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Some properties of potatoes and their starches I. Cooking, textural and rheological properties of potatoes

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Abstract

Three different potato cultivars (Kufri Jyoti, Kufri Badshah and Pukhraj) were analyzed for cooking, sensory, textural and rheological properties. Potato cultivars (Kufri Jyoti and Kufri Badshah) with higher mealiness scores had lower cooking times and compression forces than cultivars with lower mealiness scores (Pukhraj). Kufri Jyoti and Kufri Badshah potatoes also showed higher total solids loss and water uptake values during cooking than Pukhraj potatoes. The cooked potatoes from different cultivars were also evaluated by stress relaxation test and texture profile analysis (TPA). The stress relaxation test for Kufri Jyoti and Kufri Badshah cooked potatoes yielded higher Maxwell elastic moduli (E_0, E_1 *and* E_3) than Pukhraj cooked potatoes. The viscous moduli (η_1,η_2 and η_3) were found to be significantly lower for Kufri Jyoti cooked potatoes than for Kufri Badshah and Pukhraj. TPA parameters, such as hardness, fracturability, cohesiveness and adhesiveness values, were higher for Kufri Jyoti and Kufri Badshah and were found to be related to elastic factors, such as E_0, E_1 and E_3.

Keywords: Potato; Cooking; Texture; Rheology; Stress relaxation test; Texture Profile Analysis

1. Introduction

The texture of cooked potato has been a subject of interest for several decades. Different textural properties of cooked potatoes, ranging from firmness to cohesiveness, in relation to mealiness, sogginess, stickiness or gumminess, have been reported to be controlled by a number of factors, such as starch, pectic substances and cell size (Linehan & Hughes, 1969; Reeve, 1972). Cooked potato texture has also been associated with the dry solids content, specific gravity, amylose, sugars, proteins and total nitrogen content of potato tuber. Many attempts have been made to show a relationship between the texture of the cooked potato and the physical or chemical properties of potato starch, which represents the predominant substance in the tuber (Linehan & Hughes, 1969). A highly significant correlation between the starch content of the raw tuber and various textural attributes of cooked potato, such as mealiness, consistency, sloughing and sogginess, has been found by many researchers (Kirkpatrick, Mountjoy, Albright, & Heinze, 1951; Unrau & Nylund, 1957). The properties of starch and the changes in these properties during cooking should be considered to explain the variations in the texture (Talburt, 1987). Whittenberger (1951) suggested that the textural differences among the cooked potato cultivars are mainly due to the internal pressures developed inside the cells resulting from swelling of the gelled starch. Sterling and Bettelheim (1955) reported the probable role of starch in influencing the texture by slight distension of the tuber cells causing them to round ‘‘off’’ and thus separate from each other. Briant, Personius, and Grawemeyer-Cassell (1945) found a correlation between starch granule size and texture of cooked potatoes. Barrios, Newson, and Miller (1963) found that the mealy potatoes had higher specific gravities, starch and amylose contents as well as a higher percentage of large starch granules (diameter > 50 μ) than the waxy cultivars. It has been reported that tuber regions of low starch content cook softer than those containing more starch (Sharma, Isleib, & Dexter, 1959). Barmore (1937) found an inverse relationship between ease in penetration after cooking and starch content. The cooked and cooled starch forms a stiff mass, which has a relatively low resistance to penetration. Textural changes in cooked potatoes are mainly associated with the gelatinization and retrogradation behaviour of starch (Kim, Wiesen-

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born, & Grant, 1997). Davis, McMahan, and Leung (1983) demonstrated that a generalized Maxwell model, consisting of three elastic and two viscous elements, could represent stress relaxation response for cooked potatoes. Leung, Barron, and Davis (1983) studied the textural and rheological properties of cooked potatoes using the Instron Universal Machine, and correlated hardness of cooked potatoes, by sensory evaluation, with fracturability, hardness and elastic elements of the stress relaxation model. The reported effects of heat treatment on the rheological properties of potatoes include tests on the effects of cultivar and maturity on potato texture (Madsen & Christensen, 1996; Taguchi, Schafer, & Breene, 1991) and on starch properties (Briant et al., 1945).

The objective of the present investigation was to study the cooking, textural and rheological properties of potatoes from different cultivars.

2. Materials and methods

2.1. Materials

The potatoes of three cultivars viz. Kufri Jyoti, Kufri Badshah and Pukhraj were procured from Sangha Potato Farms, Jalandhar, India from 2001 harvest. Uniform-sized tubers were selected from each cultivar and washed thoroughly.

