

POTATO QUALITY XXIV. OBJECTIVE MEASUREMENT OF MEALINESS IN POTATOES¹LAURO LUJAN² AND ORA SMITH³

INTRODUCTION

Mealiness or consistency of cooked potatoes is a very important quality factor in the processing industry and of those potatoes for the fresh market. A mealy potato is one which has a mealy or relatively dry, flaky texture after cooking; it crumbles readily when mashed, and gives a dry floury mash (4). Various physical and chemical factors are considered to be associated with potato texture. Among these, the starch content of the individual cell is believed to be the principal factor in determining potato texture by effecting cell separation (3, 9, 15).

The specific gravity of tubers has long been used to provide a rapid measure of their dry matter and starch content. At present, it is generally accepted that in a given variety, dry matter content of potatoes as measured by the specific gravity of tubers, is highly correlated with the mealiness of their cooked product. However, judging by sensory means, exceptions to a correlation between specific gravity and mealiness are found. In some cases, tubers of different varieties having identical specific gravity did not necessarily have the same starch content or mealiness scores. It was suggested (2) that such exceptions may be due to the subjective nature of the taste panel method of quality evaluation. Undoubtedly, to evaluate properly for mealiness and other culinary qualities, objective methods are needed, but few attempts have been made along this line.

According to Burton (4), Rathdach in 1935 described the consistency of the cooked tuber in terms of the resistance to being cut by a wire under constant pressure. The resistance was a function of the time taken for the wire to cut through a piece of tuber of standard size and was arbitrarily expressed in seconds.

Some workers (7) reported that the adjusted Warner-Bratzler shearing machine was used to study the correlation of shear force values with palatability scores of tenderness and crispness of French-fried potatoes. Their data show a positive correlation between shear force values and the specific gravity of the tubers. Other workers (14) found a negative correlation between mealiness scores and the amount of electrical energy (line load increase) necessary to shear through a mass of boiled tubers.

An objective method of measuring texture of reconstituted potato flakes with the modified L.E.E.-Kramer shear press has been developed recently (12). The influence of moisture and temperature on shear force readings of reconstituted flakes was clearly shown. As the water to flake ratio was increased the shear force necessary was decreased. The addition

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of sodium acid pyrophosphate, $\text{Na}_2\text{H}_2\text{P}_2\text{O}_7$ (SAPP), at various locations in the processing line, increased the shear force required by about 20%. In addition to this it prevented discoloration from after-cooking darkening. From this work it was assumed that the mealy or dry cooked potatoes offer more resistance to a compression force than the soggy or watery potatoes and that these differences can be accurately measured by a sensitive instrument using homogeneous samples.

The aim of this study was to find an objective method for the measurement of mealiness in whole tubers, which will furnish reasonable, dependable and reproducible results. A preliminary comparison also was made of the objective texture measurements with the conventional organoleptic scores of mealiness in ten varieties.

MATERIALS AND METHODS

The following varieties were used: Cherokee, Chippewa, Delus, Green Mountain, Katahdin, Kennebec, Merrimack, Norland, Plymouth, Pungo and Sebago. They were grown under conventional cultural methods at Freeville Farm, Ithaca, New York during the summer of 1962.

The modified (5) L.E.E. Kramer shear press Model 1957, with a displacement indicator and a recorder, was used to obtain numerical values of the shear force applied to raw tubers cut into cubes and to mashed potatoes. The specific gravity of cooked tubers was determined by the weight-in-air : weight-in-water method.

Shear press readings on raw tubers

Katahdin tubers from a sample of 720 U.S. No. Ones, stored at 40 F for 3 months, were cut into strips using a hand French-fry slicer. From the apical end portion of each strip a cube of $\frac{1}{2} \times \frac{1}{2} \times \frac{14}{16}$ in. was cut, consisting mostly of tissue located between the periderm and the pith.

