SPECIFIC GRAVITY OF RUSSET BURBANK POTATOES[1]

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Abstract

Variability in specific gravity of Russet Burbank potatoes was documented in a single 32 hectare field. Maximum variation was 40 units among individual tubers within hills (one unit equals one part in 1000th of specific gravity measurement) and 15 units among hills. Field site variability of 10-15 units was common between sampled grid lines in the field; but bulked samples (truckloads) reduced the sampled variability to 8-10 units. When the samples were taken from bulked lots as opposed to single hill samples, the variability decreased. Grower lots, which were pooled samples from several truckloads, showed specific gravity differences of 2-7 units even though all lots were from the same field. These variations among specific gravity samples should be taken into account when considering total solids content in any lot of potatoes.

Degree of russetting of the skin and hollow heart also influenced specific gravity measurements. Measured differences between peeled and unpeeled lots of 10 units in specific gravity corresponded to 2% difference in total solids content. Statistically, the variance of the peeled lot was one half that of the unpeeled lot, therefore, to minimize the measured differences due to skin type, peeled potatoes could be used for the specific gravity measurements.

Compendio

Se probó la variabilidad en la gravedad específica de las papas Russet Burbank en un solo campo de 32 hectáreas. La variación máxima entre tubérculos individuales dentro de los puntos de siembra fue de 40 unidades (una unidad es igual a una parte por milésimo de la gravedad específica medida) y 15 unidades entre puntos de siembra. Fue común encontrar una variabilidad de 10-15 unidades entre las diferentes muestras tomadas en el terreno convenientemente dividido; pero muestras al granel (camionadas) redujeron la variabilidad de las muestras a 8-10 unidades. Cuando las muestras fueron tomadas de lotes al granel en oposición a muestras de un

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solo golpe o punto de siembra, la variabilidad disminuyó. Los lotes de los productores, que fueron una mezcla de muestras tomadas de varias camionadas, mostraron diferencias de 2-7 unidades en la gravedad específica aún en el caso que todos los lotes fueran del mismo campo. Estas variaciones en las muestras, en cuanto a gravedad específica, deben tomarse en cuenta cuando se considere el contenido total de sólidos en cualquier lote de papas.

El grado de reticulado de la piel y el de corazón vacío influencian también las mediciones de la gravedad específica. Las diferencias en las mediciones de la gravedad específica entre lotes pelados y sin pelar, que fueron de 10 unidades, corresponden a un 2% de diferencia en el contenido de sólidos totales. Estadísticamente, la variancia de los lotes pelados fue la mitad que la de los lotes sin pelar, por lo tanto, para minimizar las diferencias en las mediciones, debidas a las condiciones de la piel, se podrían usar papas peladas para las medición de la gravedad específica.

Introduction

Specific gravity determinations by the weight in air - weight in water method is an accepted procedure for estimating solids content of potatoes. This procedure is reasonably accurate and relatively easy to make. A majority of Russet Burbank potatoes grown in the Pacific Northwest is used for processing, therefore, the solids content of this variety is of primary importance in determining the processed-product recovery. As more and more emphasis is placed on final product consistency by the processor, the raw products supplied to the plant must meet increased standards for quality. Consequently, many processor contracts are stressing the need for higher quality potatoes. Growers may find that crop quality requirements for processing are above those that can be reasonably met during some growing seasons.

Estimates of dry matter content from specific gravity measurements are used as a tuber quality measurement of harvested tubers. The relationship of specific gravity to dry matter or starch content has been documented (1, 7, 8, 9, 11). Not only have different regions within the tuber been shown to differ in starch content, but differences in specific gravity have been reported with respect to point of origin and storage history (5, 7, 12). Iritani, *et al.* (3) and Kleinkopf, *et al.* (4) have reported on factors, both abiotic and biotic, which affect the accuracy of specific gravity determinations. Gas content in periderm tissue has a large effect on the specific gravity estimate of solids content (6, 7) as does the degree of netting of the skin (4) and hollow heart (2). Nevertheless, the estimate of tuber dry matter content from weight in air - weight in water specific gravity determinations has become a standard practice by USDA inspectors at processing plants (10). The purpose of this paper is to determine the extent of specific gravity tuber variability in the production and processing of Russet Burbank potatoes.

