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Comparison of the consistencies of cooked mashed potato prepared from seven varieties of potatoes

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Abstract

Potato protein concentrates (PPC) were isolated from potato juice of seven studied varieties by thermal coagulation of 6.0–6.2 pH juices at 90–95 °C, followed by freeze-drying. Three levels of PPC were added to cooked mashed potato to raise the protein contents to 3, 4 and 5%, along with three levels of dry potato to obtain similar dry matter contents in mashed potatoes after the additions. The consistency of cooked mashed potato was measured objectively by a "back extrusion cell" connected to an Instron 1140 texturometer. Studied varieties differed in their consistencies of cooked mashed potato which increased with the dry matter content and increased after applying additives: (PPC and dry cooked potato). In spite of the similar dry matter contents the hardness of cooked mashed potato was higher when the PPC was used as an additive than with the dry potato addition.

Keywords: Consistency; Cooked potato

1. Introduction

Potato varieties differ from each other in the texture of the tuber after cooking. This feature, of the edible potato, often determines the direction of its usage. It includes their consistency, as well as their tendency to breakdown, their mealiness, dryness and structure (Howard, 1974). Preferences of food manufacturers and individual consumers, concerning the quality of the potato, depend on eating habits in different countries. Cooked mashed potato is widely consumed in Europe. It is consumed with soft and delicate consistency with clearly perceptible moisture or with a harder and drier consistency. Applied techniques of evaluation of the texture of the cooked potato comprise both sensory and microscopic evaluation (Baier & Pichert, 1998; Thybo, Martens, & Lyshede, 1998; van Marle, Clerkx, & Boekestein, 1992; van Marle, Stolle-Smits, Donkers, van Dijk, Voragen, & Recourt, 1997a; van Marle, van Der Vuurst De Vries, Wilkinson, & Yuksel, 1997b) and instrumental methods, using different sorts of texturometers, consistometers or penetrometers (Bourne, 1978, 1979; Freeman, Jarvis, & Duncan, 1992; Jarvis & Duncan, 1992; Kozempel, 1988; Leung, Barron, & Davis, 1983; McComber, Osman, & Lohnes, 1987; Nonaka, 1980). Diversity of techniques for instrumental evaluation of the texture of the cooked potato and diversity of potato varieties, however, make the synonymous characterisation of the texture difficult. The texture of the cooked tubers is affected, not only by single chemical components of the potato, but also by interactions among them (Jarvis, Mackenzie, & Duncan, 1992; Linehan & Hughes, 1969b; Marshall & Chrastil, 1992), dependent on variety (Burton, 1989; Leung et al., 1983; Malone, True, & Bardon, 1977) and cultivation and storage factors (Keijbets & Vaal, 1974; van Marle, van Der Vuurst De Vries et al., 1997b) as well as interactions occurring during cooking and mashing (Burton, 1989; Iritani, Powers, Hudson, & Weller, 1977; Taguchi, Schafer, & Breene, 1991). The texture of cooked potato has been the subject of research for many years. Several reports (Barrios, Newsom, & Miller, 1963; Freeman et al., 1992; Keijbets & Vaal, 1974; Linehan & Hughes, 1969a; McComber et al., 1988) emphasize the influence

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of specific gravity of the potato and the size of its cells, as well as the contents of dry matter and starch of tubers on their mealiness after cooking. Some reports (Linehan & Hughes, 1969a, b; van Marle, Stolle-Smits et al., 1997a; van Marle, van Der Vuurst De Vries et al., 1997b; Reeve, 1977; Thybo et al., 1998) demonstrate the influence of the structure and content of pectic substances, of potato cell walls and the middle lamella, on the texture of the cooked potato. Existing differences in the contents of dry matter and particular components of tubers do not always explain differences between potato varieties in respect of their consistency after cooking (Leung et al., 1983; Linehan & Hughes, 1969a; McComber et al., 1988). Among the components of the potato cell walls and the middle lamella (pectins, hemicellulose, cellulose and protein substances) proteins are little understood in respect of their influence on the texture of cooked tubers. Proteins which are present in the middle lamella probably do not influence the texture of the cooked potato (Linehan & Hughes, 1969c); however, some authors (Ilker & Szczesniak, 1990; Van Buren, 1979) emphasize the potential influence of cell wall proteins of plants on integrity of cell membranes. That is confirmed by the contribution of cell wall proteins in building the protein–hemicellulose matrix. High nutrition quality of potato proteins (Kapoor, Desborough, & Li, 1975; Rexen, 1976), and their possible influence on texture of food products has contributed to research on the methods of isolation and evaluation of functional properties of potato protein (Knoor, 1980; Wojnowska, Poznański, & Bednarski, 1981). Knoor (1977, 1980), applying denatured potato protein preparations to produce wheat bread, confirmed its potential but in quantities not larger than 10%. In the literature there are few data concerning the application of potato proteins to potato products (e.g. mashed potato), or their influence on the final consistency of the product.