The shear press with a flat plunger attachment, with a tip of $1\frac{3}{8}$ inches in diameter and $\frac{9}{16}$ inch thick was used. The instrument setting was as follows: milli volts (M.V.) 20 on the recorder, calibration (Cal.) 30 on the displacement indicator, displacement indicator (D.I.) 10 on the displacement indicator, piston speed (P.S.) $1\frac{1}{2}$ (.3922 mm) on the fluid flow regulator, and one chart division was equal to 454 g. With five samples from each tuber a total of 3,600 values was recorded.

Shear press readings on cooked potatoes

Unpeeled and peeled tubers of medium size (about 200 grams) were cooked with and without SAPP in the boiling water. The cooked tubers were cooled, in jars of 1 liter, to room temperature (75 F), and they then were passed through a potato ricer and whipped with an electric food mixer, at the lowest speed, for 30 seconds. The mashed potato samples were placed in a stainless steel cup of $1\frac{6}{8}$ inches in diameter and 1 inch deep. Its resistance to a compression force was measured by the shear press with the same flat plunger but with smaller top (1 inch in diameter and $\frac{9}{16}$ inch thick). The instrument setting was varied according to different cases, but the following setting as used in most instances: M.V. 2, Cal. 100, D.I. 10, P.S. 2 (.6221 mm/sec.), and one chart division was equal to 10 grams.

Temperature, evaporation and other factors influencing the objective measurements were standardized.

Objective measurements and subjective scores of mealiness

A preliminary experiment with ten varieties was conducted in a factorial arrangement, considering 2 varieties, 3 harvest dates, 3 specific gravities and with 3 tasters, in order to compare the texture measurements of the shear press with mealiness ratings of a taste panel.

Within a variety, for each specific gravity, four medium size tubers were selected and boiled in water with skin on, and cooled to room temperature. Each cooked tuber was cut longitudinally in four pieces of approximately the same size. Four pieces, one from each tuber, were blended to obtain three shear force readings and the other three pieces from each tuber were supplied to the taste panel. The three experienced members of the taste panel graded the mealiness of each sample ($\frac{1}{4}$ of a tuber) according to the scale used by Sweetman (13).

RESULTS AND DISCUSSION

Correlation between specific gravity and shear force values of raw tubers

The specific gravity of the 720 Katahdin potatoes showed a normal distribution pattern and a wide variation. There was a difference of .051 between the lowest (1.045) and the highest (1.096) recorded specific gravities, which is almost the same as the variation of .050 reported by Kirkpatrick et al (7) for Katahdin potatoes grown in Colorado. There was also a wide variation in shear force values within each specific gravity. The over all coefficient of variability was 11.8%. Presumably damage of tissue in the cutting process, differences in the amount of medullary tissue included in the samples and hollow heart were the main sources of variation.

The correlation of the shear force values, of raw tubers cut into cubes, with their specific gravity was negative ($-.19$) and significant at 1% level. The increase in shear force readings with decreasing specific gravity seems to indicate that the turgor pressure of the cells may be an important factor governing the resistance of the raw tuber as a whole to pressure.

Correlation between specific gravity and mealiness of tubers

1) *Measurements with half tubers*:- Experiments with half tubers showed that, for the objective method of measurement of mealiness, the varieties considered as being soggy apparently were more suitable than the mealier ones. For peeled and halved tubers the following correlations, between specific gravity and shear force values, were determined: Chippewa .98**, .83**; Kennebec .84**, .90**; Katahdin .54*, .37 (NS); and Delus .65*, .05 (NS). The first correlation coefficient refers to half pieces boiled in water and the second to halves boiled in 2% SAPP solution. Two asterisks indicate significance at 1% level and one asterisk indicates significance at 5% level, and NS indicates non-significance. Sloughing and water absorption of the half tubers boiled in SAPP probably is the main reason for the lack of correlation in Delus and Katahdin.

Peeled and steamed Katahdin tubers gave non-significant correlation

coefficients of .30 (NS) and .25 (NS) for untreated halves and halves soaked for 2 minutes in a hot SAPP solution, respectively.

The results obtained with half tubers showed the necessity to avoid water absorption and sloughing samples. Thus in subsequent work, medium-size, whole tubers, unpeeled and peeled were boiled slowly and this gave a fairly satisfactory control of sloughing. The standardized method of mashing whole tubers eliminated the problem of uneven starch distribution within the tuber.

