CONTINUED STUDIES OF THE RELATIONSHIP OF SPECIFIC GRAVITY TO TOTAL SOLIDS OF POTATOES[1]

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Abstract

The reliability of specific gravity as a measure of total solids was studied statistically. Studies on an expanded number of currently popular American potato samples indicated that differences were great enough that the accepted Von Scheele regression curve now borders on the obsolete. Variations in the relationship caused by lack of uniformity in analytical techniques, as well as inherent variations in the potatoes themselves indicated that a linear regression curve based on American potato varieties is sorely needed. It is suggested that such a curve be obtained through cooperative effort sponsored by the American Potato Association.

Resumen

La dependabilidad de la gravedad específica como una medida de sólidos totales ha sido estudiada estadisticamente. Estudios sobre un gran número de ejemplares de papas norteamericanas populares al presente, indicaron que las diferencias eran suficientemente grandes de tal manera que la generalmente aceptada curva d rgesión de Von Scheele es ahora casi obsoleta. Variaciones causadas por la falta de uniformidad en técnicas analíticas, como también variaciones inherentes en las papas mismas, indicaron que una curva de regresión basada sobre variedades de papas norteamericanas es muy necesaria. Se sugiere que tal curva se obtenga mediante un esfuerzo patrocinado por la American Potato Association.

Specific gravity of raw potatoes is widely accepted by the potato processing industry as a measure of total solids, starch content, and other qualities. Since it is also used as a basis of payment for raw material, the importance of the reliability of the specific gravity-total solids relationship should not be underestimated. With the constant re-evaluation of accepted potato varieties and the unending search for new and improved varieties, the potato industry must be aware of the fact that the criteria of quality found satisfactory in the past may no longer be applicable to the produce and the product uses of the present.

In a previous publication (4), the inherent effect of tuber variations on the specific gravity-dry matter relationship was pointed out. This effect was apparent even when the analytical techniques were rigidly controlled. In addition, the relationship between specific gravity and total solids is directly related to the analytical methods employed, because the results of this study indicate that the use of various methods for the determination of total solids can yield data having wider confidence limits than would be obtained if a single method were employed.

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In the above mentioned preliminary report (4) the linear regression curve of a limited number of American potatoes was compared with the curve produced by means of the Von Scheele (6) equation which was based upon analysis of European potatoes. There was considerable difference between the two curves although both fell within the 95% confidence limits of ± 1.5% of total solids.

This study is an expansion of the preliminary work, but incorporates the potato samples upon which the original report was based for the purpose of ultimately obtaining the most accurate regression curve for the varieties of American potatoes in current use.

Materials and Methods

The samples used in this study were obtained from three sources:

Series 1. A series of 83 potato breeding samples. Ten of these samples were parents and crosses furnished by Dr. Joseph J. Pavek of the Agricultural Research Service Branch Experiment Station, Aberdeen, Idaho. The remaining 73 were parents and crosses made under the supervision of Dr. Robert V. Akeley at the Maine Experiment Station, Presque Isle, Maine.

Series 2. A series of 135 potato samples. These consisted of five varieties grown in six different geographical locations for two consecutive growing seasons. This series was treated separately in the preliminary publication (4).

Series 3. A series of 265 potato samples. These tubers were grown in the northeastern and north central section of the United States. These samples had been previously analyzed for total solids by specific gravity and by direct drying by one of us (Houghland) at Beltsville, Maryland.

The method of analysis for the first series of potatoes was the same procedure, with slight modifications, previously reported for the second series (4). The total weight of each of these parents and crosses was in the order of 5 pounds. Therefore, each was divided into two subsamples of 1200 to 1400 grams each, and the final result was the average of the duplicates. These samples were accurately weighed in both air and water by the method of Murphy and Goven (3). Each subsample was then ground in a Waring Blendor[4] with sufficient absolute ethanol to convert the estimated water present (from Von Scheele (6) data) to 70% ethanol by weight. Aliquots of the slurry were placed in weighed moisture dishes, covered, and immediately weighed on a Mettler B-5 Macro balance. Ethanol and water were removed by drying in a convection oven at 60 C for three hours followed by two hours at 130 C. The per cent total solids was calculated from the residue.

The method of analysis for the third series of potatoes consisted of specific gravity determination by weighing the samples in air and water, and the determination of dry matter by weight loss of tissue macerated in a Herles press and then dried at 104 C for two hours.