The objective of this work was to compare the consistency of cooked mashed potato prepared from seven potato varieties as well as to determine the influence of the added protein or dried cooked potato on the consistency of cooked potato mass.

2. Materials and methods

2.1. Raw material

Samples of potato tubers included seven varieties: very early Snogg, middle-early Laila and Brage, middle-late Saturna, Beate and Danva and very late Pimpernel, grown in the regions of As in Norway, during the growing season 1995. The tubers used were stored at 7 °C and taken out in March from the store of the Agricultural Experimental Station, of the Agriculture University in As. Potato protein concentrates were obtained from tubers of the investigated varieties of potato and powders prepared from cooked tubers.

2.2. Preparation of cooked mashed potato

Seven tubers of approximately the same size (Φ 45–55 mm) were cooked in water for 30 min. Cooked tubers were cooled, kept at 7 °C for 12 h, peeled and mashed with a Kenwood kitchen robot. The potato mass obtained was mixed with the preparation of its own potato protein, so as to increase the content of protein up to 3, 4 and 5% or with the dry potato powder in such quantities (in the text marked as "3%", "4%" and "5%") as to make the dry matter contents of the potato mass, after applying both additives, similar.

2.3. Preparation of potato protein concentrate

Peeled potato tubers (1 kg) of each variety were disintegrated in the Hakon & Lunde blender with 2 ml of a water solution containing (in 50 ml) 10 g $Na_2SO_4 + 7.5$ g $Na_2S_2O_5$, in order to prevent darkening of the potato mass. The slurry was pressed through a cloth and the juice centrifuged for 8 min at 8000 ***g*** which removed starch and other solid contaminants. Clear juice was subjected to dialysis against distilled water for 2.5 days at 7 °C, which process retained compounds with a molecular weight higher than 12,000. Then, the juice (pH 6.0–6.2) was subjected to heating in boiling water bath. From the moment when the juice reached the temperature of 90 °C, the process was continued for 10 min. After cooling, the coagulated protein was separated by centrifuge for 6 min at 12,000 ***g***. The protein precipitate obtained was washed once in distilled water, then centrifuged and freeze-dried. The dry potato concentrate obtained was passed through a 0.3-mm sieve and kept tightly closed at −20 °C until the experiment started.

2.4. Preparation of dry potato powder

Potato tubers were cooked in water for 30 min, cooled, peeled and then freeze-dried. The powder obtained was passed through a 0.3-mm sieve and kept tightly closed at −20 °C until the experiment started.

2.5. Method of the measurement of the consistency of cooked mashed potato

The measurement of the consistency of the mashed potato, with or without the addition of the protein preparation or the dry potato powder, was performed with the use of the Instron 1140 consistometer, with the "Back Extrusion Cell" attachment. A cylindrical measurement chamber of 44 mm diameter and a piston of 35 mm diameter were used. The maximum force (N; Kozempel, 1988) needed for squeezing a portion of 60 g of mashed potato to about 2 mm from the bottom of the attachment was measured. All the measurements were carried out with a crosshead speed of 50 mm/min and paper speed of 100 mm/min. The measurement of the consistency was performed three times for each sample.

2.6. Analytical methods

Standard AOAC methods (1975) were used for the analysis of the nitrogen content in raw and cooked potato tubers as well as in the potato protein concentrates and dry potato powders and the crude protein content was calculated as N×6.25. The dry matter of potato tubers and lyophilized protein concentrates and potato powder was determined by the reduced weight after drying at 102 °C and until constant weight was achieved (AACC, 1962). For the potato protein concentrates, water holding capacity of the protein, as g H_2O/g (Sosulski, 1962) was also determined.

