



## EFFECT OF ADDITION OF PROTEIN PREPARATIONS ON THE QUALITY OF EXTRUDED MAIZE EXTRUDATES

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### ABSTRACT

The method of extrusion enables enrichment of snacking products with protein preparation simultaneously providing a high quality of end products. Maize semolina with particle size of 500-1250  $\mu\text{m}$  was used as raw material and as additives soybean protein isolate, distillery yeast Safethanol 3035 and laboratory obtained potato protein preparation. Snacks were determined for contents of dry matter, protein, fat as well as for texture, volume weight, bulk density and sensory traits. The application of 3% and 6% additions of protein preparations in extruded snacks production was found to exert a beneficial effect on their chemical composition without deteriorating sensory characteristics. The higher, 6%, addition of proteins to extrudates turned out to significantly reduce content of fat (by 18%) and ash (by 50%), and to increase total protein content by 26%, on average, in the products examined as compared to the samples free of additives. The addition of potato protein to extrudates, especially at the higher dose (6%), significantly improved their consistency and texture, simultaneously diminishing the expansion ratio of ready products. The higher (6%) addition of yeast protein applied in the production of extrudates resulted in slight deterioration of their taste and aroma, yet had a positive effect on the structure and expansion ratio of the ready

products. The extrudates produced with the addition of soybean protein were characterized by a good expansion ratio, uniform structure, irrespective of preparation dose and simultaneously demonstrated lower bulk mass as compared to the other products obtained in the experiment.

**Keywords:** Extruded snacks; Protein additives

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## **INTRODUCTION**

In recent years, the food market has been fast adapting to diversified needs and requirements of a contemporary consumer. The proceeding economic, social and cultural changes have resulted in an increased demand of consumers for the so-called “convenient food”. The concept of convenient food encompasses food products obtained upon such processing of raw material that enables using them for fast, convenient and easy preparation of meals. The group of convenient foodstuffs includes, among others, prepared cereal-flour products, e.g. extruded snacks (**Świdorski, 2003**). Substantial extension of the assortment of produced snacks and improvement of their quality, including especially their sensory attractiveness, have been due to intensive development of the extrusion technology. Extrusion – a technology combining such processes as: mixing, cooking, plasticization and formation, is especially useful in the production of expanded snacking products, e.g. maize extrudates. Most often, they are produced by means of a “collet” type extruder. Extruders of that type allow the processing of raw materials with a low moisture content, usually below 14%. Temperature of the extruded mass reaches ca. 175-180°C. Once leaving extruder’s die, the extrudate is subject to strong expansion as a result of which 7-10% of water contained in the raw material evaporates. This creates conditions for gelatinization of starch, polymerization of proteins and formation of lateral bonds between proteins and starch that determine the structure and appearance of extruded products (**Ding et al., 2004; Obuchowski and Michniewicz, 1993**).

Raw materials used in the production of extrudates include dry products, e.g. maize semolina, flour and starch; potato semolina, starch and potato flakes or granules as well as wheat flour. In some countries, use is also made of rice, tapioca, oat, pea and fish flours (**Chen and Yeh, 2001; Lucas and Rooney 2001**). Due to a high consumption of the „snack food” type products by children and youth, the extruded products are increasingly enriched with a number of nutritive substances, including vitamins, dietary fibre or protein preparations (**Almeida-Dominguez et al., 1998**).

The latter, concentrates and isolates of soybean proteins in particular, have been used in the food production (e.g. in the meat industry) for years. High costs of protein preparations of animal origin substantiates the application of less expensive protein preparations from unconventional sources, both the plant and microbiological ones. A severe problem is also the management of wastes from food processing. Waste products of plant, animal or microbiological origin, due to high contents of valuable components, may thus constitute an inexpensive and valuable source of protein (**Schieber et al., 2001**). Such products include potato juice from starch processing plants or yeasts being a by-product of the distillery industry. A number of authors (**Eppendorfer and Eggum, 1994; Kapoor et al., 1975; Pęksa 2006**) have for years been emphasizing a high nutritive value of potato protein and recent investigations have also demonstrated its beneficial effect on the quality of extruded products (**Pęksa, 2006**). In turn, distillery yeast are acknowledged as a good source of both easily digestible proteins and B group vitamins as well as macro- and microelements (Walker, 1998). Addition of potato protein preparations and distillery yeast to recipes of maize extrudates may not only improve their nutritive value, organoleptic and physicochemical parameters.