Procedures

Specific Gravity Determinations

The weight in air - weight in water method [SG=wt in air ÷(wt in air - wt in water)] for determining specific gravity is an accepted procedure in the potato industry. This method is a rapid way for estimating solids content of potatoes. Percent solids content of potato is related to specific gravity by the following formula:

$$\% \text{ SOLIDS} = -214.9206 + 218.1852 \text{ X} \qquad R^2 = 0.99$$

where X is the specific gravity of the sample in thousandths of units (10). This linear relationship allows an estimation of percent solids from various lots of potatoes given the specific gravity which has been corrected for water and tuber pulp temperature.

Sample Selection

All USDA/State inspection services follow a similar procedure for measuring specific gravity at the processing plants. For each grower on each delivery day, several "grab" samples of approximately 10 kg each are collected as the trucks are unloading. All "grab" samples are pooled into a "grower lot" for that day. Five kilograms of washed potatoes are weighed in air and in water for the calculation of specific gravity. Corrections are made for water and tuber temperatures and for wet tuber surfaces. The inspection service samples about 0.1% of the delivered potatoes for determination of grade and quality. The specific gravity value for each "grower lot" calculated by the inspection service is an average from the number of truckloads of potatoes delivered daily to the processing plant from each grower. For this study, "grower lot" samples from different growers were randomly selected during the 1984 processing year from the USDA Inspection Service. Processors across southern Idaho also provided specific gravity data from grower lots as needed.

Field data were taken from a single 32 hectare field at harvest. Grid lines were laid out at 60 m intervals. Fifteen samples were taken at evenly spaced intervals along each grid line. Each sample of approximately 6 kg was used to measure field site variability. Selected areas within this field were used to gather 10 consecutive hill samples along an individual row. These hill samples were used to measure individual tuber and hill variability.

During harvest, trucks are filled with approximately 15 t of potatoes and then are taken to the processing plant for unloading. Each truck was sampled at the unloading dock by taking five 12 kg samples (20-30 tubers) from the unloading belt at 5 minute intervals. Unloading time for each truck was about 25-30 minutes, consequently, each 12 kg sample represented about one-fifth of the truck load. Tubers included in all specific gravity measurements were randomly selected, greater than 113 g, US #1's and #2's but excluded undersize and culls.

Results and Discussion

Field Studies

The field site for these tests was selected because of its general uniformity. Soil type was consistent and grower management practices had been documented for several years. Therefore, the variability in this potato field might represent the minimum differences growers could expect within any given crop.

Specific gravity measurements of individual tubers within a hill are presented in Table 1. Differences of greater than 40 units were common (one unit equals 1 part in a thousandth, *i.e.*, a specific gravity value of 1.070 versus 1.080 would differ by 10 units). Values from four representative hills are shown in Table 1. Within each hill of potatoes, there was considerable variability in specific gravity among individual tubers. These differences in specific gravity can be due to a number of factors, principally, tuber size and maturity. This tuber variability can be present in all lots of potatoes and should be recognized by the grower as a normally occurring condition.

TABLE 1. — *Specific gravity of individual tubers within a hill.*

Number of Tubers/hill	Range	Hill Mean	s[1]
7	1.065 - 1.089	1.082	.008
11	1.060 - 1.085	1.075	.009
7	1.083 - 1.125	1.097	.015
5	1.080 - 1.088	1.084	.002
$LSD_{(.05)}$[2]		.004	

[1]s=standard deviation
[2]LSD=Least significant difference, 5% significance level.

The specific gravity range of ten consecutive individual hills at various locations in a single field is shown in Table 2. An eight to 14 unit variation among hills in the same field was common. Sixty hills representing 544 individual tubers were measured. In general, the variation between consecutive hills was about ⅓ the variation between individual tubers.