Linear regression curves for each of the three series of potato samples and for the total (483) of all samples were calculated and plotted with the aid of an IBM model 1130 computer.

[4]Mention of any specific piece of equipment does not imply endorsement by the U. S. Department of Agriculture over similar equipment available.

The procedure used to calculate the linear regression curves was a computer method based upon least squares curve fitting (2).

The following equation used in arriving at the 95% confidence limits for each set of data was derived from information obtained from the publication by Walberg (7).

$$CL = \sqrt{\frac{\Sigma (Y_{ex} - Y_{cal})^2}{n - p}} \cdot t$$

where Y_{ex} = Total Solids from experimental data
Y_{cal} = Total Solids calculated from the regression equation
n = Number of samples
p = Number of parameters
t, taken from a table of values at the 95% level for the number of samples (5).

Results

Figs. 1, 2, and 3 show the specific gravity versus total solids data for the three individual groups of potatoes included in this study. Each figure contains the individual data points and includes the linear regression curve for these points as well as the 95% confidence limits about each curve.

For comparison, these graphs contain the linear regression curve (dotted line) for the total of all of the potato samples. The total results are summarized in Fig. 4 by the linear regression curve for the total of all samples and the 95% confidence limits about this curve. For comparison the curve for the Von Scheele (6) equation is included with this summation of the total data.

TABLE 1.—*Total solids, % calculated from specific gravity by the regression equation for each set of samples.*

Sample	Breeding samples	Variety, area year, samples	Northeastern samples	Total samples	Von Scheele
No. of samples	83	135	265	483	—
Sp. Gr.	%T.S.	%T.S.	%T.S.	%T.S.	%T.S.
1.06	15.96	16.83	17.35	16.84	15.99
1.08	20.47	20.79	21.08	20.88	20.21
1.10	24.98	24.75	24.81	24.91	24.44
Cl[1]	1.48	1.58	2.39	2.11	unknown[2]
F value	858.7	889.3	495.2	1615.9	$r_{xz} = 0.937$
F_1 %[3]	6.95	6.83	6.74	6.69	

[1]Cl = 95% confidence limits.
[2]Estimated from distribution table as ca. ± 2%.
[3]The minimum value of F that is required to indicate a highly significant result at the 1% level.

