

## **Influence of process conditions on selected texture properties of precooked buckwheat pasta**

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**Summary.** The paper presents the results of measurements of selected texture properties of gluten-free precooked pasta made from buckwheat flour using variable parameters of extrusion-cooking process. The different level of water addition to buckwheat flour was used due to the moisture content from 30 to 34%. Processing of buckwheat pasta products was performed at the barrel temperature ranged 90-110°C and cooling section temperature ranged 55-65°C on single-screw modified extrusion-cooker TS-45 with L/D = 18:1 using a varied screw speed: 60, 80, 100 and 120 rpm. Radial expansion ratio and selected texture properties of dry and hydrated products were tested depend on the screw speed and the dough moisture content applied. The cutting test was used for determination of cutting force of dry pasta and after 5-minutes hot water hydration for ready-to-eat products. Also OTMS tests with Ottawa equipment were performed for firmness, adhesiveness and chewiness by double-compression tests of hydrated precooked buckwheat pasta products. Highest screw speed increased cutting force of dry and hydrated buckwheat pasta, also affected by higher radial expansion ratio values for these products. Increased moisture content of raw materials lowered firmness of hydrated pasta and higher screw speed applied during processing improved chewiness of pasta products. Precooked buckwheat pasta processed at presented process conditions and raw materials moisture content characterized an acceptable texture and may be recommended as convenient food for consumers with celiac disease.

**Key words:** extrusion-cooking, buckwheat, precooked pasta, gluten-free pasta, texture.

### **INTRODUCTION**

The extrusion-cooking process involves the mechanical and thermal treatment of the material under high pressure. It is a processing method which combines the respective sequences of both, the mixing, heating, flow, forming and shaping. The extruder-cooker is the reactor completed with the forming die. There are single- and twin-screw extruders, and their work space can be di-

vided into three areas: dosing, mixing and compression. In the initial sections of the barrel material is mixed and moistened. Then, using a screw, material is moved to the kneading zone, which characterized a reduction in the space between the barrel and the screw, the compression ratio reaches 1:3 - 1:5 at the end of this zone and a significant increase in temperature and pressure occurs. Both, shearing and heating make the material plasticized, taking the form of precooked viscous dough [1, 5, 9, 17]. The residence time distribution of material in the extruder takes tens of seconds. The water contained in the material is overheated, and when it leaves the forming die, rapidly evaporates. This affects the expansion of the material, creating a porous structure and the consolidation of assigned shape of product [18].

In the case of instant or precooked pasta formation of this stage must be eliminated; if the final product should have the appropriate characteristics, the final part of the barrel must be cooled down, prevent the temperature exceeds 100°C, for example, by modifying the design of the extruders' barrel [12]. Precooked pasta products obtained in this way characterized by a high rate of starch gelatinization degree, compact internal structure, without the presence of empty spaces inside the pasta cross-section which can be caused by the presence of water vapor in the product [26, 28]. Extrusion-cooking used to produce precooked pasta brings several advantages, which include:

- the possibility of varying the raw materials composition, using not only wheat but also other cereal products, including gluten-free such as rice, corn and buckwheat,
- to obtain products with different structures,
- simplicity, since extrusion-cooked pasta doesn't require cooking or boiling in water, which reduces production costs and the finished product is ready for consumption after a short-time hot water hydration

- significantly reduced processing time and the drying of pasta compared with conventional press methods.

Gluten-free diet is used in the treatment and prevention of celiac disease or gluten intolerance. Celiac disease is a disorder consisting in the occurrence of digestive disturbance and intestinal absorption associated with intolerance of gluten in cereals [4].

The therapy requires the use of gluten-free diet, which consists in the total elimination of food products containing gluten: wheat, rye and barley [8, 19]. Even a minimal amount of gluten contained in products may cause a relapse. The long-term celiac disease left untreated can cause irreversible damage to the intestines that leads to impaired assimilation of nutritional components and malnutrition [10, 25].

