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Studies on the Sampling and Grading of Shelled Green Peas

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STUDIES ON THE SAMPLING AND GRADING OF SHELLED GREEN PEAS

INTRODUCTION

The sampling and grading studies presented in this report represent a continuation of a research program initiated in 1967 with the purpose of evaluating the current practices for determining the raw product grade of shelled green peas in the Pacific Northwest. These investigations have been supported cooperatively by pea growers and processors of the region and have been carried out under an agreement between grower organizations, the Northwest Food Processors Association, the Departments of Agriculture of Oregon and Washington, and the Oregon Agricultural Experiment Station.

The introduction of new bulk methods for transporting peas from field to processing plant and the increasing variations in the sampling and grading operations among processors in recent years have created a need to evaluate current grading practices and to support efforts toward standardization. The studies carried out in 1967 were designed to identify variables which significantly influence the reliability of tenderometer and usable weight data obtained from the lot sample of shelled green peas. The results of the 1967 studies which have been reported previously (Ref. 4), form the basis for the investigations completed during the 1968 pea season.

EXPERIMENTAL PLAN AND PROCEDURES

General

The purposes of the 1968 program were to extend the findings of the previous year's research and to investigate other variables associated with sampling and grading procedures for raw shelled peas. Four studies, as described below, were planned for the 1968 season by personnel of the Oregon Agricultural Experiment Station in consultation with an industry research committee appointed jointly by pea grower and processor organizations of the Pacific Northwest. A study proposal submitted to the committee was reviewed and approved by the supporting grower and processor organizations prior to the start of the 1968 pea season.

The cost of the 1968 project was funded jointly by the Oregon-Washington Pea Growers Association, the Northwest Canners and Freezers Association, and the Washington State Department of Agriculture. The Washington Department of Agriculture coordinated the project; the Oregon Agricultural Experiment Station provided the program, technical supervision, and data analysis.

Program Schedule

The following four studies were conducted during the 1968 program:

Study 1. Effect of Water Hardness on the Tenderometer Reading of Washed Shelled Peas

Study 2. Effect of Sample Temperature on the Tenderometer Reading of Shelled Peas

Study 3. Reliability of Proposed Sampling Methods for Bulk Lots of Shelled Peas

Study 4. Reliability of the FTC Texturepress Versus the FMC Tenderometer for Maturity Measurement of Shelled Peas

Arrangements were made to conduct the studies at two processing sites in each of the major pea-growing areas of the Pacific Northwest. Sites 1 and 2 were located in the eastern Oregon-Washington area (Area 1) while sites 3 and 4 were located in the Puget Sound area of western Washington (Area 2). The processors provided site facilities, certain equipment, and one of the two on-site personnel needed to carry out the research. The lead member of the site team was obtained from the Washington Department of Agriculture.

The studies began in Area 1 near the start of the harvest season. Studies 1 and 3 were conducted at Site 1, studies 2 and 4 at Site 2. Project personnel moved from one site to the other on a weekly schedule in order to spread the data collection over the season with minimum disruption at each site. After a period of five weeks in Area 1, the project personnel moved to Area 2 to repeat Studies 1 and 3 at Site 3 and Studies 2 and 4 at Site 4. The studies in Area 2 occupied a four-week period with a similar alternating weekly schedule between the two sites.

Raw Product

The 1968 investigations were restricted to the Dark Skinned Perfection variety of peas used by freezers in both areas. Where possible, lots offering a range of maturity were selected from those available and convenient for sampling. All tests were made on field-run peas passed through conventional dry sample cleaning equipment (Area 1) or in-plant commercial cleaning mills and washers (Area 2). Except where otherwise specified, all tenderometer measurements on shelled pea samples were obtained on FMC Tenderometers in regular use by raw-product grading personnel at the processing site.

Study 1: Effect of Water Hardness on the Tenderometer Reading of Washed Shelled Peas.

Plant water from different sources will vary in degree of hardness because of the presence of dissolved alkaline earth salts. Lots or samples of raw peas may be immersed in these plant waters for a short time for the purpose of washing the peas or controlling the temperature. Study 1 was designed to assess the effect of different levels of water hardness on the tenderometer reading of peas grown in both producing areas.

A single 25-pound sample of raw peas was drawn from selected lots of varying maturity when available at the site. Samples drawn from a lot before cleaning were passed through a cleaning mill and rinsed for 15 seconds in plant water. From the drained and mixed sample, four subsamples of three pounds were drawn and placed in separate water baths containing four gallons of water of equal temperature but of different levels of hardness. The following four levels of hardness were used:

1) 40 ppm hardness (soft water)
2) 80 ppm hardness (slightly hard water)
3) 150 ppm hardness (hard water)
4) 225 ppm hardness (very hard water)

The hardness levels were arbitrarily selected within the range generally accepted for each hardness category (Ref. 2).

Each subsample was immersed in the appropriate water bath for a period of five minutes with gentle stirring, then was removed and drained. Three tenderometer cuts were obtained on each sample.

The water hardness level of each bath was adjusted to within ±10 ppm of nominal by adding to zeolite-softened plant water the required volume of 2 molar calcium chloride solution. Further additions of the calcium solution were made as necessary to maintain the prescribed hardness level before each sample immersion. Hardness was determined in ppm as calcium carbonate, using the Schwartzenbach EDTA titration method (Ref. 1). The temperature of the four hardness baths was equalized to within 2° F.

Study 2: Effect of Sample Temperature on the Tenderometer Reading of Shelled Peas.

The investigations conducted during the 1967 season were extended by the current study to include the two major pea-producing areas in the Pacific Northwest and to obtain information on the tenderometer-temperature relationship for peas over two seasons.

A single 25-pound sample was drawn from selected lots of random maturity at each site. Samples drawn from lots before cleaning were cleaned on a sample cleaning mill, and the temperature of the dry-cleaned sample was taken. The sample was then rinsed briefly under cold water and mixed well. Six subsamples of three pounds were withdrawn for temperature adjustment. Each subsample was adjusted in turn to a different specific temperature in the series 50°, 60°, 70°, 80°, 90°, and 100° F by immersion for five minutes in a soft water bath maintained within one degree of the required temperature. After removal from the bath, the subsample was drained and placed in a small, closed styrafoam container to retain temperature constant until three tenderometer cuts could be taken.

The time required for peas to reach the extreme high or low bath temperatures was determined by use of a Tele-Thermometer probe inserted through the side of the styrafoam container into the center of the sample of peas. Accurate temperature measurement on the six water baths was also accomplished by use of the Tele-Thermometer.