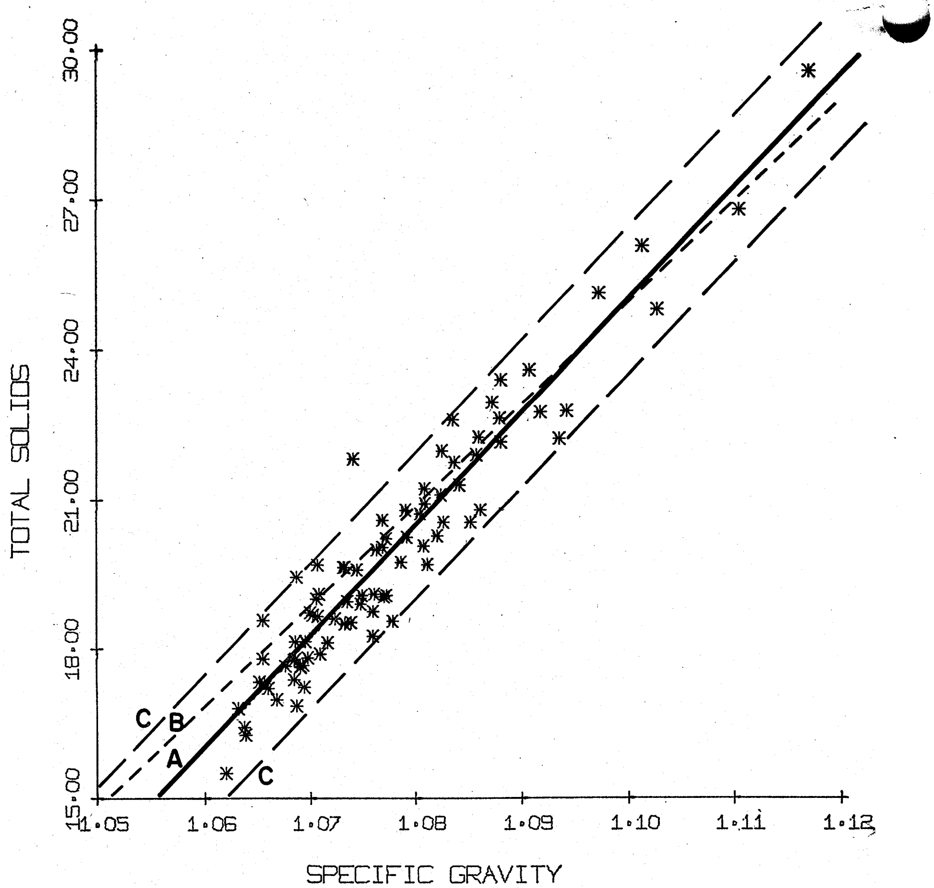

FIG. 1.—Specific gravity versus per cent total solids. Distribution of data for 83 potato breeding samples.
A = Regression curve for the breeding samples.
B = Regression curve for the total samples.
C = 95% confidence limits for A.
Per cent Total Solids = —223.03 + 225.46 (sp. gr.)

Table 1 presents the data which can be employed to plot the regression curves and the Von Scheele curve, along with their confidence limits and the significance of each set of data.

Discussion

In Fig. 1, which includes the data for 83 potato breeding samples, the upper end of the scale is dominated by the 10 samples from Idaho. The solids content for these ranged from a low of 21.75% to 29.57% for the newly developed Lenape-A variety. All 10, however, were within the confidence limits for this series of samples. The remaining 73 samples fell in the lower half of the scale, with sufficient point scatter to set the 95%

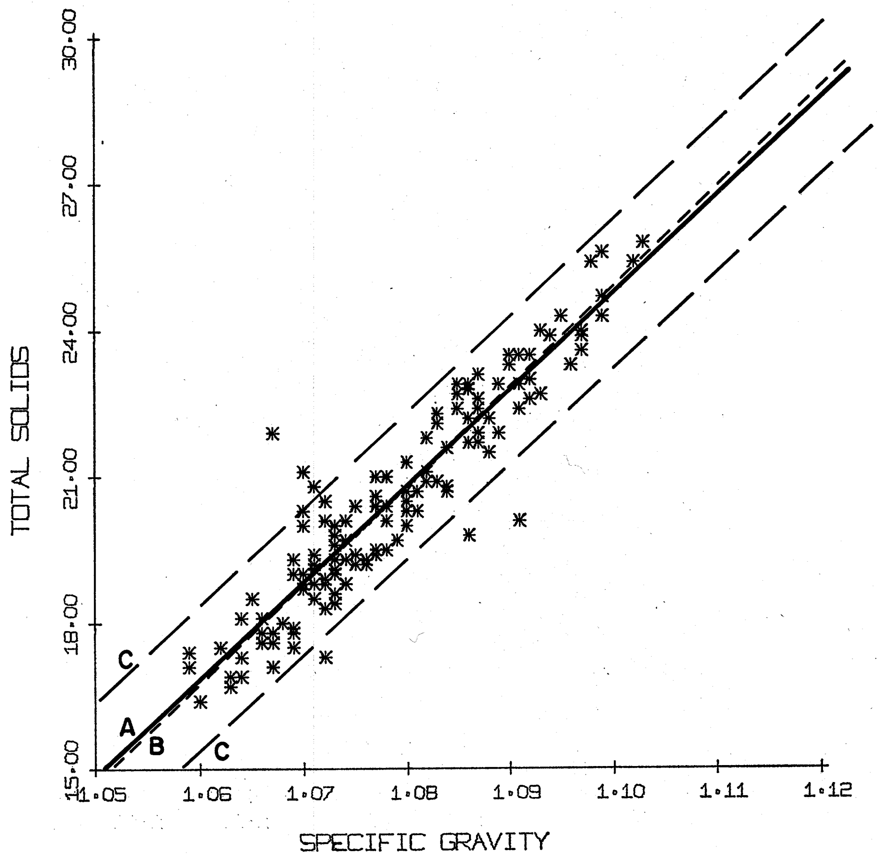

FIG. 2.—Specific gravity versus per cent total solids. Distribution of data for 135 potato samples consisting of six varieties grown in five different areas for 2 years.
A = Regression curve for 135 potato samples.
B = Regression curve for the total samples.
C = 95% confidence limits for A.
Per cent Total Solids = —193.02 + 197.97 (sp. gr.)

confidence limits at ± 1.48. The linear regression curve for these samples was slightly steeper than the curve for the total of all potato samples. The latter curve, however, was within the confidence limits for the 83 potato sample series.