For gluten-free pasta starchy raw materials include: corn flour, rice, oats, potato flour and flour from the seeds of leguminous plants [3, 4, 14]. The complicated method of gluten-free pasta production and functional additives (like guar gum, monoglycerides, carboxymethylcellulose, alginates, modified starches) required to obtain a structure make products more expensive than conventional pasta [6, 7, 11, 16].

Common buckwheat (*Fagopyrum esculentum*) is characterized by interesting nutritional properties, such as the presence of proteins of a high biological value, natural antioxidants, minerals, vitamins (especially those of the B group) and dietary fiber [2, 22]. Presented in this paper a method for producing precooked buckwheat pasta not only allows to get gluten-free products without the use of any technological additives, but it gives an opportunity to create desired quality as well texture characteristics of pasta products which could be classified as convenience food.

The aim of this study was to determine some texture characteristics of extrusion-cooked buckwheat pasta processed with variable screw speed and different moisture levels of raw materials.

## MATERIALS AND METHODS

As the raw material buckwheat flour used (protein – 11.39%, fat – 1.06%, ash – 1.65%, fiber – 9.3%). Raw materials were moistened with appropriate amount of water and mixed to obtain a moisture content of the dough at 30, 32 and 34%. After mixing the raw materials were processed using a modified single-screw extrusion-cooker TS-45 (Metalchem, Gliwice, Poland) with L/D = 18:1, compression ratio 3:1, equipped with additional cooling section with glycol (chiller SW 8P MINI's Cool, Chotomów) at the end of the barrel, in the temperature ranged from 90 to 110°C in the plasticizing zone and from 55 to 65°C in the cooling section of the extruder. Pasta products were shaped using a forming die with 12 openings with a diameter of 0.8 mm. Buckwheat pasta were processed at different screw speeds of 60, 80, 100 and 120 rpm. After drying, the samples were stored in closed bags.



Fig. 1. Test adapters for texture measurements: a) Warner-Bratzler's knife, b) OTMS – Ottawa cell

Based on data collected during multiple measurements the radial expansion ratio of dry buckwheat pasta was tested as the ratio of the pasta single thread diameter to the die diameter (0.8 mm) [27]. Measurements of the diameter of pasta made with a digital caliper with accuracy of 0.01 mm. For selected texture properties of pasta it was used the universal testing machine Zwick BDO-FB0.5TH (Zwick GmbH & Co, Germany) equipped with Warner-Bratzler's knife, as shown on the Fig. 1a, for cutting tests of dry and hydrated pasta products, and with OTMS Ottawa cell for firmness tests of hydrated ready to eat buckwheat pasta (Fig. 1b). The evaluations of cutting force of dry pasta depend on processing conditions was tested as follow: single pasta thread was placed at testing adapter plate and cutting test was performed [24]. Value of cutting force was set at sample break.

Cutting force measurements of hydrated pasta was following after five minutes of hot water hydration, every 60 seconds single pasta thread was taken, rinsed with cold water and placed at 90° to the cutting knife, cutting force was reported at sample break. The distance between grips during the test was 210 mm, the threshold of force exclusion was set at 95%  $F_{max}$ , the threshold of damage control was set at 10%  $F_{nom}$ . The tests were performed with the head speed of 100 mm min<sup>-1</sup> in five replications.

The texture measurements of hydrated gluten-free pasta involved firmness, adhesiveness and chewiness evaluation with OTMS cell (Ottawa Texture Measuring System) with double compression test to 70% of sample layer thickness. Firmness was recorded as maximum force during compression, adhesiveness – as work required to overcoming an adhesion between sample and cell material surface, and chewiness was calculated as multiplication of firmness, cohesiveness and springiness registered during hydrated pasta products compression tests [21]. The tests were performed at 3 replications by placing 50 grams of hydrated and drained pasta and then double compressing with the head speed of 100 mm·min<sup>-1</sup>. The distance between testing grips was 210 mm, the threshold of force exclusion was set at 95% F<sub>max</sub>, the threshold of damage control was set at 0.1% F<sub>nom</sub>. *TestXpert®10.11* was applied for interpretation of measurements results of texture characteristics [25].

