MEASUREMENT OF TEXTURE IN COOKED POTATOES

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Introduction

In the state of Washington 83% of the potato crop is commercially processed. The Russet Burbank cultivar makes up approximately 85% of the state's production. Thus, consideration of potato production, handling, storing, and marketing problems should focus on Russet Burbank potatoes destined for processing.

The marketability of Washington's potatoes hinges on the quality of its potato products. Washington's large potato size has gained a high reputation for the production of premium french fries. Washington potatoes are also known for their high specific gravities. The production of high-quality processed products can be accomplished only if high-quality raw products are used.

The consumer is the final judge of processed potato quality. To the consumer, desirable potato quality depends primarily on color and texture. Whiteness and mealiness are the two most desirable characteristics. Whiteness (color) can be affected by controlling storage temperatures prior to processing, but texture (mealiness) is a structurally-related attribute established during the growth of the tuber and affected by other factors. Thus, an understanding of potato texture, its measurement, and its ability to be altered would be beneficial to the potato industry. A method for accurately predicting cooked potato texture from raw product properties would be valuable for minimizing waste of financial, space, energy, and time resources of growers and processors.

Texture

Texture is the sensory manifestation of the structure or inner make-up of foods (Civille and Szczesniak, 1973). Texture changes occur during maturation, storage, and processing. Mealiness is the most important textural attribute of potatoes whether boiled, baked, or mashed (Ridley et al., 1981). Cooked mealy potatoes have been characterized as having flaky texture that crumbles easily to a soft, dry, and friable mush (Burton, 1948). To date, however, a reliable method for measurement of mealiness in potatoes has not been developed.

Specific gravity is used an an indicator of potato cooking quality because specific gravity has been correlated to mealiness of potatoes, however, this relationship between specific gravity and mealiness is not always reliable. Because specific gravity is a measure of tuber composition rather than tissue structural strength, it is not reasonable to expect a consistently reliable correlation between specific gravity and mealiness. A mechanical measurement of potato tissue response to forces or deformations would be more appropriate as a measurement method for texture.

The most reliable method available for measurement of texture is provided by a taste panel. Sensory (taste panel) evaluations of texture, however, are subject to variations between panel members and fatigue of the panelists. A reliable instrument method for measuring cooked potato texture would eliminate the subjectivity of texture evaluation by panelists and provide a convenient, repeatable evaluation in a minimum amount of time.

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Mechanical Properties

The tissue of food products can be described by mechanical analogies. Food products subjected to deformations respond with characteristics corresponding to both solid and liquid materials. Thus, they may be described as having properties which are a combination of elastic (or solid) and viscous (or fluid) properties. Mechanical properties of foods are, therefore, called "viscoelastic". The potato is a viscoelastic material (Finney et al., 1964).

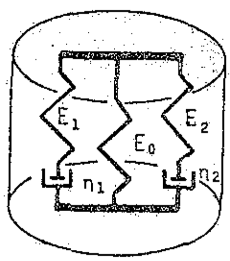
Properties appropriate for describing the response of cooked potato tissue to chew-like deformations must include both elastic and viscous parts. The elastic elements of the cooked potato model respond as elastic springs, providing a resistive force or stress which is directly proportional to the amount of deformation or strain. The viscous elements respond as shock absorbers, providing a resistive force or stress which is directly proportional to the rate of deformation (velocity) or strain rate.

A viscoelastic model for cooked potato tissue developed by Davis et al. (1981) is shown in Figure 1. This model describes the tissue response as that similar to three elastic elements (springs) and two viscous elements (dashpots). The proportionality constants for the elastic and viscous elements are the E and η parameters, respectively. As the tissue model is subjected to a chew-like compression, the elastic and viscous elements offer time-varying resistive forces simulating the feeling of the potato tissue texture.

The viscoelastic parameters (E_0, E_1, E_2, n_1, and n_2) are determined for a potato tissue specimen by the following procedure.

1. A 1 cm diameter by 1 cm length tissue sample is removed from the whole raw potato.
2. Tissue samples are cooked in boiling water until they are "properly cooked".
3. A tissue sample is suddenly compressed longitudinally to 90% of its original length and held in that state while the resistive force of the sample is monitored.
4. Based on the expected response pattern of the five-element viscoelastic model, viscoelastic parameters are determined to cause the model to respond as the sample did.

Figure 1. Viscoelastic Model for Cooked Potato Tissue.



Viscoelastic Properties and Texture-Related Factors

Because cooked potato texture was expected to vary with different specific gravities, group lots, cultivars, and cooking times, these texture-related factors were selected as variables for a study of cooked potato viscoelastic properties (McMahan, 1981). (A group lot was a group of tubers grown in a limited region of a field where identical growing conditions existed). A control test group and eleven different test groups with specific gravities, group lots, cultivars, and cooking times shown in Table 1 were tested to determine viscoelastic properties of each sample. At least ten samples were tested in each test group.