2.7. Statistical analysis

The results obtained in the experiment were subjected to statistical calculations according to the Statgraphics programme. One-way and multificator analysis of variance and the least significant difference range test were used for determination of significance of the influence of the additives, and interactions between them and potato varieties, on the consistency of the cooked mashed potato. In order to compare the contents of the dry matter in the masses of cooked potato tubers of seven varieties and their consistencies, as well as to determine the significance and the character of the dependence between these features, an analysis of regression was performed, which made it possible to determine the coefficient of correlation (r), examine the significance of the correlation and draw the lines of regression described by the general equation: $Y = e^{a+bX}$ (exponential model) as well as $Y = aX^b$ (multiplicative model). The chosen models were characterised by the lowest standard errors.

3. Results and discussion

The investigated potato varieties differed in contents of the dry matter and protein (Table 1), as well as the consistency of the mashed potato tubers (Fig. 1). Hardest were the masses prepared from potato varieties Danva and Pimpernel, with high contents of dry matter in cooked tubers (26 and 28%, respectively): 65 and 77 N. Slightly less hard were the potato varieties Beate and Saturna: 45 and 50 N, with an intermediate content of dry matter (24%) and the softest (13 N), was the cooked mashed potato of the Snogg variety with a low content of dry matter in cooked tubers (about 18.5%). There was no influence of the protein content, either in raw or cooked potato, on the consistency of the tubers after cooking (Table 1). However, the influence of the addition of protein, up to 4 and 5% of the mass of the cooked tubers, as well as the maximum "5%" addition of potato powder, turned out to be significant. Probably, relatively small amounts of protein in the potato (about 2%), which additionally undergo degradation and leaching during cooking, do not play any significant role in the texture of the tubers after cooking. Other authors (Linehan & Hughes, 1969c) have also noted the lack of influence of protein content of the potato on its consistency after cooking.

When the additives were applied to the cooked mashed potatoes, their consistency increased (Figs. 2 and 3). The addition of protein to the mass of cooked tubers of a particular potato variety, influenced its hardness much more than did the addition of potato powder with a similar content of dry matter. The addition of the protein preparation at 5% caused almost three times as large an increase of the force needed for squeezing the mashed potato of the Beate variety (from about 45 to 127 N), about 2.5 times for the Laila variety (from about 35 to 80 N), the Saturna variety (from about 50 to 125 N) and for the Danva variety (from

Table 1
The content of the dry matter and crude protein in the raw and cooked potato tubers of seven varieties (figures are means of two determinations)

Variety	Raw potato		Cooked potato	
	Dry matter (%)	Protein in dry matter (%)	Dry matter (%)	Protein in dry matter (%)
Pimpernel	24.80	8.91	28.32	7.34
Danva	23.70	11.1	26.10	11.6
Saturna	24.60	13.1	24.20	12.9
Beate	22.35	7.92	23.87	7.85
Brage	22.20	12.6	22.38	10.3
Laila	21.10	10.0	21.15	9.12
Snogg	19.90	14.2	18.48	8.30

about 65 to 162 N) and about twice as large for the Pimpernel variety (from about 77 to 156 N). The differences found in effects of proteins separated from the investigated potato varieties could be due to differences in their structures (Seibles, 1979) and amino-acid compositions (Rexen, 1976; Zayas, 1997). The addition of dry potato powder to the mass of cooked potato tubers caused a slight increase in their hardness—maximum about 1.5 times—for potato tubers of Saturna variety (from about 50 to 73 N). On average, for all investigated