The results were processed statistically with Statistica 6.0 with response surface regression analysis [13] of influence of processing screw speed and moisture content applied on tested pasta characteristics. Correlation coefficients and Levene’s univariate tests of significance were performed at p=0.05.

RESULTS

The moisture content of tested buckwheat pasta varied from 7.5 to 8.5% what is reasonable for storage stability of processed cereal products. The expansion ratio evaluated for precooked pasta reached values 1.35 to 1.60, dependencies of screw speed and initial moisture content of raw materials during processing on this parameter are illustrated on the Fig. 2.

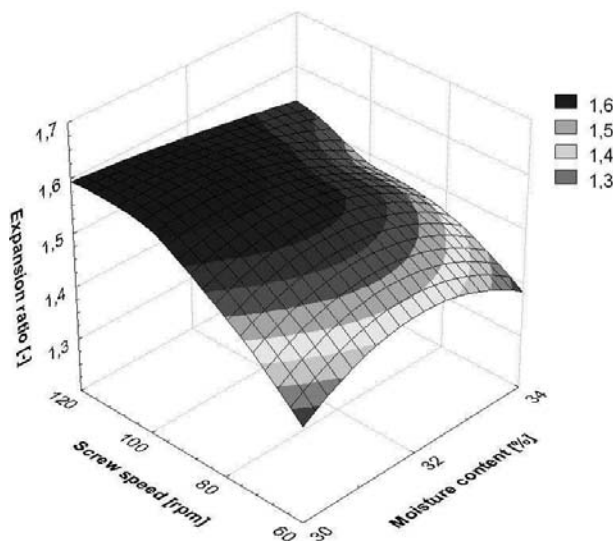


Fig. 2. Radial expansion ratio of gluten-free precooked pasta depend on processing conditions

Increasing of screw speed raised this parameter (correlation coefficient 0.80 at significance level p=0.002). It was found that the higher values of radial expansion index

assessed in pasta products processed at lower moisture level and highest screw rpm.

Some texture characteristics of dry and ready to eat pasta are very often estimated as its quality aspects. The instrumental methods utilizing cutting tests, compression and extrusion tests allows to assignation a wide range of texture properties of food products [6, 7, 11, 20, 30]. For hardness measurements the cutting test may be useful with calculation of maximum cutting force necessary to break the sample [15, 24, 29].

Fig. 3 showed the results of cutting forces results of dry buckwheat pasta. The highest hardness of tested products was observed when extrusion-cooked pasta was processed at 100 and 120 rpm at buckwheat flour moisture content of 32% (16.94 N). Lowest values were evaluated for products extruded at 60 rpm at 34% initial moisture content of raw materials (8.15%). Hardness of gluten-free precooked pasta increased significantly with higher screw speed used (correlation coefficient 0.70 at significance level p=0.011). Growth of buckwheat flour water content influenced on rapid reduction of pasta hardness (even 50%) when up to 100 rpm was applied during processing, at highest screw speed unclear effect of increased moisture on cutting force was observed. Significant correlation of pasta cutting force and expansion ratio was evaluated (correlation coefficient 0.71 at significance level p=0.010).