2) *Influence of cooking on dry matter-water relationship*:- It was observed that the differences found in texture measurements greatly depended on the moisture content of the mashed product. To find out if the cooking process itself had some influence on dry matter-water relationship, the correlation between the specific gravity of raw and cooked tubers with their shear force values was studied. Table 1 gives the results of two separate experiments with unpeeled Katahdin tubers. The specific gravity of both steamed and boiled tubers was determined after six hours of cooling at room temperature.

TABLE 1.—*Influence of two cooking methods on specific gravity of cooked tubers.*

Cooking method ¹	Ave. S.G. of raw tubers	Ave. S.G. of cooked tubers	Ave. Shear force values in grams	Correlation coefficients ²	
				A	B
Steamed.....	1.087	1.037	385	.92**	.44(NS)
Boiled in water.....	1.080	1.069	746	.95**	.86**
Boiled in 2% SAPP.....	1.080	1.061	783	.86**	.64(NS)

¹Steaming method: sample of 24 tubers, instrument setting different from boiling method.

Boiling method: sample of 13 tubers, two sets of similar samples.

²Correlation coefficients: A = Raw specific gravity versus shear force value.

B = Cooked specific gravity vs. shear force value.

** indicates significance at 1%

NS indicates non-significance

In another experiment with unpeeled Cherokee tubers the variation of specific gravity from raw to cooked tubers was more accurately determined. For each specific gravity a sample of 30 tubers of medium size was separated by the brine solution method and about two weeks later

TABLE 2.—*Change in specific gravity from raw to cooked tubers.*

Brine solution method	Weight-in-air : weight-in-water method	
	S.G. of raw tubers	S.G. of cooked tubers
1.080	1.065	1.065
1.085	1.067	1.066
1.090	1.069	1.071
1.095	1.073	1.074
1.100	1.076	1.079

the specific gravity of individual tubers was determined by the weight-in-air : weight-in-water method and then they were boiled in water. The cooked tubers were cooled at room temperature for 24 hours and their specific gravity again determined individually. The results are given in Table 2.

The results obtained with half and whole tubers (Table 1) shows that the steaming method may have a lowering effect on specific gravity when the cooked tubers are not completely cooled to room temperature. Under the same cooling period, the boiling method had a less decreasing effect on specific gravity and gave better correlation between cooked specific gravity and the shear force values

The results obtained with an adequate sample size and the proper cooling time, second and third columns in Table 2, show that the specific gravity of raw tubers is not affected by the boiling process. The average difference between raw and cooked specific gravity was .001, which is not significant.

3) *Mealiness of Katahdin and Cherokee tubers of equal specific gravity*:- Some investigators believe that between Katahdin and Cherokee tubers of identical specific gravity, Katahdin tubers are mealier than Cherokee tubers. Since this contention is based entirely on subjective observations it was of interest to check the trueness of such a belief. The results of the subjective measurements of mealiness in these two varieties are given in Table 3.

TABLE 3.—*Shear force values of Katahdin and Cherokee tubers of identical specific gravity.*

Unpeeled tubers poiled in water ¹			Peeled tubers boiled in 2% SAPP ²		
Specific gravity	Cherokee Shear force gms.	Katahdin Shear force gms.	Specific gravity	Cherokee Shear force gms.	Katahdin Shear force gms.
1.068	377	332	1.067	371	419
1.070	380	378	1.071	527	561
1.072	408	416	1.073	562	575
1.074	481	567	1.076	588	657
1.076	442	599	—	—	—
1.078	592	592	—	—	—
1.080	619	646	—	—	—
1.074	471	505	1.072	512	553

¹Each shear force value is an average of 9 readings (3 for each tuber).

²Each shear force value is an average of 15 readings (3 for each tuber).

The bottom line of Table 3, which shows the average of the measurements, indicates that, in general, shear force values of Katahdin tubers are higher than those for Cherokee tubers. For tubers boiled in water the correlation between specific gravity and shear force values was 0.93** for Katahdin and 0.96** for Cherokee, and for tubers boiled in SAPP it was 0.95 (NS) for Katahdin and 0.98 (NS) for Cherokee. The latter

correlation coefficients were not significant because of small sample size.