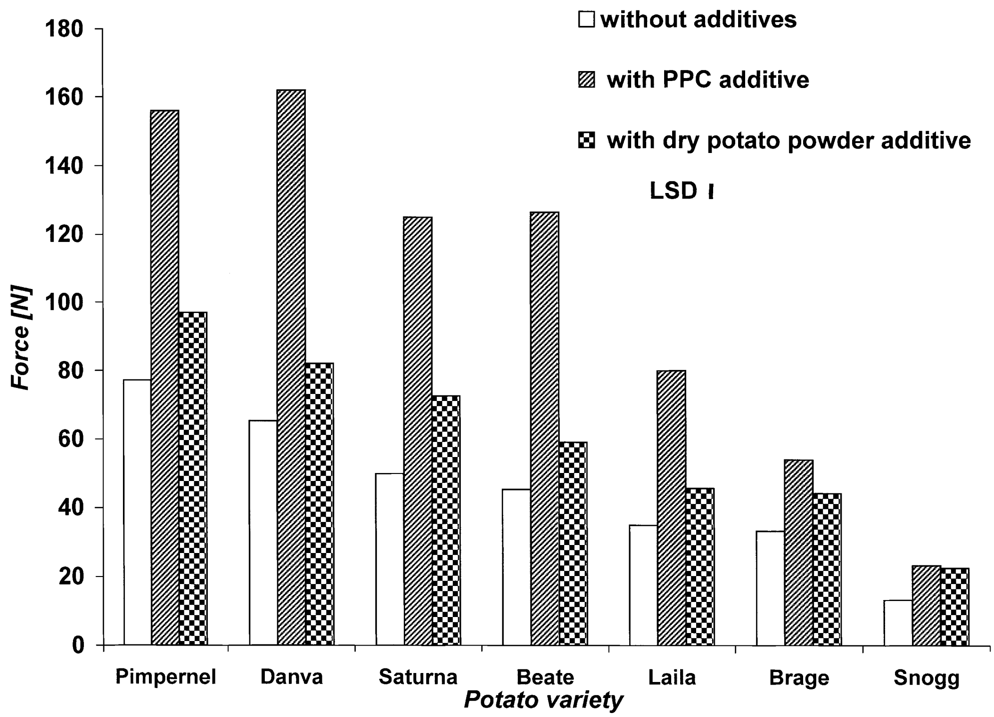

Fig. 1. The consistency of the cooked mashed potato of seven varieties, without additives or with the addition of 5% protein or "5%" potato powder to the cooked potato (figures are means of three determinations).

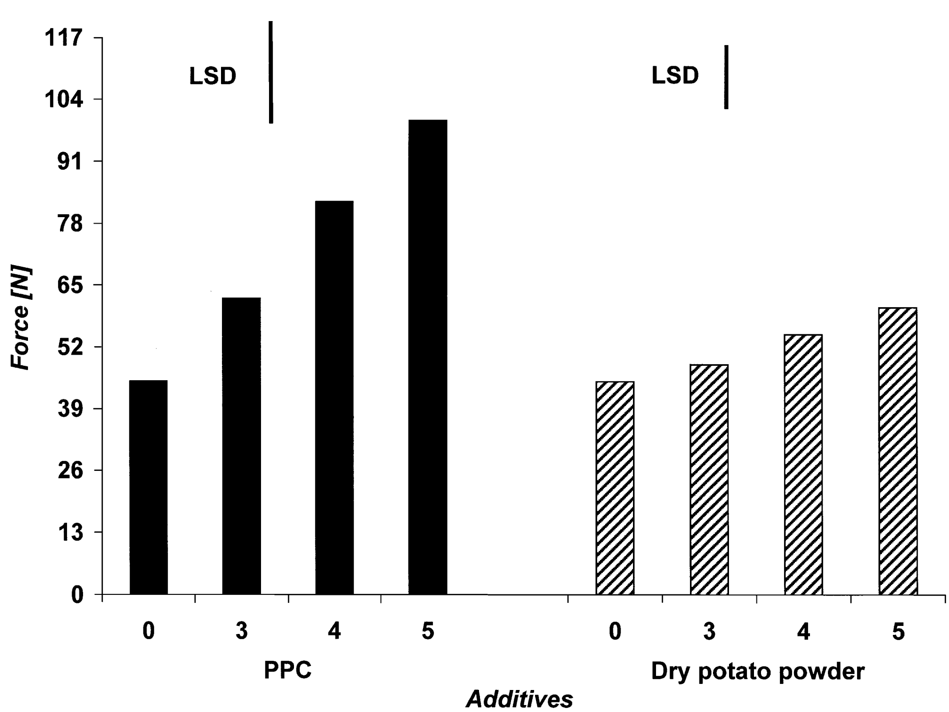

Fig. 2. The influence of added potato protein concentrate or potato powder on the consistency of the cooked mashed potato (average results for seven potato varieties).