TABLE 2. — *Specific gravity range of 10 consecutive individual hills within a row at different field sites (n=10).*

Field Site	Range	Mean	s
a	1.075 - 1.085	1.080	.003
b	1.074 - 1.082	1.079	.002
c	1.083 - 1.092	1.088	.003
d	1.074 - 1.084	1.079	.003
e	1.074 - 1.088	1.080	.004
f	1.076 - 1.087	1.083	.004
$LSD_{(.05)}$		.003	

In order to estimate field variability within a 32 ha field, six grid lines were sampled 15 times each at 60 meter intervals. At each field location, one sample of approximately 6 kg was taken from nine hills (3 hills from each of 3 adjacent rows). This combined sample was used as the measure of specific gravity at that site. Ninety total field sites were measured and representative data for four grid lines are presented in Table 3. Even though the specific gravity mean for each field grid line was nearly equal, differences among individual samples along the grid line was 10 to 16 units.

TABLE 3. — *Specific gravity range by field location (gridlines).*

Grid	Range[1]	Mean	s
a	1.976 - 1.086	1.081	.004
b	1.075 - 1.089	1.082	.004
c	1.077 - 1.088	1.083	.004
d	1.078 - 1.094	1.085	.004
$LSD_{(.05)}$		.003	

[1]Range of 15 samples taken from a grid line.

The above data suggest that field variability among specific gravity samples was dependent upon sample size and location within the field. Consequently, it would be possible to have potato lots from this field differ in specific gravity by 10 units. According to the USDA Solids Conversion Chart, 4.5 units represent a one percent change in potato solids. This type of variability can affect both the grower's returns from contract incentives and the processor's estimate of finished product recovery.

With this range of variability among individual tuber lots, it is likely that there would also be some variation among bulked samples for specific gravity measurements. Data from four representative truckloads are presented in Table 4. Within each load of approximately 15 t, specific gravity ranges from 2 to 9 units were among the 5 samples.

TABLE 4. — *Specific gravity range of 5 samples taken from each of 4 truckloads.*[1] *n=5.*

Truckload Number	Range	Mean	s
1.	1.078 - 1.085	1.083	.002
2.	1.079 - 1.081	1.080	.001
3.	1.085 - 1.088	1.086	.001
4.	1.081 - 1.090	1.085	.003
$LSD_{(.05)}$		.003	

[1]Samples taken as the truck unloaded at the plant. Samples were taken at equally spaced time intervals to represent 1/5 of the truckload.

The mean specific gravity from 108 truckloads for the 32 hectare field was 1.083. A similar value was obtained by the USDA Inspection Service.

Data from this field study indicate that specific gravity estimates of total solids can be used with relative confidence provided the samples are truly representative of the bulked population of field harvested tubers. The very large difference in solids content among individual tubers can be minimized by using many tubers (20-30) in the specific gravity sample. Even though significant differences exist among samples taken from different areas in the field, and truckloads from the same field, samples taken from each truck and pooled into grower lots can provide a good estimate of total solids of the harvested crop.

Hollow Heart

Because potato specific gravity measurements are made in water, conditions that affect the buoyancy of the tubers can change their weight in water. Hollow heart, for example, substantially reduces the specific gravity of affected tubers (Table 5). Whole individual tubers were tested for solids content, then cut lengthwise and again measured by the weight in air - weight in water method. Some tubers with large internal cavities actually floated and accurate specific gravity measurements were impossible. If a sample of potatoes used for specific gravity determination contained one or more tubers with hollow heart, measurements for percent total solids content could be underestimated by 1% or more from the actual values.

TABLE 5. *Effect of hollow heart on specific gravity of five Norgold potatoes.*

Tuber size (g)	Specific Gravity			Hollow Heart
	Whole	Cut	Change[1]	Volume (cm^3)
355	1.077	1.079	2	1.6
528	1.062	1.071	9	6.3
665	1.056	1.075	19	13.1
687	1.068	1.072	4	4.1
1064	1.043	1.073	30	37.3

[1]Change=specific gravity difference (units) between whole and cut tuber.