The undertaken study was aimed at determining the effect of addition of potato protein concentrate, distillery yeast and soybean protein isolate to maize extrudates on their chemical composition, texture and sensory characteristics.

## **MATERIAL AND METHODS**

The experimental material was maize semolina produced by Newcorn Comp., with particle size of 500-1250 $\mu$ m. Additives used in the study included salt and the following protein preparations: soybean protein isolate Supro 595 (applied in the meat industry for cured meat products chopping), distillery yeast Safethanol 3035 by Fermentis, potato protein preparation obtained experimentally according to technology described by **Pęksa (2006)**. The characteristics of raw material used in the experiment was presented in Table 1.

**Table 1** Chemical composition of corn grace

<b>Component</b>	
dry matter [%]	88.83
total nitrogen[%]	1.15
total protein N x 6,25 [%]	7.21
ash [%]	0.42
starch [%]	73.45
total sugar [%]	0.83
reducing sugars [%]	0.14

### Sample preparation for extrusion

Dry components were mixed following the recipe, i.e. 86-88% of maize semolina, 12-14% of protein preparations and 1.5% of salt. Moisture content of the mixtures was adjusted to 12% by adding an appropriate volume of water. Samples were ground, sieved through a screen with mesh diameter of 1 mm and closed in plastic packages. Next, they were kept at a temperature of ca. 18°C for 24h and sieved again to unify their particle size and moisture content.

### Extrusion

The process of extrusion was carried out in a laboratory single-screw extrusion-cooker (AEV 650, Brabender) using the following process parameters: a compression ratio of 4/1, screw speed of 161 rpm, screw load of 5 A, and die diameter of 4mm. Temperature of the extrusion process in particular segments of the extruder accounted for 140/160/180°C, respectively. The extrudates were left for 24h at a room temperature for the equalization of their moisture contents.

### Chemical analysis of raw materials and snack

Moisture content of raw materials and extrudates was determined by drying at a temperature of 105°C to a constant weight. The total nitrogen content of raw materials and extrudates was assayed with the Kjeldahl method, and the total content of protein – by multiplying the percentage content of nitrogen by 6.25 coefficient (**Boutrif, 1994**). The extrudates were determined for the content of fat after hydrolysis with the Soxhlet method, using a Büchi apparatus. Raw materials were additionally assayed for contents of total ash and

fat, whereas their content of carbohydrates was computed as a difference between contents of dry matter and the sum of the analyzed components (PN-ISO 2171:1994).

## **Analysis of snack**

### ***Texture measurements of snack:***

Texture of extrudates was determined with the objective method using an Intron type 5544 texturemeter with Merlin software. Measurements were made for the minimal shear force [N] necessary to brake an extrudate, by means of a shear blade working at a displacement rate of 250 mm/min.

### ***Determination of expansion index of snack:***

The expansion ratio of extrudates was expressed as a ratio of extrudates section to die diameter of extruder.

### ***Determination of volume weight of snack:***

The product was poured into a measuring cylinder with a capacity of 500 cm<sup>3</sup>, shaken for 3 min, and supplemented with extrudates to a volume of 500 cm<sup>3</sup>. Next, the contents of the measuring cylinder were weighed, and the result was expressed in g/dm<sup>3</sup>.

### ***Bulk density analysis of snack:***

Ground extrudates were poured into a vessel with a known volume and weighed. Their density was expressed in g/cm<sup>3</sup>.

## **Analysis of sensory traits of the snack**

The extrudates were subjected to a sensory analysis according to a 5-point scale of scores for their appearance and structure, consistency, aroma and taste. Assessments were performed by 10 experienced panelists.

## **Statistical analysis**

Results obtained were elaborated with a one-way analysis of variance using Statistica 8.0. software (Stanisz, 1998). Calculations were performed at a significance level of  $p \leq 0.05$ . Homogenous groups were determined with the use of Duncan's multiple comparisons test. The significance of differences between mean values was calculated based on the criterion of the least significant difference (LSD). Standard deviations of the results obtained were computed as well. Results of the chemical composition of extrudates are means of two laboratory replications, whereas texture scores are means of 16 measurements. Results of the expansion ratio are means of 14 measurements, and those of analyses of density and bulk mass of extrudates – means of three measurements. Results of the qualitative analysis of extrudates obtained in the experiment are mean values of two technological replications.