Fig. 2 included the 135 potato samples comprised of the Katahdin, Kennebec, Cobbler, Red Pontiac, and Russet Burbank varieties, each grown in Maine, Long Island, Pennsylvania, Wisconsin, Idaho, and the Red River Valley for the growing seasons of 1962 and 1963. The linear regression curve for these tubers is quite closely aligned with the regression curve for the total samples, to the point of being almost superimposed. The 95% confidence limits for this set of data are ± 1.58, with the data points being generally well distributed.

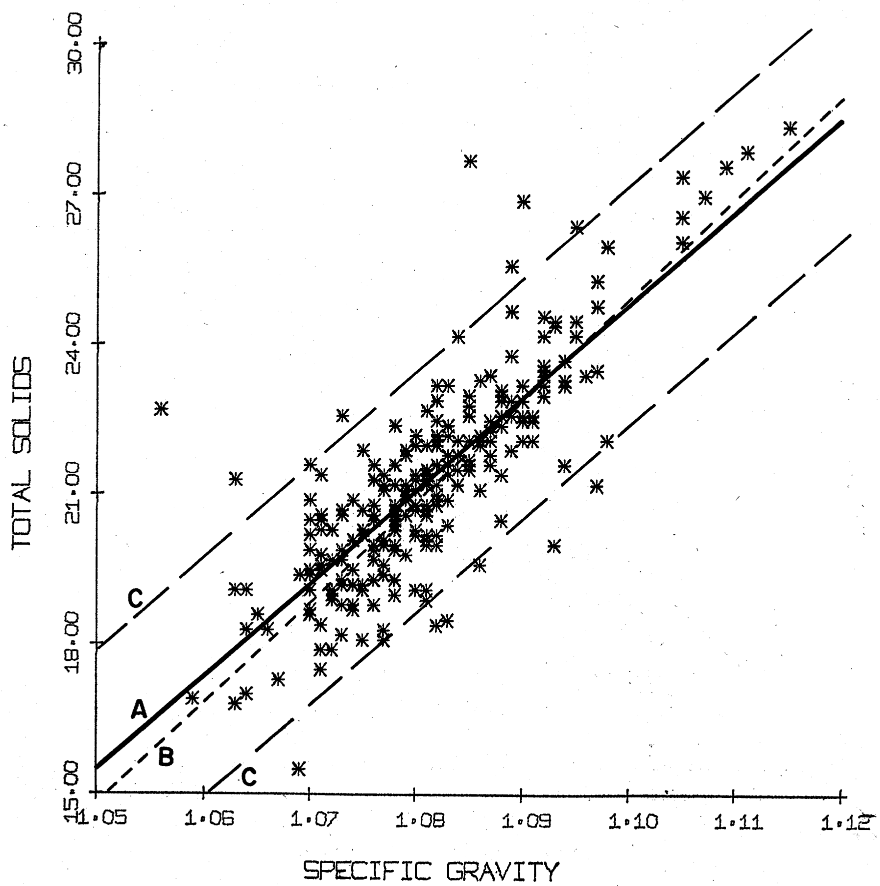

FIG. 3.—Specific gravity versus per cent total solids. Distribution of data for 265 potato samples grown in the northeastern U. S.
A = Regression curve for the 265 potato samples.
B = Regression curve for the total samples.
C = 95% confidence limits for A.
Per cent Total Solids = —180.09 + 186.27 (sp. gr.)

In Fig. 3, which includes the 265 potato samples analyzed at Beltsville, the 95% confidence limits of ± 2.39 are the widest of all three sample groups and wider than the confidence limits for the total of all samples. Since this series of samples made up 55% of the total population, the linear regression curve coincided fairly well with the regression curve for all samples but was slightly less steep.