varieties, the force needed for squeezing a portion of the potato mass with a content of 5% of protein (addition of the protein preparation) was 122% larger in comparison to the samples without the additives and, after applying the maximum dose of "5%" of the dry potato powder, was about 35% larger (Fig. 2). The differences found were probably due to different chemical compositions of the additives and differences in absorption of water. The main component (from 83 to 93% of dry matter) of the protein preparation was denatured potato protein (Table 2) while the dry potato powder contained mainly gelatinized starch and a relatively small amount of denatured protein—within the range of 7.34 to 12.9% of dry matter (Table 1). The high protein content of the applied concentrates and their good water-holding capacity (about 4.5 g/g of protein; Table 2; Knoor, 1980; Wojnowska et al., 1981) as well as the high hygroscopy of the dry preparations (dry substance—over 95% on average), could cause water binding in the cooked potato and give the product a harder consistency. Possibly, the water-holding capacity of proteins in the concentrates increases along with the increase of water activity, as it allows amino-acid polar groups to bind water and this is a critical factor in evaluation of functional and sensory properties of food products (Zayas, 1997). Results obtained in the experiment confirm the research of Knoor (1980) who applied denatured potato protein (raw protein of about 78–88% and water-holding capacity of 3–4 g/g) to wheat bread. He observed that, along with the increase of water-holding capacity of potato proteins isolated, porosity of the dough increased and the bread obtained had a smaller volume, and was characterised by a smaller deformation coefficient and shorter time of relaxation. Increasing the amount of the added protein beyond 10% resulted in significant lowering of the quality of bread, including its texture. Yazicioglu and Tabju (1978), applying potato puree, as flakes, to wheat bread, observed an increase of volume and extension of the period of its freshness compared with control samples.

As a result of this research a correlation was found between the force needed for squeezing the mass of cooked tubers and the content of the dry matter in it, both without additives ($r = 0.97$) and the application of additives: as potato protein ($r = 0.86$) and as potato

Table 2
The content of crude protein and water-holding capacity of the protein isolated from seven potato varieties[a]

Variety	Protein in dry matter (%)[a]	Water-holding capacity (g water/g)[b]
Pimpernel	90.2	5.1
Danva	93.3	4.9
Saturna	90.5	5.6
Beate	90.3	5.0
Brage	90.2	5.3
Laila	84.7	5.5
Snogg	83.0	6.4

[a] Figures are means of two determinations.
[b] Figures are means of four determinations.

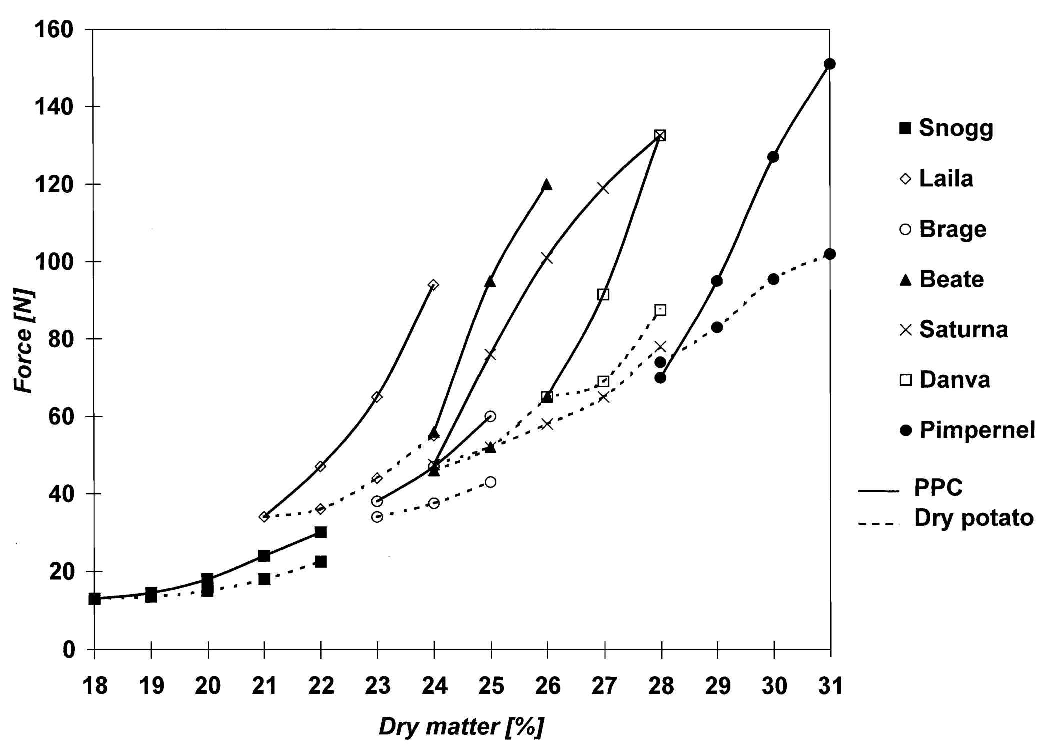

Fig. 3. Dependence between the content of the dry matter in the cooked mashed potato of seven varieties and its consistency without additives or with the addition of potato protein concentrate or potato powder up to, respectively, 3–5% or "3–5%".