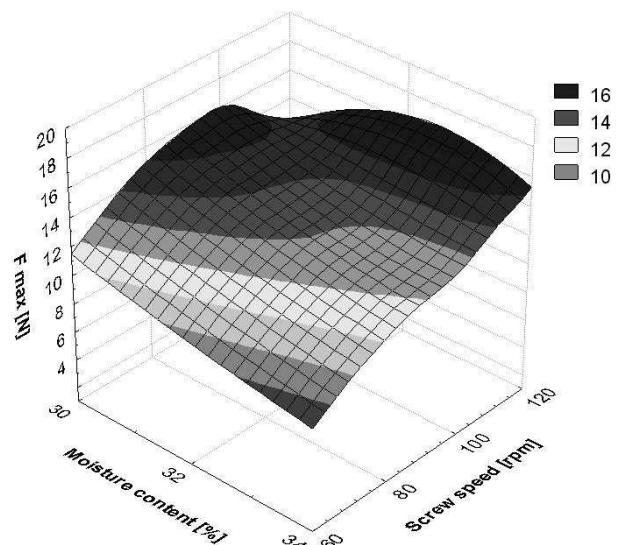


Fig. 3. Hardness of dry buckwheat precooked pasta in cutting test

Minimal preparation time for ready to eat consistency by hot water hydration varied from 4.0 to 6.5 minutes, being slightly longer for precooked pasta processed at higher screw rotational speed, which characterized the largest of the tested products expansion ratio values irrespectively the raw material moisture content applied. For textural properties tests the adequate preparation time was set, when they are at ready to consumption consistency.

A longer than required hydration time of buckwheat precooked pasta adversely affected its quality, the final

**Table 1.** Results of cutting force of precooked buckwheat pasta processed at different raw materials moisture content and screw speed at various hydration time (means  $\pm$  standard deviation)

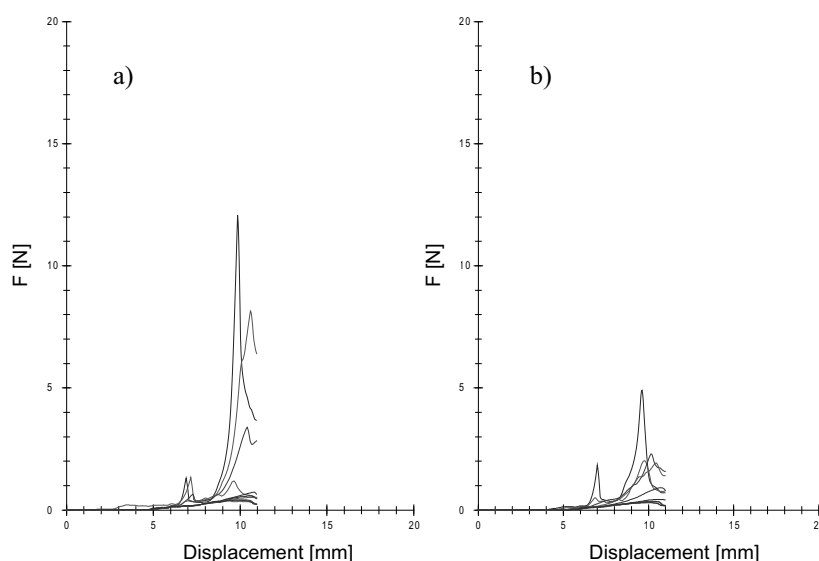
Moisture content [%]	Hydration time [min]	Cutting force of hydrated pasta [N]			
		60 rpm	80 rpm	100 rpm	120 rpm
30	1	12.57 $\pm$ 0.49	13.08 $\pm$ 1.95	15.46 $\pm$ 0.38	18.49 $\pm$ 0.59
	2	7.18 $\pm$ 0.95	6.16 $\pm$ 1.59	6.80 $\pm$ 0.64	13.89 $\pm$ 0.30
	3	3.43 $\pm$ 0.04	2.09 $\pm$ 1.13	4.92 $\pm$ 0.35	6.37 $\pm$ 0.45
	4	1.12 $\pm$ 0.07	1.67 $\pm$ 0.28	3.22 $\pm$ 0.80	4.09 $\pm$ 0.05
	5	0.80 $\pm$ 0.07	0.85 $\pm$ 0.17	1.45 $\pm$ 0.05	1.27 $\pm$ 0.15
32	1	11.29 $\pm$ 0.72	13.03 $\pm$ 2.87	14.83 $\pm$ 1.06	19.30 $\pm$ 0.29
	2	7.01 $\pm$ 1.56	7.06 $\pm$ 1.09	7.65 $\pm$ 1.58	11.22 $\pm$ 0.46
	3	3.43 $\pm$ 0.92	4.22 $\pm$ 0.48	3.46 $\pm$ 0.51	5.36 $\pm$ 0.19
	4	1.40 $\pm$ 0.06	1.42 $\pm$ 0.07	2.44 $\pm$ 0.43	3.82 $\pm$ 0.86
	5	0.86 $\pm$ 0.17	1.33 $\pm$ 0.04	1.56 $\pm$ 0.42	2.24 $\pm$ 0.95
34	1	6.30 $\pm$ 1.39	9.46 $\pm$ 0.87	12.57 $\pm$ 1.66	19.41 $\pm$ 0.37
	2	4.26 $\pm$ 0.24	5.69 $\pm$ 0.09	8.03 $\pm$ 0.21	8.36 $\pm$ 0.02
	3	2.01 $\pm$ 0.28	2.46 $\pm$ 0.21	5.71 $\pm$ 0.48	6.46 $\pm$ 0.65
	4	1.51 $\pm$ 0.41	1.51 $\pm$ 0.46	1.74 $\pm$ 0.20	3.04 $\pm$ 0.04
	5	0.86 $\pm$ 0.05	0.95 $\pm$ 0.02	0.87 $\pm$ 0.08	1.69 $\pm$ 0.29