2.2. Dry matter content

Dry matter content of the potato tubers was determined in triplicate using a Halogen Moisture Analyzer (Mettler, Switzerland).

2.3. Sample preparation

The tubers were washed and the periderm was peeled with a knife. Each tuber was cut into two equal halves. Four cylindrical pieces were taken from each half, excluding the core region, with the help of a cork borer (diameter 1 cm) and trimmed to a height of 1 cm.

2.4. Cooking properties

The cooking time was determined by cooking the cylindrical pieces in boiling distilled water in a 500-ml capacity beaker. An aluminium foil was used to cover the beaker during cooking to avoid the evaporation losses. After every 3 min of cooking, each cylindrical piece was tested for compression on Instron Universal Testing Machine (Model-4464, Instron, Buckinghamshire, England). A load cell of 10 kg was used for each compression. A flat probe (3.5 mm diameter) travelled a distance of 5-mm at crosshead speed of 50 mm/min. The compression distance was 50% of the total height of the cylindrical piece. The cooking time was determined as the time required to reach the lowest compression force during 50% compression of the sample. For the determination of the water uptake and total solids loss during cooking, the pre-weighed cylindrical pieces were cooked in 300 ml boiling water for 30 min. The cylindrical pieces were drained and rinsed with distilled water and redrained for two minutes. The cooked cylindrical pieces were weighed for the determination of water uptake (%). The rinse water was collected in a pre-weighed Erlenmeyer glass beaker and placed in an air oven at 110 °C for 24 h. The residue was weighed and reported as total solids loss (% wt. of the cylindrical piece of potato).

2.5. Texture profile analysis (TPA)

For TPA, the cylindrical potato pieces were cooked for 30 min in boiling distilled water and immediately placed in Petri dishes after cooking to avoid dehydration. TPA of the cooked cylindrical potato pieces was performed using an Instron Universal Testing Machine, as described by Leung et al. (1983). The sample was placed on the base plate of the Instron and compressed with a cylindrical probe (3.5 cm diameter) using a 10 kg load cell. The sample was preloaded 0.5% of the total load. The crosshead speed was 15mm/min and the deformation was 75% of the original length. The seven textural parameters, as modified by Szczesniak (1975), were determined from each curve.

2.6. Stress relaxation test

For stress relaxation test, the cylindrical potato pieces were cooked as described above in the case of TPA. The stress relaxation test was performed on cooked potato pieces using the Instron Universal Testing Machine. The unevenness of two ends of the sample was compensated by preloading it with 0.5% of the load. Crosshead speed was 500 mm/min and the strain was 10%.

2.7. Sensory analysis

For sensory analysis, the cylindrical potato pieces were cooked as described for TPA. A panel of 10 judges, trained for mealiness using the following scores, evaluated the cooked potato samples 0 = not mealy; 1 = slightly mealy; 2 = moderately mealy and 3 = very mealy

2.8. Statistical analysis

The data reported in all the tables are averages of triplicate observations. The data were subjected to statistical analysis using Minitab Statistical Software (Minitab Inc., USA).

3. Results and discussion

3.1. Cooking and sensory properties

The tubers from Kufri Badshah and Kufri Jyoti cultivars showed higher dry matter content of 18.2 and 16.4%, respectively, while it was lowest in the case of Pukhraj (Table 1). Kufri Jyoti and Kufri Badshah cooked potatoes showed higher mealiness scores than Pukhraj potatoes during sensory analysis (Table 1). The high dry matter content of the Kufri Jyoti and Kufri Badshah potatoes may be responsible for their more mealy characteristics. O' Beirne, Walshe, and Egan (1985) reported that mealy potatoes tended to have higher dry matter contents as than waxy potatoes. The optimum cooking time of potatoes was determined as the time required to reach the lowest compression force during 50% compression of the cylindrical potato pieces. Kufri Jyoti potatoes had the lowest cooking time (24 min) against cooking times of 27 and 30 min for Kufri Badshah and Pukhraj potatoes, respectively (Fig. 1). This may be attributed to the greater mealy nature and lower gelatinization temperatures of the starches in Kufri Badshah and Kufri Jyoti than Pukhraj potatoes. McComber, Osman, and Lohnes (1988) reported that the starch granules from the mealier potatoes gelatinized at a lower temperature. Kufri Jyoti potatoes showed the lowest compression force of 0.194 N against 0.24 and 0.255 N, respectively, for Kufri Badshah and Pukhraj potatoes at optimum cooking times. Hopkins and Gormley (2000) found a negative correlation between the dry matter content and the boiled potato shear. Kufri Badshah and Kufri Jyoti potatoes showed higher water uptakes during cooking than Pukhraj potatoes. Pukhraj potatoes showed lower losses of solids in cooking water than Kufri Jyoti or Kufri Badshah potatoes (Table 1). The loss of solids in cooking water from Kufri Jyoti and Kufri Badshah potatoes did not differ significantly.