Peeled Versus Nonpeeled Measurements

The peelings on russetted potatoes can also have a large effect on specific gravity measurements. Anatomically, the skin or periderm of a russet potato is made up of layers of corky cells, the more layers, the heavier the "net" or russetting. These skin layers can trap minute amounts of air and thus affect the weight-in-water measurement for specific gravity. These corky layers also reduce the specific gravity measurement due to normally lower levels of starch being deposited in the periderm (9).

Samples taken from four processing plants revealed differences in specific gravity due to the degree of russetting of the tubers (Table 6). Potatoes

representing twelve grower lots were measured for specific gravity, then peeled with a Dazey Stripper (Dazey Products Company, Industrial Airport, Kansas) and re-measured. The automatic peeler removes between 8 and 10% of the fresh weight of the potato depending on size and skin type. The peeled material generally contains 14-16% dry matter. The twelve lots represented potatoes with varying degrees of netting (smooth skinned Red Norland, to heavy netted BelRus). Differences of 3 to 10 units were found between peeled and non-peeled potatoes.

TABLE 6. — *Specific gravity of 12 individual grower lots.*

Lot No.	Variety	SGU[1]	SGP[2]	Difference
1	Russet Burbank	1.0910	1.0987	+ 7.7
2	Red Norland	1.0666	1.0696	+ 3.0
3	Russet Burbank	1.0748	1.0799	+ 5.1
4	Russet Burbank	1.0792	1.0843	+ 5.1
5	Russet Burbank	1.0864	1.0916	+ 5.2
6	Russet Burbank	1.0758	1.0850	+ 9.2
7	BelRus	1.0973	1.1078	+10.5
8	Lemhi Russet	1.0902	1.0987	+ 8.5
9	Russet Burbank	1.0821	1.0906	+ 8.5
10	Russet Burbank	1.0828	1.0888	+ 6.0
11	Russet Burbank	1.0848	1.0913	+ 6.5
12	Russet Burbank	1.0831	1.0893	+ 6.2

[1]SGU=Lot mean unpeeled
[2]SGP=Lot mean peeled

Peeling reduces the variability among lots. The variance of the peeled lots when compared to the unpeeled lot was about one half (Table 7).

TABLE 7. *Regression equations and correlations of peeled (SGP) and non peeled (SGU) lots. Specific gravity versus total solids.*

Dependent Variable	Intercept	Regression Coefficient	Variance	R^2
SGP	3.164	.2198	.1366	.97
SGU	1.546	.2576	.2786	.94

Consequently, the estimate of total solids as measured with the weight in air - weight in water procedure is a more accurate representation of the grower lot when peeled potatoes are used. The USDA/State Inspection Service could make specific gravity measurements on the peeled products without changing procedures. Peeled samples are used for the quality tests and could easily be used in the determination of specific gravity.

Three lots of Russet Burbank potatoes representing light, medium, and heavy net differed in specific gravity by 5 units (Table 8). Even though the actual solids content of the lots was the same, the three growers might receive different incentives because of the potential errors in the specific gravity measurements. In order to provide a more consistent measurement of specific gravity and one that better reflects the actual solids content of the tubers, peeled potatoes could be used for the analysis.

TABLE 8. — *Specific gravity of Russet Burbank potatoes from non-peeled and peeled lots.*

	Non peeled	% solids	Peeled	& solid	Units Change[1]
Heavy Net	1.071	18.8	1.080	20.7	+9
Medium Net	1.074	19.4	1.080	20.7	+6
Light Net	1.076	19.9	1.080	20.7	+4

[1]Units change: 1 unit=1 part in 1000th of the specific gravity value.

The definition of "light to heavy" net is subjective and not generally consistent enough to be used as a measurement criterion. However, statistical analysis of the peeled versus non-peeled measurements shows that the relationship between specific gravity and total solids is not affected by peeling, $R^2=0.92$. Therefore, the USDA Standards for Grades of Potatoes for Processing (10) would still be applicable when comparing specific gravity of the peeled lot to corresponding value of total solids. It is hoped that the information presented in this paper will help provide a more consistent use of specific gravity as a quality measurement for the processed potato industry.

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