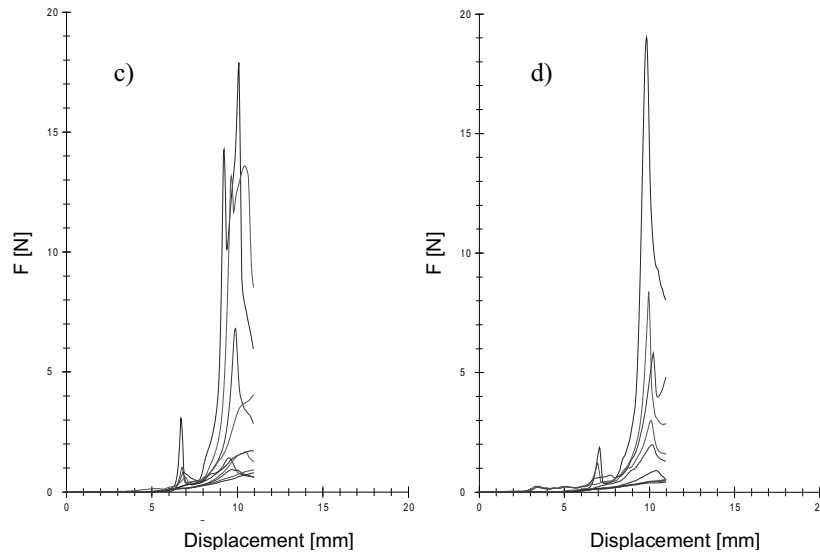
product was too swollen and too soft in consistency. Good quality final products should be stable, shape-keeping and not disintegrated until will be fully hydrated and consumed.

Measurements of cutting forces of buckwheat hydrated pasta were analyzed according the moisture content of raw materials, screw rotational speed and changes occurred during the subsequent minutes of hot water hydration. The hydration time had the greatest influence on the hardness of pasta, lengthening the time of hydration resulted a significant reduction in cutting force values (correlation coefficient 0.88-0.94 at significance level  $p \leq 0,05$ ). On the Fig. 4 diagrams of sample cutting

tests of hydrated buckwheat pasta processed at different rpm at various moisture content of raw material are presented. The greatest differences between the tested products were observed during the first three minutes of hydration, then the cutting force decreased below 1-2 N irrespective of the processing parameters, products have become very soft and less flexible. Only pasta extruded at 100 and 120 rpm showed resistance during cutting in the final stage of hydration, which proves their greater hardness after preparation.