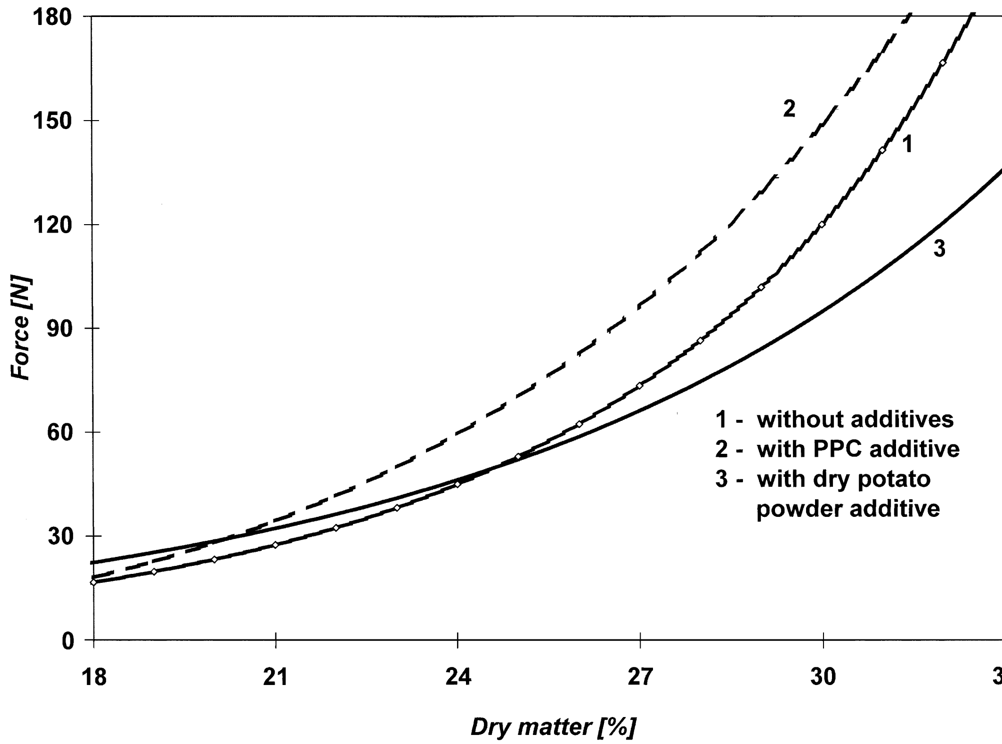

Fig. 4. Interaction between the content of the dry matter in the cooked mashed potato and its consistency without additives or with the addition of potato protein concentrate up to 3–5% protein or potato powder up to "3–5%" (average results for seven potato varieties).

Table 3
Equations of regression describing the dependence between the dry matter and the consistency of the cooked mashed potato prepared without additives or with the addition of potato protein or potato powder

Variant	Model	a	b	Coefficient of correlation	Standard error
Without additives	$Y = e^{a+bX}$	−0.134	0.164	0.97	0.15
With dry potato powder additive	$Y = e^{a+bX}$	0.952	0.119	0.95	0.10
With PPC additive	$Y = aX^b$	1.26×10^{-4}	4.11	0.86	0.24

powder ($r = 0.95$). Table 3 shows this by means of equations: exponential function $Y = e^{-134+0.164X}$ for the dependence between the consistency and the dry matter of the cooked potato without additives; multiplicative function $Y = 1.26 \times 10^{-4} X^{4.11}$, showing the influence of the addition of protein; and exponential function $Y = e^{0.95+0.12X}$, explaining the influence of the addition of the dry potato powder (Fig. 4).

4. Conclusion

The potato varieties investigated differed significantly in the consistency of tubers after cooking, which increased with increasing amount of dry matter after the application of additives (i.e. the potato protein preparation or dry cooked potato). Hardness of cooked, mashed tubers of the seven studied potato varieties was significantly higher when potato protein, instead of potato powder, was applied, despite the same amount of dry matter in the prepared potato mass. Correlation between the consistencies of the cooked tuber masses and the contents of dry matter, without applying additives and with the addition of dry potato powder, is described by equations of exponential function and, with the addition of protein preparations, by equations of multiplicative function. Results obtained in this experiment lead us to believe that the content of the dry matter in a cooked potato can make it possible to predict the force needed for squeezing the mass of cooked tubers and thus, objectively, to determine consistency. The addition of potato protein to the mass of cooked tubers may not only increase their nutritive value, but also improve their consistency.

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