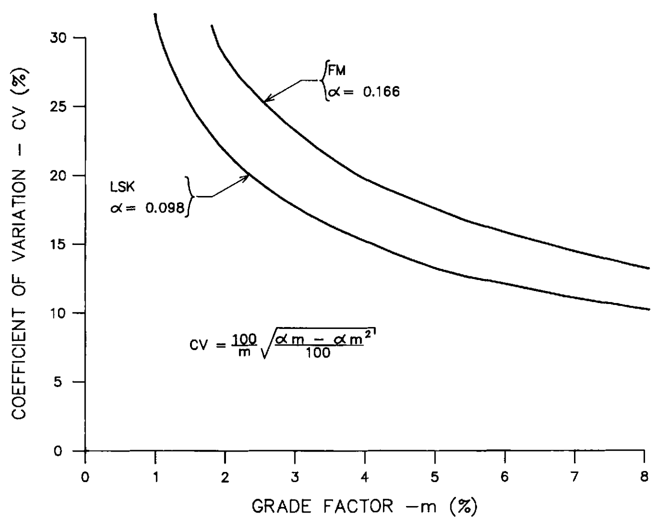

Fig. 2. Predicted coefficient of variation (%) associated with measuring foreign material (FM) and loose shelled kernels (LSK) when using an 1800-g sample.

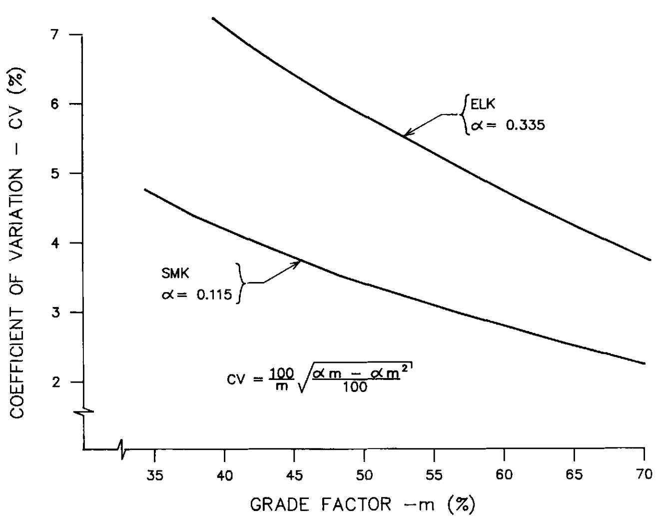

Fig. 3. Predicted coefficient of variation (%) associated with measuring extra large kernels (ELK) and sound mature kernels (SMK) when using a 500-g sample of pods.

where N is the number of sampling units. For QLV/GT, a sampling unit is defined as one 1800-g sample for %FM and %LSK and one 500-g for the remaining grade factors. The upper and lower 95% confidence limits can be determined using equations 11 and 12 where $\sigma^2_{\bar{x}}$ is defined by equation 13. When FSIS uses one sampling unit (N=1) to grade a lot with a true QLV/GT of $600.00, the computed QLV/GT based upon a 1800-g and a 500-g sample and a true variance of 184.64 would vary between $573.37 and $626.63, 95% of the time. If both segments of the grade sample were increased 4 times to 7200-g and 2000-g, the variance associated with the QLV/GT would be reduced to 1/4 its original value or $46.16. The lower and upper 95% confidence limits would then be $586.68 and $613.32, respectively. The upper and lower limits for N=1 and N=4 are shown in Figure 6 for a range in QLV/GT.

Summary

The variance associated with measuring %FM and %LSK

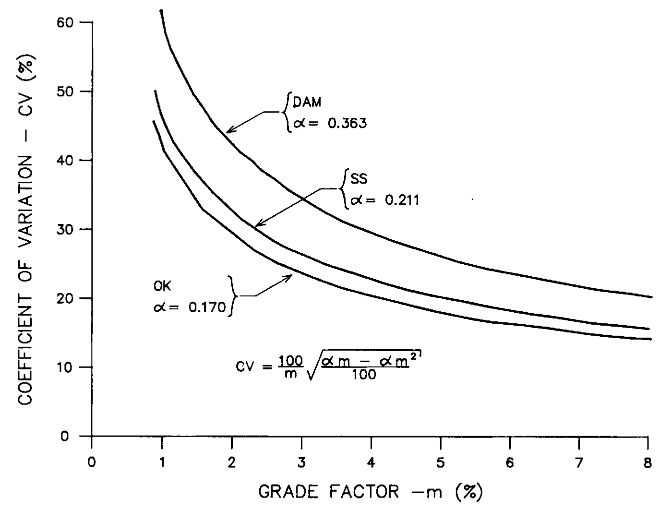

Fig. 4. Predicted coefficient of variation (%) associated with measuring damaged kernels (DAM), sound splits (SS), and other kernels (OK) when using a 500-g sample of pods.