In Table 1 the results of cutting forces of tested pasta are showed after 5-minutes hot water hydration, depend on





**Fig. 4.** Diagram of sample cutting test of hydrated buckwheat pasta processed at 60 rpm screw speed at various moisture content of raw material: a) 30%, 60 rpm, b) 34%, 60 rpm, c) 34%, 120 rpm, d) 34%, 120 rpm, after different hydration time

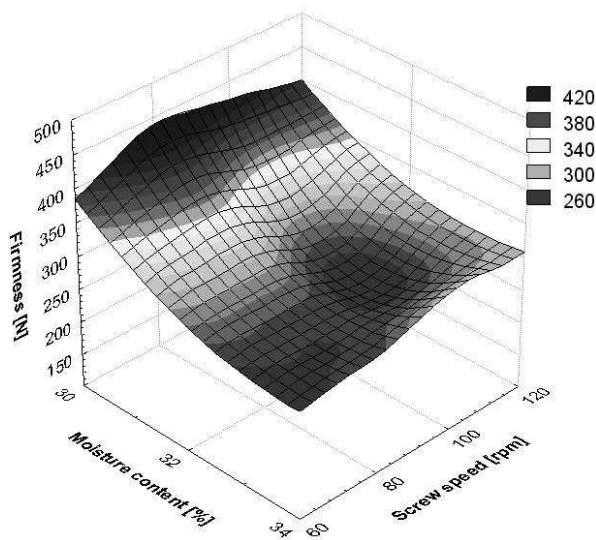
screw speed and moisture content during processing. The highest cutting forces for these products were recorded for pasta processed at 32 and 34% of buckwheat flour moisture content and a highest screw speed applied. When using a lower screw speed it was observed that cutting force of hydrated products decreased with increasing moisture content before processing.

At 120 rpm applied during processing of precooked pasta highest values of cutting forces have been noted and a slight increase in hardness with increasing moisture content of raw materials appeared. Also these products characterized the highest expansion ratio and the longest preparation time, what had impact on their greater hardness.

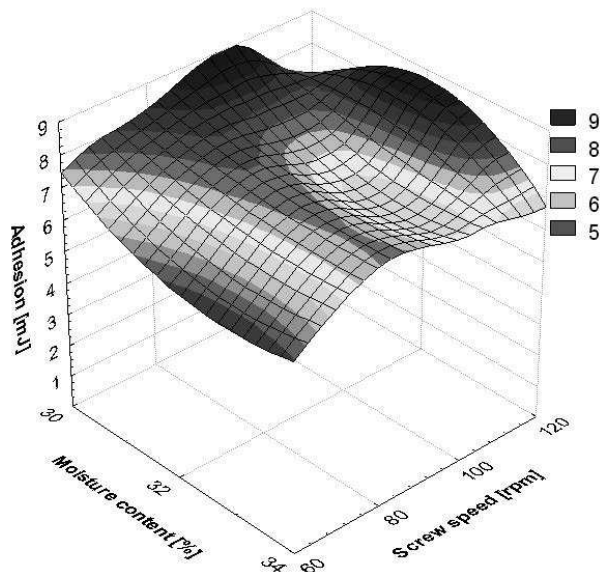
Schoenlechner et al. [22] examining buckwheat noodles obtained cutting force 1.57 N after 3 minutes of

cooking, this value was close to the cutting force of wheat noodles (1.55 N). Buckwheat precooked pasta extrusion-cooked at 60 and 80 rpm demonstrated similar values of cutting force independent of raw materials moisture content. The texture properties of precooked buckwheat pasta evaluated with OTMS Ottawa cell were analyzed according to influence of screw speed applied during processing and initial moisture content of raw materials. The results of pasta firmness depend on processing conditions are presented on the Fig. 5.