Readings of the unwashed pea temperatures were taken as regularly as feasible on a 24-hour basis at the four plant sites involved in the 1968 studies. Pea temperatures in Area 1 were taken on the unwashed sample following the dry-cleaning operation, while pea temperatures for Area 2 were taken on the lot just prior to in-plant cleaning. A record of plant water temperatures at each site also was obtained.

Study 3: Reliability of Proposed Sampling Methods for Bulk Lots of Shelled Peas.

Bulk truck sampling and in-plant flow sampling are the two most common bulk-sampling practices currently employed for peas in the Pacific Northwest. The objective of Study 3 was to assess the relative reliability of two proposed methods for bulk truck sampling and of different patterns for in-plant flow sampling of peas.

Sampling of bulk truck loads. An in-plant flow sampling of the lot was used as the reference method for evaluation of the two sampling methods proposed for bulk truck loads. Selected lots of random maturity were sampled in duplicate by each method. The designated treatment number and details of each method follow:

1. Reference method: Duplicate composite samples of 10 pounds minimum were accumulated from the lot during the complete period of in-plant flow from holding bins to the plant cleaning equipment. Samplings were made from the entire cross section of flow at five-minute intervals.

2. Truck box port sampling method: Duplicate samples of 25 pounds were drawn from the bulk truck load by removing nearly equal quantities of peas from four 8-inch-square ports on the truck box. Two ports were located on each side of the box, equidistant along the length of the box. One port on each side was located at truck-bed height and the other at a point 18 inches above the bed. Each port was sampled by raising the slide gate fully and allowing the peas to flow freely into the sample container until one-fourth of the total sample had been drawn.

3. Dump-pelican method: Duplicate composite samples of at least 10 pounds were obtained from the end of the truck box as the bulk load was being dumped into a plant holding bin. Two standard grain samplers of the pelican type (4" diameter x 12" long cylinder, 1.25" x 12" throat) were arranged in tandem to collect the duplicate samples during the first three weeks of the study at Site 1. During the final two weeks of the study in Area 1, the standard grain pelicans were replaced by a second set of pelican samplers which had a wider throat and a larger cylinder (5" diameter x 12" length, 1.75" x 12" throat). The samplers were attached in tandem to the end of a long handle and were repeatedly passed through the flow of peas from the one side of the box to the other as the load was slowly dumped.

The composite sample representing each method was weighed to the required weight, then passed through a Key sample-cleaning mill equipped with a 14/64-inch slotted-hole screen for removal of undersize dockage. The cleaned sample was reweighed and the weight reduction was calculated as percent mill dockage. The sample was mixed well, and a three-pound subsample was withdrawn. Each subsample was immersed in a bath of flowing plant water for five minutes in order to wash the peas and standardize the temperature. Three tenderometer cuts were taken on each duplicate sample after draining. Tenderometer readings and water temperatures were recorded.

Sampling of the lot during in-plant flow. In Area 2, the study of sampling methods was designed to determine whether or not a consistent upward or downward trend in pea maturity occurred during in-plant flow of a bulk lot of shelled peas. A convenient sampling point was selected on each of two product lines directly following the dry cleaning and washing operations at Site 3. The cleaned peas were sampled on line A as they left the dump scale discharge bin, and on line B as they passed out of the washer.

The lot was sampled at the start of flow and after each five-minute interval of flow. The composite of two samplings in each consecutive 10-minute period was regarded as a lot segment sample, and segment samples were numbered 1, 2, etc. in sequence. The first and third segment samples were drawn in duplicate and all samples weighed at least three pounds. Sampling was continued to the end of the lot flow. Care was taken to sample a full cross section of the flow at all times.

When each sample was complete, it was mixed and immersed for five minutes in a bath of flowing plant water to standardize the temperature. The sample was drained and placed in a styrafoam container to hold temperature constant until three tenderometer cuts were taken. Tenderometer readings for each sample were recorded by lot and line number.

Study 4: Reliability of the FTC Texturepress Versus the FMC Tenderometer for Maturity Measurement of Shelled Peas.

The T-1300 Texturepress instrument manufactured by Food Technology Corporation was tested against the Food Machinery Corporation Tenderometer for reliability in measuring the tenderness of peas. Comparisons were made among one or two Texturepress instruments and two Tenderometers at the site selected for Study 4 in each pea production area. The Texturepress instruments were loaned expressly for the study by the manufacturer, while the Tenderometers at each site were owned by the processor and used routinely for raw product grading. Each instrument used in this study was checked daily to assure correct operating conditions according to manufacturer's instructions.

A single sample of approximately 25 pounds of field-run peas was drawn from selected lots of random maturity level on each day of the study. Dry samples were passed through a Key sample-cleaning mill and washed briefly in plant water. The sample was then mixed well, immersed in flowing plant water for five minutes to standardize the temperature, drained, and placed in a styrafoam container to hold temperature constant during the testing period.

Subsamples sufficient to fill the sample box of the Texturepress or the open chamber of the Tenderometer were drawn in sequence from the sample and three cuts were made on each instrument. Tests on the Texturepress instruments were made with a level-full sample box, and a 25-second down-stroke time on the power ram with a hydraulic pressure setting of 275 psi. Both instrument types were calibrated to measure pea tenderness directly in tenderometer units.

Two Texturepress instruments were available for only one week at Site 2; therefore, the balance of the study at Site 2 and the entire study at Site 4 was conducted with one Texturepress and two Tenderometers.

PRESENTATION OF RESULTS

Study 1: Effect of Water Hardness on the Tenderometer Reading of Washed Peas.

The practice of washing raw shelled peas prior to the determination of tenderometer value is increasing at Pacific Northwest processing plants. There is a current trend to in-plant sampling of the lots after the peas have been washed, and washed samples are recommended by the manufacturer of the Tenderometer for better instrument performance. Although extreme water hardness is seldom encountered in the Pacific Northwest, processing plant waters vary in hardness according to source and locality. Since the alkaline salts which cause water hardness are known to produce textural changes in many food products, the hardness of the water used in washing green peas and its effect on the tenderometer value of the washed sample was investigated in Study 1.