The use of 2% SAPP in the boiling water, in addition to preventing after-cooking darkening, increased the shear force values by about 10% over the non-treated tubers of identical specific gravity in both varieties.

Taking into consideration the varieties which hold their shape and do not slough on boiling, the above correlation coefficients show beyond doubt the existence of a positive correlation between specific gravity of raw and cooked tubers and their mealiness recorded numerically as resistance to a compression force. This is in agreement with the positive correlation, between the specific gravity of raw tubers and their subjective scores of mealiness, demonstrated by other workers (1, 3, 6, 11, 13).

Whole tubers have proven to be the most suitable material for objective measurements of mealiness in potatoes.

The modified L.E.E.-Kramer shear press possesses enough sensitivity to detect texture differences between tubers which may differ from each other by .002 or less in specific gravity. According to organoleptic tests reported by Young (16), which are probably the most accurate tests to date, differences in specific gravity less than .005 could not be detected.

The consistent texture differences recorded for Katahdin and Cherokee tubers of identical specific gravity strongly support previous reports (1, 3, 6, 8, 10, 14) in which tubers of different varieties having identical specific gravity did not have necessarily the same starch content or mealiness rating. This was generally considered by most workers to be an exception to a correlation between specific gravity and subjective mealiness scores.

Comparison of shear force values with subjective scores of mealiness

This tentative comparison of ten potato varieties grown under the same conditions was carried out with the smallest possible number of samples. The varieties were compared two by two and the results are given in Table 4.

The recorded data show that, other factors being equal, no two varieties are alike in regard to their mealiness measured by objective or subjective means. Since no two varieties have identical genetic constitution, it is reasonable to assume that the chemical composition of potatoes of identical specific gravity, varies between varieties. It is also known (11) that certain varieties are consistently high in total solids and others are usually low in total solids if growing conditions are the same for all.

Within each variety, as the specific gravity of the tubers increases, the shear force values and subjective scores of mealiness also increase. This also indicates that the specific gravity of raw tubers, within varieties, is still the best indicator of potato mealiness. The drop of the shear force values, for the highest specific gravity, in Delus and Merrimack could be attributed to sloughing and water absorption of the samples. The drop of the mealiness score, for the highest specific gravity lot, in Pungo probably is a taste panel error.

There is a reasonable agreement between the objective measurement of texture and the conventional, organoleptic method of assessing the mealiness of cooked tubers. According to the shear force values we can separate the varieties Norland, Plymouth, Sebago, Katahdin, Kennebec, and Cherokee from the varieties Pungo, Green Mountain, Delus and Merri-

TABLE 4.—*Objective texture measurements and subjective scores of mealiness of ten potato varieties and their relation to specific gravity.*

Variety	Shear force values in gms. ¹				Taste panel scores ²				Correlation coefficients ³		
	1.062	1.065	1.069	Mean	1.062	1.065	1.069	Mean	A	B	C
Norland	1,144	1,309	1,425	1,293	.86	1.11	1.56	1.16	.95	.89	.81
Plymouth	994	1,180	1,242	1,139	1.47	2.03	2.17	1.89	.80	.73	.51
					LSD.(NS)		LSD.35**				
Sebago	1,175	1,315	1,749	1,413	1.64	2.25	2.00	1.96	.80	.44	.77
Katahdin	1,318	1,445	1,571	1,445	1.53	1.86	2.61	2.00	.65	.87	.63
					LSD.39**		LSD.(NS)				
Kennebec	1,564	1,569	1,879	1,671	1.47	1.92	2.03	1.81	.53	.72	.51
Cherokee	950	1,121	1,395	1,156	.97	1.25	1.69	1.31	.93	.75	.60
					LSD.(NS)		LSD.(NS)				
	1.069	1.075	1.078		1.069	1.075	1.078				
Pungo	2,036	2,304	2,443	2,261	1.36	2.00	2.19	1.85	.73	.92	.55
G. Mountain..	2,035	2,104	2,455	2,198	2.97	3.08	3.61	3.22	.68	.59	.61
					LSD.49**		LSD.28**				
Delus	1,952	2,283	2,183	2,141	2.39	2.94	3.22	2.85	.39	.76	.34
Merrimack	2,432	2,888	2,424	2,581	2.14	2.72	3.17	2.68	.15	.90	.00
					LSD.45*		LSD.(NS)				

¹Each shear force value is an average of 9 readings. LSD = Non-significant.