The research has shown that the firmness of buckwheat pasta in a double compression test was dependent on the initial moisture content of flour. Firmness of hydrated pasta decreased with increasing of moistening level (correlation coefficient -0.82 at significance level



**Fig. 5.** Firmness of hydrated buckwheat precooked pasta in double-compression test



**Fig. 6.** Adhesiveness of hydrated buckwheat precooked pasta in double-compression test

**Table 2.** The results of Levene univariate tests of significance for tested parameters of precooked buckwheat pasta processed at various extrusion-cooking conditions

Parameter	Variable	SS	df	MS	F	p
Expansion ratio	Screw speed	0.039	3	0.013	6.05	0.001
	Moisture content	0.003	2	0.002	0.95	0.393
Cutting force	Screw speed	0.591	3	0.197	0.22	0.880
	Moisture content	0.044	2	0.022	0.01	0.990
Firmness	Screw speed	1838.468	3	612.823	0.69	0.583
	Moisture content	68.609	2	34.305	0.27	0.767
Adhesiveness	Screw speed	10.663	3	3.554	4.26	0.045
	Moisture content	3.979	2	1.990	1.83	0.216
Chewiness	Screw speed	1303.681	3	434.560	1.66	0.251
	Moisture content	1151.848	2	575.924	1.45	0.285

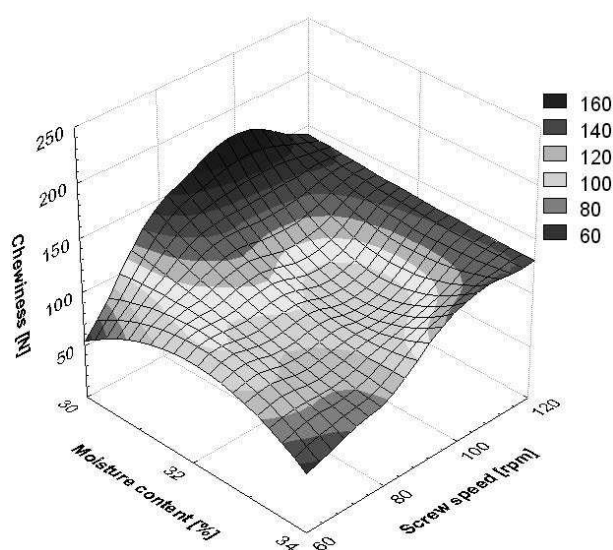
$p=0,001$ ). It was determined almost twice lower values of this parameter with increasing the moisture content from 30% to 34%. There was no significant effect of screw speed applied during processing on the firmness of buckwheat pasta after hydration.

Adhesiveness of precooked buckwheat pasta evaluated in a double compression test was low, the products were characterized by low stickiness, their surface was resilient and glossy after hydration at optimal hydration time for all the recipes used. Low values of pasta adhesion to the cell surface indicate the attractive texture of buckwheat precooked products. The results of pasta adhesiveness are presented on the Fig. 6. Slightly higher adhesiveness was observed for products processed at lowest moisture content of buckwheat flour, for these products lower hardness at cutting test and higher firmness were evaluated.

The results of Levene univariate tests of significance for tested properties of precooked buckwheat pasta processed at various extrusion-cooking screw speed and initial moisture content are presented in the table 2.

Analysis of variance revealed significant differences at  $p \leq 0.05$  in uniformity of the radial expansion ratio and adhesiveness of pasta analyzed for various screw rotational speed during extrusion-cooking of precooked pasta.