The water hardness study was carried out at Site 1 (Area 1) and Site 3 (Area 2) during the 1968 pea season. Tenderometer data representing 77 lots and four levels of water hardness from soft to very hard were collected. An analysis of variance was made on the data to establish the statistical significance of differences observed among water hardness treatments. Table 1 shows the average lot tenderometer values for each water hardness level and the least significant difference (LSD) required between treatment averages to establish with 95% confidence that hardness condition does affect the tenderometer value of peas. Average lot tenderometer values within water hardness levels are also calculated for lots in low (105 or below) and high (116 and above) tenderometer brackets in the case of Site 1 data.

A small but significant increase in tenderometer value of the average lot between the 40 ppm water hardness level (soft water) and the 150 ppm level (hard water) occurred at both sites studied. This indicates that the immersion of shelled green peas in plant water at uniform temperature for a five-minute period, as may be required to wash and/or adjust the temperature of the raw product before the tenderometer test, can produce an increase of approximately one unit in the tenderometer reading of the peas if the water contains 150 ppm or more of hardness measured as calcium carbonate ($CaCO_3$). Whether the significant effect of water hardness on the tenderometer test assumes practical importance for the industry will depend on the frequency of hard water conditions in the Pacific Northwest.

Table 2 includes a summary of actual plant water hardness values in terms of average and range for all four plant sites included in the 1968 study. Two sites had soft water, one site employed water varying from soft to slightly hard, and one site had hard water. Since the differences were of the same order for both high and low tenderometer brackets (shown for Area 1 data in Table 1), the magnitude of the water hardness effect with short-time immersion methods does not appear to be influenced by the maturity level of the peas.

The average dwell time of raw peas in a standard commercial pea washer is considerably less than the five-minute immersion period established for this study to assure internal pea temperature equalization. However, the industry may introduce new washing, cooling, or handling practices in which the raw peas are immersed in plant water for longer periods of time before sampling. In such cases, water hardness could have an important effect on the accuracy of the tenderometer reading.

TABLE 1. EFFECT OF WATER HARDNESS LEVEL ON THE MEAN LOT TENDEROMETER VALUE OF WASHED GREEN PEAS

Water hardness	Mean lot tenderometer value			
	Area 1 - Site 1			Area 2 - Site 3
(ppm $CaCO_3$)	Random tend.	Low tend. 94-105	High tend. 116-134	Random tend.
40	108.1	99.8	123.5	107.1
80	108.6	100.5	124.1	107.3
150	109.1	100.8	124.4	108.2
225	109.1	101.1	123.5	109.0
LSD (p=0.05)	0.44	--	--	1.02
No. of lots in test	57	27	13	20

TABLE 2. WATER HARDNESS AT FOUR PACIFIC NORTHWEST PROCESSING SITES

Area	Site	No. of tests	No. of days	Water hardness, ppm as $CaCO_3$ Average	Range [1]
1	1	13	8	44	36-62
1	2	19	9	107	102-115
2	3	24	12	25	24-27
2	4	11	10	23	22-26

[1] Classification of water hardness given by Kramer and Twigg (Ref. 2):

Soft water : Under 50 ppm hardness as $CaCO_3$
Slightly hard water: 50-100 ppm hardness as $CaCO_3$
Hard water : 100-200 ppm hardness as $CaCO_3$
Very hard water : Over 200 ppm hardness as $CaCO_3$

Study 2: Effect of Sample Temperature on the Tenderometer Reading of Washed Peas.

A study carried out under this project in the Puget Sound area during the 1967 season showed that sample temperature was an important variable affecting the tenderometer test of pea maturity. Results of the 1967 study (Ref. 4) indicated an increase of one tenderometer unit for each decrease of 3 to 4 degrees Fahrenheit. These results agree closely with previous findings (Ref. 3) and indicate that two lots of peas of the same maturity but differing by 20° F in temperature could deviate by five points in tenderometer reading and thus be assigned to a different maturity grade. The importance of temperature control as a part of maturity tests on peas has therefore been clearly established. The current study explored the tenderometer-temperature relationship for peas in both growing areas of the Pacific Northwest and provided additional data needed for temperature standardization.

Study 2 was made at one processing site in each growing area according to the procedure previously described. Analysis of variance computed from the data for 60 lots at Site 2 and 65 lots at Site 4 revealed a highly significant difference between average tenderometer readings for each 10° temperature increment from 50° to 100° F. Table 3 shows a uniform rate of change in tenderometer readings with change in sample temperature over the 50-degree range. An equation expressing the tenderometer-temperature relationship for mixed pea maturity was computed for each site by regression analysis. These regression equations and the equation for the combined site data are reported in Table 3. The corresponding curves shown in Figure 1 describe a relationship that is linear and essentially parallel for both sites. Since the curves also fit the plot of experimental data closely, it can be concluded that the tenderometer-temperature relationship for Dark Skin Perfection peas is quite similar between the two major production areas. Table 3 shows the rate change in tenderometer value with change in temperature for the combined site data to be 0.30 unit per degree Fahrenheit.

The effect of varying levels of pea maturity on the relationship between tenderometer value and sample temperature was investigated by dividing the lot tenderometer data into three brackets based on the average tenderometer value for all temperatures. The brackets were designated as low (less than 94), medium (95 to 102), and high (103 and above). The regression lines calculated for the three tenderometer levels at each site are illustrated in Figure 2. Since the analysis indicated a significant difference in slope among the three maturity brackets, the two slopes that differed most were compared and found to represent a deviation of 1.5 tenderometer units for a temperature adjustment of 20°F.

Temperatures of unwashed peas were recorded at all four sites during the 1968 studies (Table 4). The average and range of plant water temperatures for all sites were recorded during the same period. Results indicate that the temperature of unwashed shelled peas at the point nearest to the determination of tenderometer grade ranged from approximately 55° F to 80° F on the average processing day in both areas. Plant water temperatures varied slightly around the seasonal average for each site.

Study 3: Reliability of Proposed Sampling Methods for Bulk Lots of Shelled Peas.

The aim of all lot sampling is to remove the smallest part of the lot which is fully representative of the quality in the total lot. As quality becomes less uniform from one part of the lot to another, a fully representative sample becomes more difficult to obtain. Thus, the sampling method for a non-uniform lot of peas must be worked out carefully if it is to produce samples which can be relied on to represent the lot.

The sampling study carried out in 1967 under this project compared the uniformity of pea maturity in bulk truck load, tote-bin load, and in-plant lot flow. Results showed bulk truck lots were least uniform and lots sampled during in-plant flow have become the most common practices for obtaining lot grade on raw peas in the Pacific Northwest. Study 3 was therefore included in the 1968 program to measure the reliability of two proposed methods for sampling bulk truck lots and of different patterns for in-plant flow sampling. Methods for sampling the stationary bulk truck load were studied at Site 1 and in-sampling patterns were investigated at Site 3.