²Each mealiness score is an average of 36 ratings. LSD: **-indicates significance at 1%; *-indicates significance at 5%. NS-indicates non-significance.

Scale: 0 = Very soggy, not mealy.

1 = Soggy, not mealy.

2 = Moderately moist, slightly mealy.

3 = Slightly moist, moderately mealy.

4 = Dry, mealy.

³Correlation coefficients: A = Specific gravity vs. Shear force values.

B = Specific gravity vs. Mealiness scores.

C = Shear force values vs. Mealiness scores.

5% = .666

1% = .798

mack. This is in perfect agreement with their average specific gravities, 1.065 and 1.074 respectively. We could not, however, make such a precise separation of the varieties on the basis of their mealiness scores, although the number of subjective ratings for each specific gravity was four times as many as the shear force measurements. However, some correlations between specific gravity and the subjective scores of mealiness are somewhat higher than those between specific gravity and the shear force values, this probably is due to the limited number of subjective measurements.

In general the subjective mealiness scores of potatoes show greater variability than the objective texture measurements. For the subjective evaluation Plymouth is significantly mealier than Norland, but the average shear force value of Norland is higher than the average value of Plymouth. Both methods show that Katahdin is mealier than Sebago, and for the

subjective method the differences among specific gravities within these two varieties are significant. It is also shown by both methods that Kennebec potatoes are mealier than Cherokee potatoes. The subjective evaluation shows that Green Mountain is significantly mealier than Pungo, and it also shows significant differences among specific gravities within these varieties. The average shear force value of Pungo is slightly higher than the average value of Green Mountain. The difference among specific gravities within Delus and Merrimack are significant according to the taste panel, which also indicates that Delus is mealier than Merrimack, but there were significant differences among tasters. The sloughing problem at the highest specific gravity of Delus and Merrimack made the shear force values unreliable in this particular case.

Again the objective texture measurements show that Katahdin potatoes are mealier than Cherokee potatoes of identical specific gravity, and it was positively verified by the taste panel. The application of this objective method with an adequate number of samples will indicate accurately the texture differences between varieties grown under the same conditions, and it also can be used to rank for mealiness all the commercial varieties on the basis of their average specific gravity. The adoption of this method to a potato breeding program will be limited by the size and number of tubers per sample and the time required to get shear press readings.

SUMMARY

The modified L.E.E.-Kramer shear press Model 1957 was used for objective measurements of mealiness in potatoes. Numerical values of the resistance to a compression force of the mashed potato was recorded as an indication of mealiness. The sensitivity of the shear press permits detection of texture differences between tubers which may differ from each other by .002 or less in specific gravity. Boiled whole tubers have proven to be the most suitable for objective measurements of mealiness in potatoes.

The cooking process itself has no significant influence on the dry matter-water relationship of cooked tubers as determined by the difference of raw and cooked tuber specific gravities. The steaming method may have greater lowering effect on specific gravity than the boiling method of cooking.

As a rule different varieties of potatoes of identical specific gravity differ in mealiness, namely Katahdin potatoes are mealier than Cherokee potatoes, etc. The degree of difference may depend on the varieties subjected to comparison and the sensitivity of the test used. Some varieties may differ slightly in mealiness and the possibility of two varieties of potatoes of identical specific gravity of having similar degree of mealiness is rather remote, but if this coincidence occurs, it should be regarded as an exception.

Within each variety, the mealiness of cooked tubers is highly correlated with their specific gravity, and the specific gravity of raw tubers is the best estimator of mealiness.

The resistance of raw tuber cubes to a pressure force is significantly correlated with their specific gravity.

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