Table 1
Dry matter content, water uptake, total solids loss and taste panel scores of different potato cultivars[a]

Cultivar	Dry matter content (%)	Water uptake (%)	Total solids loss (%)	Taste panel scores
Pukhraj	13.20a	3.03a	3.54a	0.9a
Kufri Jyoti	16.40b	5.21b	5.8c	3.0c
Kufri Badshah	18.20c	5.1b	5.7b	2.75b

[a] Values with similar letters in column do not differ significantly ($P<0.05$).

3.2. Stress relaxation test and texture profile analysis

A typical TPA curve for cooked potato is illustrated in Fig. 2, while the TPA parameters are summarized in Table 2. The stress relaxation data, subjected to non-linear regression analysis, indicated that the relaxation curve (Fig. 3) can be fitted with an equation consisting

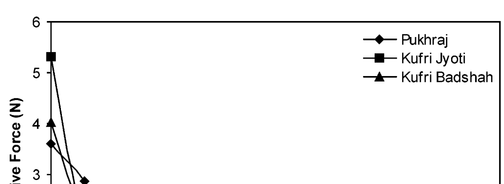

Fig. 1. The effect of cooking time on compressive force of cooked potatoes.

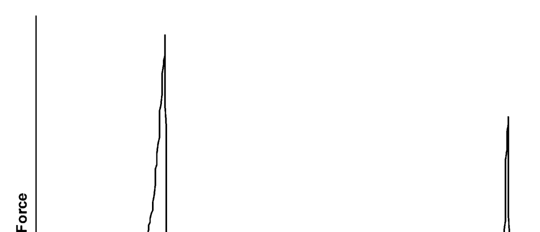

Fig. 2. A typical texture profile analysis (TPA) curve of cooked potatoes.

Table 2
Texture profile analysis parameters of cooked potatoes from different cultivars[a]

Cultivar	Fracturability (Newton)	Hardness (Newton)	Cohesiveness	Adhesiveness (Joules)	Springiness (Metre)	Gumminess (Newton)	Chewiness (Joules)
Pukhraj	3.91a	7.00c	0.1049a	2.167×10^{-4}a	0.0012b	0.7343a	0.00128b
Kufri Jyoti	4.80b	9.54b	0.1124b	6.8341×10^{-4}b	0.0009a	0.8475a	0.00076a
Kufri Badshah	4.85b	11.42c	0.1078a	8.991×10^{-4}c	0.00104b	1.231b	0.00128b

[a] Values with similar letters in a column do not differ significantly ($P<0.05$).

of three components, namely, an equilibrium stress and two exponential decay terms (Leung et al., 1983). The following equation represents the stress relaxation behaviour of the cooked potato samples:

$$\sigma(t) = \varepsilon_o(E_o + E_1 e^{-t/T1} + E_2 e^{-t/T2} + E_3 \mathrm{e}^{-t/T3}) \quad (1)$$

where σ = stress; t = time; E_{o} = constant strain; $T_1 = \eta_1/E_1$; $T_2 = \eta_2/E_2$; $T_3 = \eta_3/E_3$; η_1, η_2, η_3 = viscosities; E_o, E_1, E_2, E_3 = elastic moduli.