TABLE 3. EFFECT OF SAMPLE TEMPERATURE ON TENDEROMETER VALUE OF SHELLED GREEN PEAS

Site	Number of tests	Avg. tenderometer value at given temp., °F						(p=0.05)	Rate change in tenderom.[1] (units per °F)
		50	60	70	80	90	100		
2	60	108.5	105.5	102.4	99.0	96.2	93.1	0.61	0.31
4	65	105.8	103.0	100.4	97.1	94.5	91.5	0.48	0.29
2&4	125	--	--	--	--	--	--	--	0.30

[1] Derived from the respective regression equations as shown:

Site 2 regression: $\hat{y} = 124.0 - 0.31\,x$
Site 4 regression: $\hat{y} = 120.2 - 0.29\,x$
Common regression: $\hat{y} = 122.2 - 0.30\,x$

Where x = temperature in degrees Fahrenheit, $\hat{y}$ = tenderometer units.

TABLE 4. RECORD OF UNWASHED SHELLED PEA TEMPERATURES AND PLANT WATER TEMPERATURES AT PACIFIC NORTHWEST PROCESSING SITES DURING 1968 PEA SEASON

	Unwashed pea temperature, °F									
	East. Ore.-Wash. area[1]			Puget Sound area[2]			Plant water temperature °F			
Hour of day	No. of tests	Avg.	Range	No. of tests	Avg.	Range	Site	No. of tests	Avg.	Range
12 midn.	8	62	52-72	8	62	54-76	(Eastern Ore.-Wash. Area)			
1 a. m.	9	64	51-73	9	60	51-74				
2	13	62	52-73	8	58	48-64	1	67	57	53-60
3	12	61	50-67	7	58	48-66				
							2	65	70	67-74
4 a. m.	11	59	48-68	6	56	48-63				
5	9	58	53-65	6	56	54-58	(Puget Sound Area)			
6	5	55	48-64	-insuffic. data-						
7	-insuffic. data-			-insuffic. data-			3	60	69	66-70
8 a. m.	6	62	54-69	9	58	51-62	4	48	70	68-73
9	16	63	54-73	17	59	53-66				
10	21	67	55-77	17	62	56-69				
11	21	69	59-80	18	65	55-72				
12 noon	17	71	60-82	18	69	63-77				
1 p. m.	16	72	67-86	12	71	63-77				
2	31	74	65-87	15	75	62-83				
3	25	76	62-88	18	79	65-85				
4 p. m.	18	78	65-86	17	79	58-88				
5	7	75	59-91	11	78	66-87				
6	7	72	57-82	6	75	65-86				
7	5	74	62-84	7	74	66-85				
8 p. m.	15	71	56-84	9	72	62-83				
9	15	69	54-82	9	69	62-80				
10	11	65	53-78	9	67	58-79				
11	11	65	52-76	8	64	57-78				
AVERAGE		67.1	56-78		66.6	58-75				