Comparison of viscoelastic parameters from different test groups yielded the results presented in Table 2. It is interesting to note that for properly cooked samples elastic parameter (E_0 and E_2) differences occurred, but no viscous parameters differed. Both elastic and viscous parameter changes occurred during cooking. Specifically, the observations from this study are the following:

1. Test groups with different specific gravity (1.11 to 1.12 vs. 1.06 to 1.07) and from different group lots (A & C) were different.
2. Test groups with different specific gravity (1.11 to 1.12 vs. 1.08 to 1.09) and from the same group lot (A) were not different.
3. Test groups with the same sample specific gravity (1.11 to 1.12) but one of which came from whole tubers with specific gravity 1.08 to 1.09 and all from the same group lot (A) were not different.
4. Test groups with the same specific gravity (1.11 to 1.12) but from different group lots (A & B) were different.
5. Test groups with the same specific gravity (1.08 to 1.09) but from different group lots (A & C) were not different.
6. Test groups from different cultivars (Russet Burbank and Red), different specific gravities (1.11 to 1.12 vs. 1.06 to 1.07), and different group lots (A & D) were different.
7. Test groups with the same specific gravity (1.06 to 1.07), of different cultivars (Russet Burbank and Red) and from different group lots (C & D) were different.
8. Test groups which were under-cooked or over-cooked were different than those which were properly-cooked.

It is apparent from these results that specific gravity and viscoelastic properties are not in agreement about cooked potato differences. Thus, if textural differences occurred between one test group and another, specific gravity or viscoelastic properties may be an indicator but both can not be accurate indicators. A second study was performed to settle the dispute.

Table 1. Test Groups Used to Determine Effects of Specific Gravity, Group Lot, Cultivar, and Cooking Time on Viscoelastic Properties.

Test Group	Specific Gravity	Group Lot	Cultivar	Cooking Time (min.)
Control	1.11 to 1.12	A	Russet Burbank	8**
1	1.06 to 1.07	C	Russet Burbank	10**
2	1.08 to 1.09	A	Russet Burbank	9**
3	1.11 to 1.12*	A	Russet Burbank	8**
4	1.11 to 1.12	B	Russet Burbank	8**
5	1.08 to 1.09	C	Russet Burbank	9**
6	1.06 to 1.07	D	Unknown Red	10**
7	1.11 to 1.12	A	Russet Burbank	5
8	1.11 to 1.12	A	Russet Burbank	6
9	1.11 to 1.12	A	Russet Burbank	7
10	1.11 to 1.12	A	Russet Burbank	7.5
11	1.11 to 1.12	A	Russet Burbank	9

*Samples with specific gravity from 1.11 to 1.12 taken from whole tubers with 1.08 to 1.09 specific gravity.

**Cooking times which produced "properly cooked" samples.

Table 2. Viscoelastic Parameter and Texture-Related Factor Differences.

Test Groups With Different* Responses	Viscoelastic Parameters Which Were Different*	Texture-Related Factors Which Were Different
Control & 1	E_0	Specific gravity & group lot
Control & 4	E_0 and E_2	Group lot
Control & 6	E_0 and E_2	Specific gravity, group lot, and cultivar
1 & 6	E_0	Group lot and cultivar
Control & 7	E_0, E_1, E_2, η_1, η_2	Cooking time
Control & 8	E_1, E_2, η_1	Cooking time
Control & 11	E_0, E_1, E_2, η_1, η_2	Cooking time

*Different at the 0.05 significance level.

Texture and Viscoelastic Properties

A study was performed to compare the viscoelastic properties of cooked potatoes to texture as evaluated by taste panel. (Barron, 1982). A taste panel of twelve members evaluated the texture of cooked potato samples using textural scales of soft to hard and gummy to mealy. Other samples taken from the same region of the same potatoes were used to determine viscoelastic parameters (E_0, E_1, E_2, n_1, and n_2). Approximately 30 samples were used for each of the test groups identified in Table 3.

Table 3. Specific Gravities and Cooking Times for Cooked Potato Samples.

Test Group	Specific Gravity	Cooking Time (min.)*
White Rose	1.105	7.5
Kennebec	1.100	6.25
Russet Burbank	1.090	8.75
A 503-42**	1.100	6.0
Russet Burbank	1.075	10.5
Red	1.075	19.5

*Cooking times producing samples fully cooked but without disintegration.
**An experimental cultivar developed for high yields without concern for quality.

Results of the taste panel evaluations showed that there were significant differences in hardness and mealiness among the test groups. (See Table 4). This demonstrated that panelists could detect textural differences among these groups. More differences in mealiness were observed than differences in hardness.

Table 5 presents the viscoelastic parameters determined for each of the test groups. Differences in the elastic parameters occurred among most test group comparisons; however, few viscous parameter differences were significant. Thus, the elastic parameters discriminated most clearly between test groups and appeared to have the greater potential as texture indicators.