Eq. (1) can be represented by the Maxwell model (Mohsenin, 1970) consisting of four elastic elements (dashpots) as illustrated in Fig. 4. The three Maxwell elements, each consisting of a spring and a dashpot in series, correspond to the three exponential terms in Eq. (1). The lone elastic element corresponds to the equilibrium modulus (E_o) at infinite time. The fitted model is in agreement with the findings of Davis et al. (1983) and Leung et al. (1983). The elastic moduli of potatoes of all three cultivars differ significantly. Kufri Jyoti and Kufri Badshah potatoes showed higher values for E_0, E_1, and E_3 than Pukhraj potatoes (Table 3). This shows that Kufri Badshah and Kufri Jyoti potatoes are harder than the Pukhraj potatoes. Leung et al. (1983) also indicated higher hardness values for mealy potato cultivars. Adhesiveness values were also found to be higher for Kufri Jyoti and Badshah potatoes. This may be due to the higher amylose contents in the starches of these potatoes. Linehan and Hughes (1969) have observed a correlation between intercellular adhesion and amylose content during studies on the texture of cooked potatoes. During cooking, amylose leaches out through the weakened cell walls and acts as a cementing material between the cell walls of the tuber cells, thus leading to an increase in the intercellular adhesion (Linehan & Hughes, 1969). The $\eta_1\eta_2$ and η_3 values of the potatoes from three cultivars also differed significantly. The $\eta_1\eta_2$ and η_3 values of Kufri Jyoti potatoes were significantly lower than Kufri Badshah and Pukhraj. The η_2 value of potatoes from the Pukhraj and Kufri Badshah cultivars did not differ significantly. Fracturability, hardness and gumminess were observed to be highest for Kufri Badshah potatoes, followed by Kufri Jyoti and Pukhraj potatoes. Kufri Jyoti potatoes showed the highest value for cohesiveness and lowest for chewiness and springiness. This may be due to the greater mealy nature of the Kufri Jyoti potatoes. McComber, Lohnes, and Osman (1987) also reported higher cohesiveness values for mealy American potatoes. Cohesiveness of cooked potatoes was observed to related to E_0, E_1 and E_3 elastic factors. The potato cultivars showing higher values of E_0, E_1 and E_3 also showed higher cohesiveness values.

In summary, potato cultivars having greater mealiness scores showed higher Maxwell elastic moduli, hardness, fracturability, cohesiveness and adhesiveness values than the cultivar with lower mealiness score. The cooking properties of potatoes, such as cooking time, compression force, total solids loss and water uptake values, were found to be related to their textural properties. The total solids loss and water uptake values of pota-

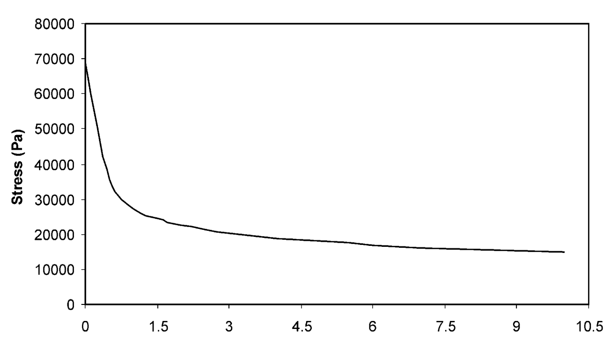

Fig. 3. A typical stress relaxation curve of cooked potatoes.

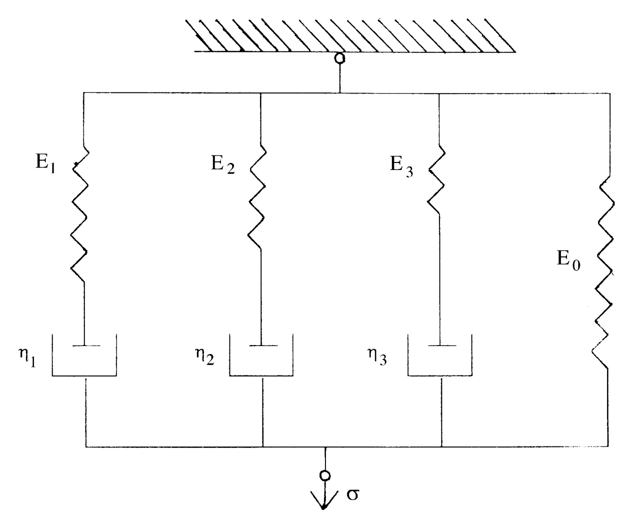

Fig. 4. A seven element-Maxwell model representation for cooked potatoes.

Table 3
Stress relaxation test parameters of cooked potatoes from different cultivars[a]

Cultivar	E_0 (Pa)	E_1 (Pa)	E_2 (Pa)	E_3 (Pa)	η_1(Pas)	η_2 (Pas)	η_3 (Pas)
Pukhraj	1.612×10^4a	1.715×10^5a	1.476×10^5b	1.185×10^5a	1.011×10^6a	0.0785×10^6a	0.00978×10^6a
Kufri Jyoti	6.481×10^5c	1.858×10^5b	2.247×10^5c	2.138×10^5b	8.835×10^5b	2.967×10^5b	0.2605×10^5c
Kufri Badshah	5.172×10^4b	2.013×10^5c	0.94×10^5a	2.013×10^5b	1.263×10^6a	0.078×10^6a	0.05×10^6b

[a] Values with similar letters in column do not differ significantly ($P < 0.05$).

toes during cooking were also observed to depend on their mealiness scores.

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