1 Sites 1 and 2 combined.
2 Sites 3 and 4 combined.

FIGURE 1: REGRESSION OF SAMPLE TEMPERATURE ON RAW PEA TENDEROMETER VALUE

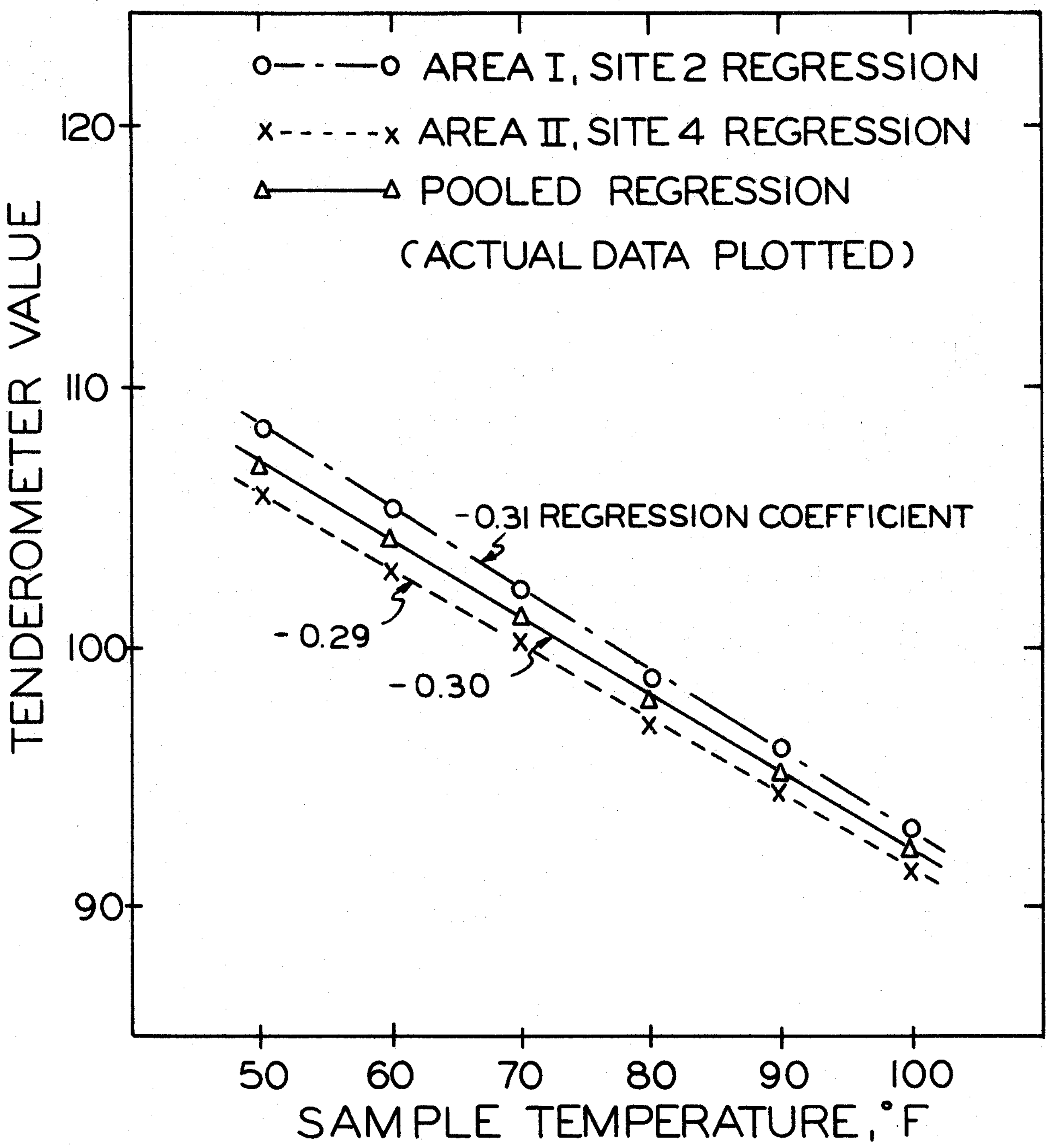
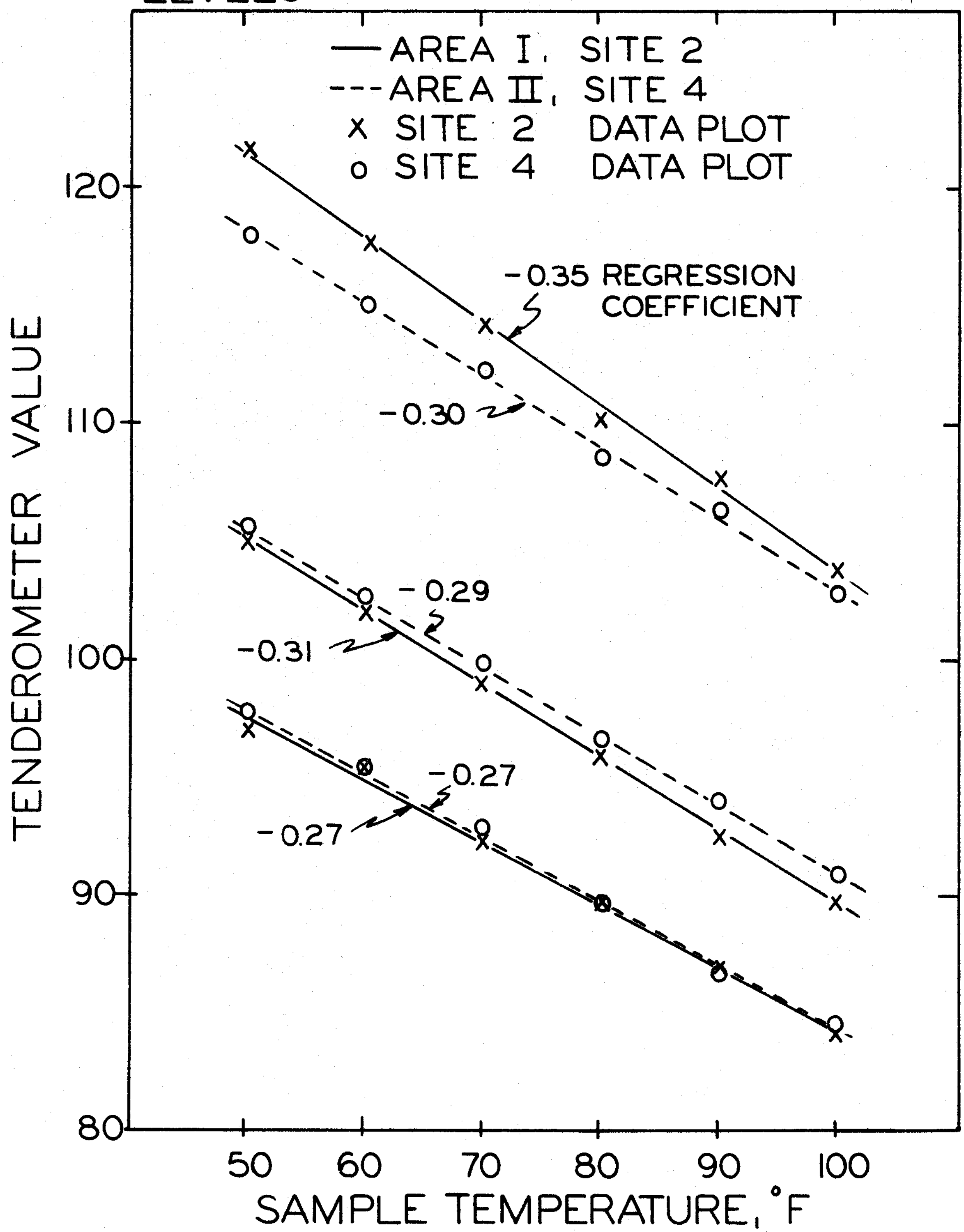


FIGURE 2: REGRESSION OF SAMPLE TEMPERATURE ON RAW PEA TENDEROMETER FOR THREE MATURITY LEVELS



Sampling of bulk truck loads. An in-plant sampling procedure (Method 1) was employed as a reference method against which to measure the relative reliability of the proposed sampling methods, designated the truck box port method (Method 2) and the dump-pelican method (Method 3). A series of 57 lots of peas of varying maturity were sampled in duplicate by these three methods according to the procedures described previously in this report. The tenderometer data and mill dockage data were subjected separately to analysis of variance in order to determine the effect of sampling method on the mean lot data (accuracy) and on the variation among samples and tests within the lot (precision). Table 5 gives the mean lot tenderometer value and mean percent mill dock for the three sampling methods. The least significant difference (LSD), which may be used to assess the statistical importance of the differences observed in the lot means, is also shown in Table 5. The results indicate that the truck box port and dump-pelican methods gave significantly lower tenderometer values on the average than the in-plant sampling method (reference). For 57 lots ranging in tenderometer units from 90 to 137, the mean tenderometer value averaged 1.8 units low in the truck box port sampling and 1.3 units low with the dump-pelican method. The latter method also gave significantly lower mill dock values, 1.7% lower when using the standard grain pelican sampler and 1.5% lower when using the enlarged pelican sampler.

Relative measures of precision for the three sampling methods used on bulk truck loads are given in Table 6 with respect to lot tenderometer value and in Table 7 for percent mill dockage. A statistical comparison of the variance estimates for the three methods indicates that the amount of variation in tenderometer value within a given lot was statistically similar regardless of the sampling method used. In the case of mill dockage values, the truck box port method produced substantially more sample-to-sample variation than the other two methods. Thus the three methods were equally precise when measuring tenderometer value, but the truck box port method gave less precision in the determination of mill dockage.