Fig. 4 includes the data points for all 483 potato samples included in this study and the linear regression curve for these points. The 95% confidence limits for all samples is ± 2.11. The curve for the Von Scheele (6) equation appearing on Fig. 4 is within these confidence limits. The differences between the linear regression curve and Von Scheele's curve are more pronounced at the lower range of specific gravity. Although the

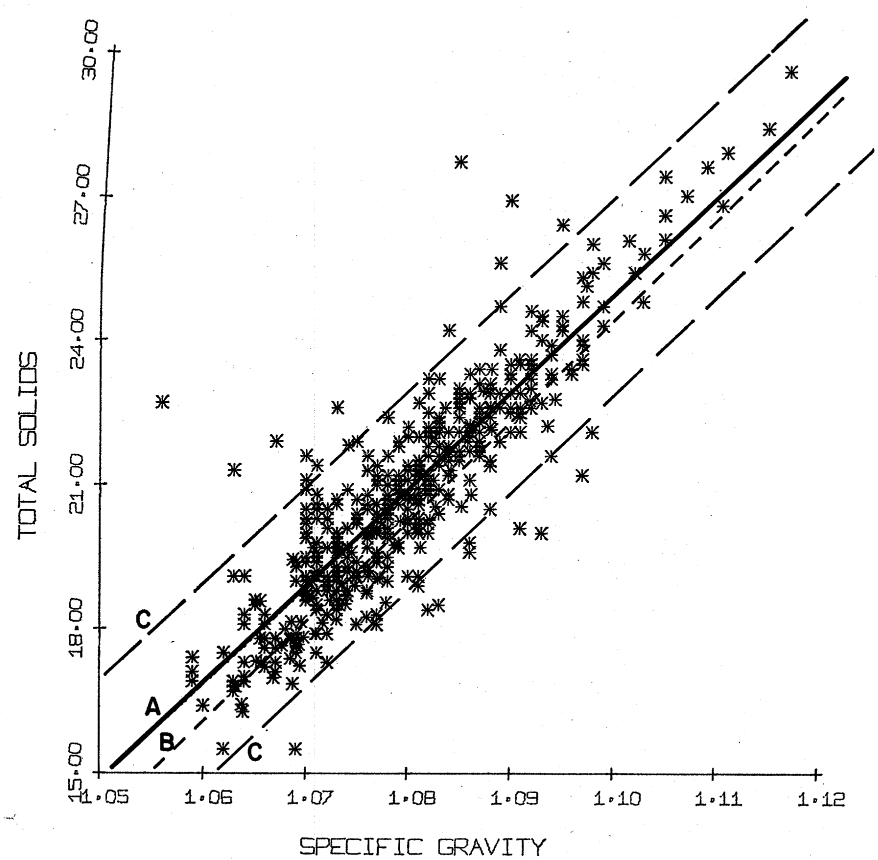

FIG. 4.—Specific gravity versus per cent total solids. Distribution of data for 483 potato samples.
A = Regression curve for all samples.
B = Regression curve from Von Scheele's data.
C = 95% confidence limits for A.
Per cent Total Solids = —196.98 + 201.72 (sp. gr.)

two curves do not converge they approach each other in the higher specific gravity range. This would be expected since Von Scheele's curve was based on European potato varieties which, in general, have a higher dry matter content than the popular U. S. varieties.

The confidence limits of ± 2.11 in Fig. 4 further demonstrate the fact that equating specific gravity with potato solids has limitations. In these samples, for example, tubers with a specific gravity of 1.08 might range in total solids from 18 to 22%.

On observing the data, it was found that the majority of points falling outside the confidence limits were from a set of samples whose total solids content was determined by a procedure nominally different from that used for the other two sets. Apparently there is no standard procedure for drying raw potatoes to determine their solids content. The inherent pitfalls of most procedures encountered in the literature are underdrying by using too low a temperature or insufficient time, or by using potato slices or pieces so large that case hardening and subsequent moisture entrapment occur. Overdrying, causing removal of water of crystallization may also lead to erroneous results. It is quite possible that standardization of the dry matter determination of potatoes could result in greater accuracy when correlating specific gravity with potato solids.

In our opinion the specific gravity-total solids relationship is in a state of confusion due to variations caused by such factors as variety, area of growth, internal composition of tubers, analytical techniques, and perhaps others.

Agle and Woodbury (1) believe that existing tables for predicting dry matter from specific gravity data should be used until such a time as a better test than specific gravity becomes available. However, we believe that the industry is quite far away from developing an alternate test which is as convenient and economical as the present test for specific gravity. Under these circumstances we think that the existing tables should be retained only as long as it takes to obtain sufficient data on currently produced United States potato varieties, through a cooperative project using standardized analytical procedures. A study of this nature should produce a regression curve with narrow confidence limits, suitable for industrial use.

We suggest that these investigations could be carried out in a collaborative way by a committee appointed by The Potato Association of America.

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