Table 4. Sensory Evaluation of Hardness and Mealiness for Cooked Potatoes.

Test Group	Mealiness*	Hardness**
White Rose	8.05 a	4.02 b
Kennebec	6.99 b	5.99 c
Russet Burbank (1.090)	6.92 bc	3.81 b
A 503-42	6.00 c	4.35 b
Russet Burbank (1.075)	4.97 d	5.05 bc
Red	1.65 e	0.89 a

Values within each column followed by the same letter are not statistically different at the 95 percent confidence level.

*Mealiness scale: 0 = gummy, 10 = mealy

**Hardness scale: 0 = soft, 10 = hard

Table 5. Viscoelastic Parameters for Cooked Potatoes.

Test Group	E_0 (Kg/cm^2)	E_1 (Kg/cm^2)	E_2 (Kg/cm^2)	η_1 ($Kg\ s/cm^2$)	η_2 $Kg\ s/cm^2$)
White Rose	4.54 b	7.39 bc	2.65 bc	16.0 a	0.257 c
Kennebec	7.57 d	9.57 d	3.84 d	18.1 a	0.311 c
Russet Burbank (1.090)	5.87 c	7.56 bc	3.01 c	15.3 a	0.259 c
A 503-42	4.22 b	6.47 b	2.20 b	13.9 a	0.189 b
Russet Burbank (1.075)	4.79 b	7.80 c	3.76 d	13.4 a	0.274 c
Red	1.16 a	2.79 a	0.87 a	6.28 a	0.093 a

Means within each column followed by the same letter are not statistically different at the 95 percent confidence level.

Table 6. Correlation Coefficients Between Sensory Parameters and Elastic Parameters.

Sensory Parameters	Elastic Parameters E_0	E_1	E_2
Mealiness	N.S.	0.832*	N.S.
Hardness	0.899	0.960**	0.925**

*Significant at 95 percent confidence level.

**Significant at 99 percent confidence level.

N.S. = not significant at 75 percent confidence level.

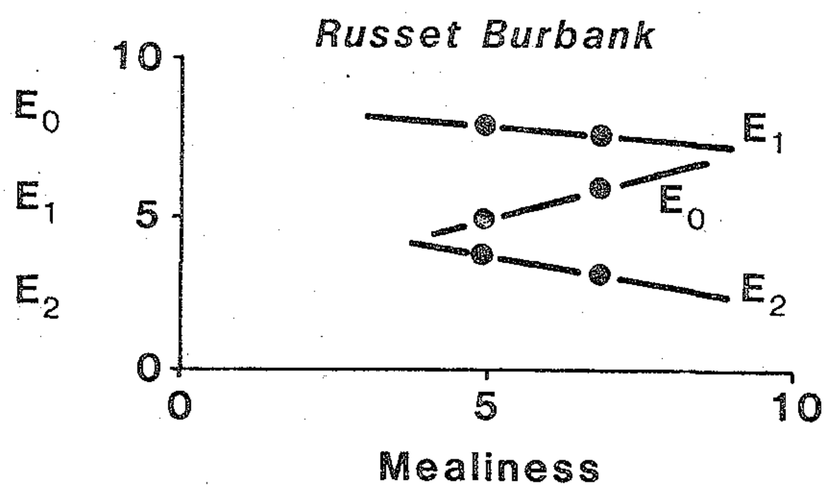
Correlations between sensory parameters and elastic parameters for cooked potatoes are presented in Table 6. The largest correlations occurred between hardness and the elastic parameters E_1 and E_2. Only a weak correlation occurred between mealiness and one elastic parameter (E_1). No viscous parameters had significant correlations with mealiness. Thus, over all test groups (different cultivars) considered there was not an outstanding viscoelastic indicator of mealiness in cooked potatoes.

Recalling that the Russet Burbank cultivar is the most important one for Washington's processed potatoes, the correlations for only Russet Burbanks were considered further. Figure 2 shows the elastic parameters and the corresponding mealiness scores for the two Russet Burbank test groups. Contrary to correlations for all of the cultivars, for the Russet Burbank cultivar the E_0 and E_2 parameters appear to be correlated with mealiness while E_1 is not. More analysis of these test data is required before the merit of E_0, E_2, or some combination of these for a measure of mealiness in cooked Russet Burbank potatoes is known.

Conclusions

1. Cooked potato tissue responses to bite-type inputs can be described by viscoelastic models.
2. Only elastic parameters are different for potatoes with different specific gravities, group lots, and/or cultivars.
3. *All elastic and viscous parameters change when potato tissue is cooked.*
4. Specific gravity and viscoelastic parameters can not both be indicators of potato texture.
5. Elastic parameters for cooked Russet Burbank tissue may provide a measure of mealiness.

Figure 2. Elastic Parameters vs. Mealiness for Cooked Russet Burbank Potatoes.



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