TABLE 5. ASSESSMENT OF ACCURACY IN METHODS OF SAMPLING THE BULK TRUCK LOAD

Sampling method	Avg. lot tend.	Percent mill dock, avg. lot [1]	
		Group 1	Group 2
1. In-plant flow	106.3	14.7	16.0
2. Truck box port	104.5	14.1	16.2
3. Dump-pelican	105.0	13.0	14.5
LSD (p=0.05)	0.60	1.16	1.01
No. of lots	57	33	24

[1] Group 1 series: Standard grain pelican sampler used in dump-pelican method; Group 2 series: Enlarged pelican sampler used in dump-pelican method.

TABLE 6. PRECISION OF THE TENDEROMETER VALUE ASSOCIATED WITH METHODS OF SAMPLING THE BULK TRUCK LOT OF SHELLED PEAS

	Variance components within lot and method		
Sampling method	Cuts (V_c)	Samples (V_s)	Precision [1] (p=0.05)
1. In-plant	3.04	0.70	± 2.6
2. Truck box port	3.36	1.26	3.1
3. Dump-pelican	4.72	0.27	2.7
No. of lots sampled	57	57	
No. of cuts/sample	3	3	
No. of samples/lot	2	2	

[1] Precision estimated at twice the standard error of the mean ($S_{\bar{x}}$) where

$$S_{\bar{x}} = \left(\frac{V_c + n\,V_s}{nr}\right)^{1/2}$$

with n = 3 cuts per sample
r = 1 sample per lot

TABLE 7. PRECISION OF MILL DOCKAGE VALUE ASSOCIATED WITH METHODS OF SAMPLING THE BULK TRUCK LOT OF SHELLED PEAS

Sampling method	Lot sample variance	Precision[1] (p=0.05)
1. In-plant	0.89	± 1.9
2. Truck box port	4.12 **	4.1
3. Dump-pelican	0.62	1.6
No. of lots sampled	33	
No. of samples/lot	2	

[1] Precision estimated at twice the std. deviation among % mill dockage values for samples within a lot.

** Variance ratio between methods 1 and 2 highly significant.

Sampling the lot during in-plant flow. A 1967 study of sampling methods under this project (Ref. 4) revealed that lots of raw field-run peas sampled over a period of flow from holding bins and washers were relatively free of maturity stratification. Since processors use varying procedures to sample the lot during in-plant flow, an investigation was made in 1968 to detect any lot-flow patterns toward increasing or decreasing maturity which could affect the reliability of an in-plant sampling procedure.

In study 3, two groups of 47 lots each were sampled over the season at given points in the in-plant flow at Site 3. Table 8 contains a summary of tenderometer values (mean of 3 or 6 cuts) for each successive 10-minute segment sample averaged over all lots in the given group. Reading the data in the table horizontally, one can find no obvious up or down trends in tenderometer values proceeding from interval to interval of flow. An analysis of variance of the data confirmed this observation by finding differences in tenderometer values among lot segment samples to be nonsignificant.

The cut, sample, and lot segment components of tenderometer variation obtained by analysis of the in-plant lot flow data are reported in Table 9. The relative magnitude of the two variance components within the 10-minute segment of flow indicates that the sample component is negligible in this case. The cut-to-cut variation within one sample therefore expresses virtually all of the maturity variation to be found within a 10-minute segment of the lot flow. The variation among lot segments is approximately at the same order of magnitude as the cut variation.

This section of Study 3 has shown that pea maturity remains relatively stable throughout the lot flow sampled after the washing operation. The analysis of components of within-lot variation in tenderometer values indicates that the most reliable sampling procedures would involve several single samples drawn randomly throughout the lot flow with a minimum of two cuts per sample. A single composite sample accumulated from several random segments of the lot flow can give similar precision if a sufficient number of cuts are made from the sample.

TABLE 8. AVERAGE TENDEROMETER VALUES FOR SUCCESSIVE TEN-MINUTE SEGMENTS OF IN-PLANT LOT FLOW OF SHELLED GREEN PEAS

Sample point	No. of lots	Avg. tenderometer value by lot segment				
		1	2	3	4	5
Washer	47	111.2	111.6	111.7		
	40	111.4	111.7	111.7	111.2	
	10	110.9	111.4	111.5	111.5	110.4
Scale hopper	47	108.8	108.5	108.7		
	44	108.9	108.5	108.7	108.5	
	34	109.3	109.2	109.4	109.4	109.3

TABLE 9. PRECISION FACTORS ASSOCIATED WITH TEN-MINUTE SEGMENT SAMPLES DRAWN FROM BULK LOT IN-PLANT FLOW (TENDEROMETER TEST)

Sample point	Within-lot variance			Precision [1]
	Cuts (V_c)	Samples (V_s)	Segments (V_t)	(p=0.05)
Washer	6.7	< 0.1	4.7	± 2.8
Scale hopper	7.1	< 0.1	3.8	± 2.7

[1] Precision estimated at twice the standard error of the mean tenderometer value for four segment samples and two cuts per segment sample.

Study 4: Reliablity of the FTC Texturepress Versus the FMC Tenderometer for Maturity Measurement of Raw Shelled Peas.

Since 1967, the Food Technology Corporation of Reston, Virginia, has offered the green pea industry the T-1300 Texturepress, an instrument for measuring pea maturity directly in tenderometer units. This instrument uses the basic design of the Kramer Shear-press, with a hydraulic-force piston, a standard shear-compression cell to hold the sample, and a steel-alloy compression ring to detect the resistance force of the test sample. The T-1300 component system of the Texturepress was developed for routine tenderometer measurement in peas by the incorporation of an indicator dial which converts the shear resistance of the sample into units of measurement comparable to the tenderometer unit (pounds force per square inch of grid) of the FMC Tenderometer.

The manufacturer of the Texturepress claims that the instrument is more accurate in the tenderometer measurement of peas than the FMC Tenderometer. A number of pea processors and growers of the Pacific Northwest therefore indicated an interest in a study comparing the reliability of the two instruments under actual plant conditions. The study of instrument reliability was included in the 1968 program for this purpose. The original plan was to test two instruments of each type at one plant site in each growing area but component shortages prevented the Texturepress manufacturer from supplying two Texturepresses for the full season. Study 4 was therefore conducted for only one week with a full set of four test instruments (Site 2 in the eastern growing area), and for the remainder of the season, with one Texturepress in conjunction with two FMC Tenderometers.