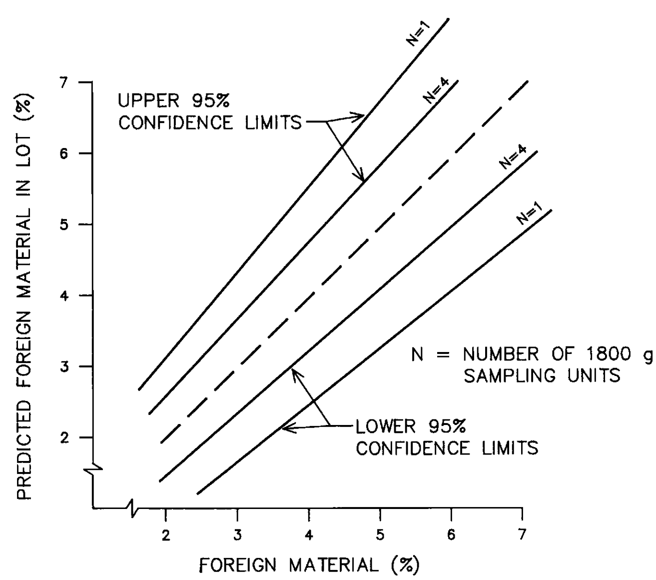

Fig. 5. Expected range of sample results when measuring foreign material with either 1 or 4 sampling units with 95% confidence limits.

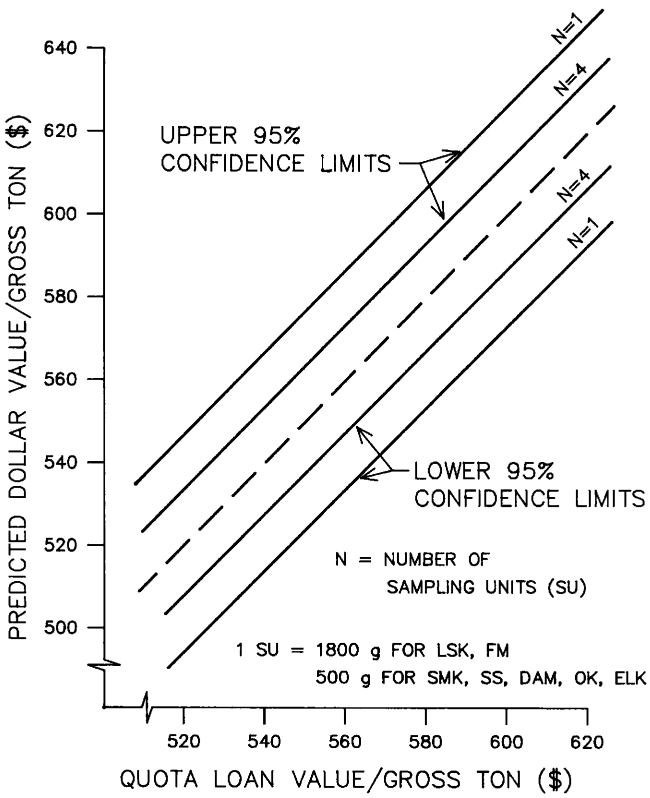

Fig. 6. Expected range of quota loan values per gross ton when using either 1 or 4 sampling units with 95% confidence limits.

using a 1800-g grade sample and measuring %SMK, %SS, %OK, %DAM, and %ELK using a 500-g grade sample was determined. The variance associated with computing the quota loan value per gross ton from the above grade factors using the 1988 loan schedule was also determined. The variance associated with each grade factor was found to be a function of the mean and could be estimated using binomial theory. The variance associated with the quota loan value per gross ton did not appear to be a function of the mean. The CV associated with a QLV/GT of $555 was 2.4%. Theoretically, increasing sample size reduces the variance. However, these variance reductions may not be achieved in practice due to increased errors associated with inspectors having to handle larger volumes of peanuts.

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