The results of chewiness of precooked buckwheat pasta are presented on the Fig. 7 depend on processing conditions. Higher values of chewiness were reported for products processed by extrusion-cooking at higher screw speed and at low moisture content of raw materials. Increasing the buckwheat flour moisture content resulted in the lower chewing ability of hydrated pasta products. Chewing ability was mostly affected by screw speed applied during processing, higher values were determined by increasing the screw speed (correlation coefficient 0.66 at significance level  $p=0,018$ ). Greater chewiness was significantly correlated with a higher cutting force of dry pasta (0.77 at  $p=0,003$ ), radial expansion ratio (0.73 at  $p=0,006$ ) and firmness of hydrated buckwheat pasta products (0.61 at  $p=0,010$ ).

**Fig. 7.** Chewiness of hydrated buckwheat precooked pasta in double-compression test

## CONCLUSIONS

The evaluation of influence of processing parameters as screw speed and moisture content during the extrusion-cooking on selected properties of precooked buckwheat pasta showed a significant effect of screw speed applied on radial expansion ratio and cutting force of dry pasta and also for firmness and chewiness of hydrated products.

Application of proposed initial moisture content of raw materials and varied intensity of material mechanical treatment due to the screw speed during precooked pasta extrusion-cooking with single-screw TS-45 modified equipment allowed producing buckwheat pasta with acceptable texture properties without any technological additives. After hot water hydration gluten-free precooked pasta characterized stable consistency, low adhesiveness and proper firmness.

The best properties, confirmed by sensory analysis, were determined for buckwheat pasta processed at 80-100

rpm and 30-32% of flour moisture content. It could be an attractive precooked buckwheat pasta product ready for consumption after few minutes of hot water hydration, especially for consumers on a gluten-free diet.

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WPLYW PARAMETRÓW PROCESU NA WYBRANE  
CECHY TEKSTURY PODGOTOWANYCH  
MAKARONÓW GRYCZANYCH

**Streszczenie.** W artykule przedstawiono wyniki pomiarów wybranych cech tekstury bezglutenowych makaronów błyskawicznych ekstrudowanych z mąki gryczanych przy zmiennych parametrach procesu. Podczas wytwarzania zastosowano zróżnicowany poziom dowlżenia mąki gryczanej do wilgotności od 30 do 34%. Ekstruzję podgotowanych makaronów gryczanych przeprowadzono z zastosowaniem temperatury cylindra w zakresie 90-110°C i temperaturą sekcji chłodzącej w zakresie 55-65°C z zastosowaniem zmodyfikowanego ekstrudera jednoślimakowego TS-45 z  $L/D = 18:1$  przy użyciu zróżnicowanych prędkości ślimaka: 60, 80, 100 i 120 obr.min<sup>-1</sup>. W zależności od obrotów ślimaka i wilgotności surowców przeprowadzono badanie wskaźnika ekspandowania promieniowego oraz ocenę wybranych cech tekstury suchych i uwodnionych podgotowanych makaronów gryczanych. Zastosowa-

no test cięcia do wyznaczenia siły cięcia produktów suchych i poddanych 5-minutowej hydratacji wyrobów makaronowych gotowych do spożycia. Przeprowadzono także test podwójnego ściskania z zastosowaniem komory Ottawa (OTMS) do wyznaczenia jędrności, adhezyjności i żujności uwodnionych makaronów gryczanych. Zastosowanie wyższych prędkości ślimaka podczas ekstruzji wpłynęło na wyższą siłę cięcia zarówno suchych, jak i uwodnionych makaronów gryczanych, co również było spowodowane wyższym wskaźnikiem ekspandowania promieniowego. Zwiększenie wilgotności surowców wpłynęło na obniżenie jędrności makaronów uwodnionych, zaś wyższe obroty zwiększyły żujność wyrobów po hydratacji. Podgotowany makaron gryczany wytworzony w zaproponowanych warunkach procesu ekstruzji i przy przyjętej wilgotności surowców charakteryzował się akceptowalną teksturą i może być polecany jako żywność wygodna dla konsumentów chorych na celiakię.

**Słowa kluczowe:** ekstruzja, gryka, makaron podgotowany, makaron bezglutenowy, tekstura.