Analysis of variance. Lot tenderometer values measured on a single common sample have been summarized by area and site in Table 10. The data were subjected to analysis of variance in order to determine the least significant difference (LSD) between instrument readings (Table 10). Results shown in

Table 10 reveal that where four instruments were tested at Site 2 (Area 1), the two instruments of each type agreed statistically in their measurement of tenderometer value averaged over 35 lots. However, the analysis shows with 95% confidence that Tenderometer B was delivering readings which were significantly higher than those of either Texturepress, while Tenderometer A gave higher readings than those of Texturepress A. Looking again at the Site 2 data showing average measurements by the two Tenderometers and Texturepress A on 80 lot samples, we note that each of these instruments generated significantly different average readings. Tenderometer B again gave the highest readings, while Texturepress A gave the lowest. At Site 4 (Area 2) where another set of instruments was under test, Tenderometers C and D measured alike but gave significantly lower readings on the average than Texturepress A. Differences in calibration between the measuring devices, both within and between type, were of sufficient magnitude to be detected by the analysis. However, high or low average readings by a test instrument usually can be avoided by a regular recalibration against an accepted standard instrument if the readings obtained by the two instruments for the same set of samples are highly correlated and if they also increase or decrease at the same rate in response to sample tenderness changes over the normal range of measurement.

TABLE 10. AVERAGE LOT TENDEROMETER VALUES AS MEASURED BY FMC TENDEROMETER AND FTC TEXTUREPRESS

		Avg. lot tenderometer by instrument						
		Tenderometer				Texturepress		LSD
Site	Compared	A	B	C	D	A	B	(p=0.05)
2	80	108.9	110.0	-	-	107.2	-	0.68
2	35	105.8	106.2	-	-	104.8	105.0	0.87
4	63	-	-	100.1	100.6	101.7	-	0.68

Correlation. A correlation analysis was made to test the degree of linear relation between lot tenderometer values measured by each two instruments compared in the study. A perfect straight-line relationship between two sets of instrument data is indicated by a linear correlation coefficient, r, of 1.0, and a good correlation is shown when the coefficient has a value of 0.9 to 1.0. The actual values determined for "r" in the comparison of instruments at each site are reported in Table 11. The correlation results demonstrate a good-to-excellent linear relationship between the measurements of any two of the instruments used in the study.

Regression. The respective change in magnitude of the tenderometer readings with change in sample tenderness was determined for each two test instruments by regression analysis of the data. An identical rate change response for the two instruments is indicated when the regression coefficient, b, has a value of 1. The actual values for the regression coefficient in the instrument comparisons at the two sites are shown in Table 11. The reported coefficients indicate that the rate change in scale reading for any two instruments varied from unity by as much as 0.15 and that similar deviations were found between instruments of the same type as between instruments of different type.

It is evident from the correlation and regression statistics that the response of the Tenderometer and Texturepress instruments to textural changes in raw peas is very similar over the full range of maturity tested. A graphical plot of one regression between Tenderometer and Texturepress measurements is illustrated in Figure 3 with both the actual and optimum regression lines included.

TABLE 11. LINEAR CORRELATION AND REGRESSION COEFFICIENTS FOR TENDEROMETER MEASUREMENT OF GREEN SHELLED PEAS BY SEVERAL TEST INSTRUMENTS

Site	Instruments compared	Linear corr. coef., r	No. of tests	Linear regression coef., b
2	Tend A vs Tend B	0.977	80	1.030
	Tend A vs T-press A	0.975	80	1.100
	Tend B vs T-press A	0.979	80	1.048
2	Tend A vs T-press B	0.974	35	1.092
	Tend B vs T-press B	0.969	35	0.962
	T-press A vs T-press B	0.969	35	0.896
4	Tend C vs Tend D	0.913	63	0.842
	Tend C vs T-press A	0.963	63	1.087
	Tend D vs T-press A	0.933	63	1.142

Precision. An estimate of instrument precision was determined for each unit from the variation obtained in the measurement of three cuts on the same field-run sample of peas. Instrument precision, as reported in Table 12 for group comparison, indicates the maximum range of values expected by change for repeated readings on the same sample and instrument (95% confidence).

Results given in Table 12 indicate that Texturepress A measured tenderometer values with less precision than the FMC Tenderometer instruments. However, Texturepress B, which was employed in only one group comparison, showed a degree of precision comparable to that of the two Tenderometers and superior to Texturepress A. Precision among the Tenderometers varied also, with Tenderometer D giving the most uniform readings.

TABLE 12. INSTRUMENT PRECISION IN THE TENDEROMETER MEASUREMENT OF RAW SHELLED PEAS

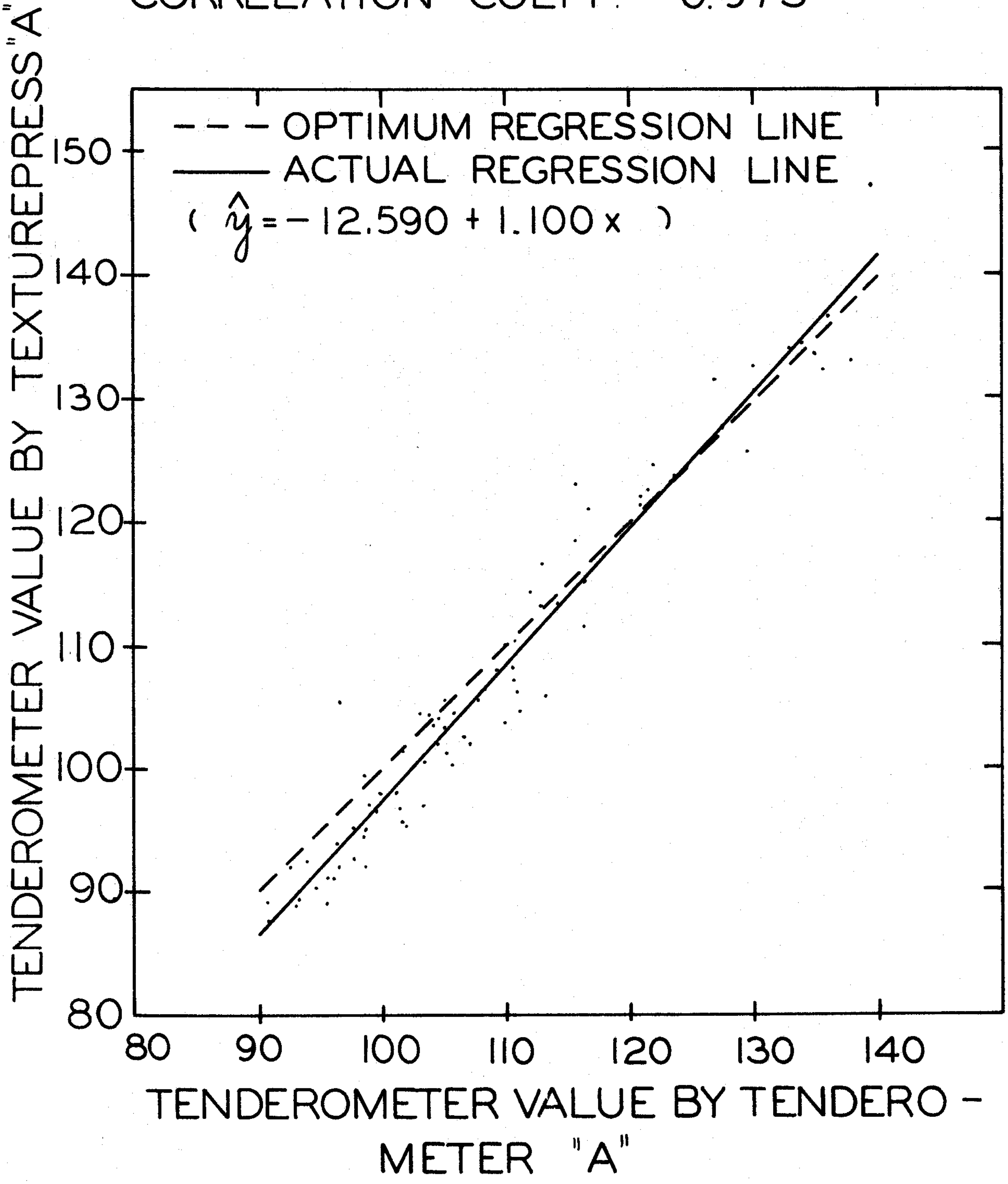
Site	Test instrument	No. of tests	Std. dev. among cuts	Precision [1] (p=0.05)
2	Tend A	80	2.23	± 4.5
	Tend B	80	2.50	5.0
	T-press A	80	2.69	5.4
2	Tend A	35	2.30	± 4.6
	Tend B	35	2.40	4.8
	T-press A	35	2.73	5.5
	T-press B	35	2.33	4.7
4	Tend C	63	2.14	± 4.3
	Tend D	63	1.96	3.9
	T-press A	63	2.46	4.9

[1] Expressed as twice the standard deviation among the tenderometer cuts.

Study 4 has provided evidence that the Texturepress and the Tenderometer, when subjected to the same experimental variables, are capable of similar reliability in measuring the maturity of green peas. Thus the two instruments have potential interchangeability after due consideration is given to factors such as ease of maintenance, adjustment, and operation under routine plant use.

FIGURE 3: PLOT OF TENDEROMETER VALUES DETERMINED ON RAW PEAS BY TENDEROMETER "A" VERSUS TEXTUREPRESS "A"

CORRELATION COEFF. = 0.975



SUMMARY

A series of four studies were conducted at Pacific Northwest pea processing plants during the 1968 season in the second year of a research program designed to evaluate sampling and grading practices for raw product grade on shelled green peas. The project has been supported by grower and processor organizations with the purpose of providing information necessary for improving and standardizing grading procedures in the green pea industry.

The 1968 studies were conducted at two plant sites in each of the two major pea-producing areas of the Pacific Northwest. A large amount of data was collected from many lots of green peas during the processing season. These data provide the basis for the conclusions below.

<u>Study 1. Effect of water hardness on the tenderometer reading of washed raw peas</u>. Raw shelled peas show a small but significant increase in tenderometer value when immersed for a five-minute period in water at 70° F containing 150 ppm or more hardness as calcium carbonate. The study revealed an average increase of one tenderometer unit during the brief immersion in hard water. Although hard water is not normally encountered in the Pacific Northwest, this variable may become important in cases where methods of washing or cooling require longer periods for immersion of the peas in water.

<u>Study 2. Effect of sample temperature on the tenderometer reading of raw peas</u>. A linear relationship was demonstrated between sample temperature and tenderometer value of raw shelled peas over the temperature range of 50° to 100° F. The temperature effect was found to be essentially equivalent for Dark Skin Perfection peas of random maturity in both growing areas of the Pacific Northwest. An increase of 0.30 tenderometer unit per degree Fahrenheit drop in sample temperature was established as the average rate change for both areas. The temperature effect was statistically greater for high maturity peas than for low maturity peas, but a deviation of more than one tenderometer unit would be expected only with extreme differences in pea maturity.

<u>Study 3. Reliability of proposed sampling methods for bulk lots of shelled raw peas</u>. Sampling the bulk truck load through four ports in the sides of the truck box and sampling with a pelican sampler while dumping the load were found to produce lower average lot tenderometer values by 1.8 units and 1.3 units, respectively, than the in-plant sampling method used as a reference. The dump-pelican method resulted in lower percent mill dockage values than the other methods. Although the three methods measured tenderometer values with equal precision, the truck box port sample was less reliable when estimating mill dockage in the lot. Thus neither of the proposed methods can be readily substituted for the reference in-plant sampling method.

In a second phase of the sampling method study, bulk lots of peas were found to be quite uniform in maturity distribution throughout the period of

in-plant flow following the washing operation. A comparison of tenderometer values for a series of 10-minute segments of the lot flow indicated that cut-to-cut variation and segment-to-segment variation were of a similar order of magnitude. This suggests that in-plant sampling is best performed by drawing several single samples randomly during the period of flow with at least two cuts per sample.

Study 4. Reliability of the FTC Texturepress versus the FMC Tenderometer for maturity measurement of raw shelled peas. A high correlation was obtained between the measurements of raw pea maturity by two FTC Texturepress instruments versus two FMC Tenderometers at one site in each area. Significant differences in average lot tenderometer value were demonstrated both within and between instrument type. Both types of instruments measured with essentially the same level of precision. Study 4 therefore demonstrated that Texturepress and Tenderometer measure the same maturity-tenderness characteristic of raw peas with about equal sensitivity to maturity changes. The disagreement in average reading among the instruments suggests that both types of instruments require regular calibration to attain good accuracy.

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