## **RESULTS AND DISCUSSION**

The raw material composition of dough mixtures used in the study had a significant effect on the quality of maize extrudates produced.

The proximate chemical composition of extrudates with 3% and 6% addition of protein preparations was presented in Table 2. The products obtained were observed to differ significantly in the contents of protein, ash and fat. As indicated by data collected in Table 2, the increasing addition of protein to extrudates was accompanied by an increase in their content of total protein and a decrease in their contents of ash and fat as compared to the sample without protein addition. Irrespective of the type of protein added to dough mixtures, the higher addition of that component (6%) significantly reduced contents of fat (by ca. 18%) and ash (by ca. 50%) as well as increased the content of protein (by ca. 26%) as compared to the sample without additives. The greatest increase in protein content was recorded in extrudates with the potato protein concentrate. Boosting its addition from 3% to 6% affected ca. 20% increase in protein content of the extrudates. In contrast to extrudates produced without protein addition, the incorporation of the 6% potato protein concentrate to the extrusion mixture resulted in increasing the content of total proteins in ready products by ca. 37%.

**Table 2** Chemical composition of snacks with 3 and 6 % addition of protein preparations

component	SNACKS						
	without protein addition	3% addition of soybean protein	3% addition of potato protein	3% addition of yeast	6% addition of soybean protein %	6% addition of potato protein	6% addition of yeast
moisture [%]	7.12 ±0.02 <sup>c</sup>	6.35±0.05 <sup>a</sup>	6.47±0.18 <sup>a</sup>	6.74±0.04 <sup>b</sup>	6.83±1.03 <sup>b</sup>	6.84±0.03 <sup>b</sup>	6.93±0.03 <sup>bc</sup>
total nitrogen [%]	1.38±0.05 <sup>a</sup>	1.83±0.05 <sup>d</sup>	1.58±0.01 <sup>c</sup>	1.37±0.01 <sup>a</sup>	1.90±0.01 <sup>e</sup>	1.89±0.05 <sup>e</sup>	1.47±0.01 <sup>b</sup>
total protein n x 6,25 [%]	8.63±0.05 <sup>a</sup>	11.42±0.05 <sup>d</sup>	9.85±0.01 <sup>c</sup>	8.53±0.01 <sup>a</sup>	11.84±0.01 <sup>e</sup>	11.81±0.05 <sup>e</sup>	9.16±0.01 <sup>b</sup>
ash [%]	1.04±0.05 <sup>c</sup>	1.31±0.01 <sup>d</sup>	1.26±0.01 <sup>d</sup>	1.09±0.01 <sup>c</sup>	0.56±0.01 <sup>b</sup>	0.31±0.01 <sup>a</sup>	0.63±0.01 <sup>b</sup>
fat [%]	0.27±0.16 <sup>c</sup>	0.25±0.01 <sup>bc</sup>	0.26±0.01 <sup>c</sup>	0.25±0.01 <sup>bc</sup>	0.23±0.15 <sup>ab</sup>	0.22±0.02 <sup>a</sup>	0.20±0.01 <sup>a</sup>

Legend: a,b,c,d,e – the same letters in rows means homogenous groups

The proper course of the extrusion process is affected, to a great extent, by water content of the extruded material. Usually, moisture content of the initial raw material used for the production of maize extrudates is lower than 10%. However it is not enough for the formation of plastic mass inside the barrel and for gelatinization of starch present in the raw material. Hence, it is necessary to add additional volume of water so that its content ranged from 12 to 15% (optimal in high-temperature extrusion). Excessive addition of water results in obtaining too soft, highly expanded and sometimes pulpy product, while its insufficient content makes the extrudate too hard (Brümmer *et al.*, 2002; Ding *et al.*, 2004; Harper, 1986). The extrudates obtained in the study were characterized by water content below 8% (table 2). Such a low water content of products affects their higher storage stability (Ding *et al.*, 2004; Harper, 1986) and is consistent with reference standards for such type of products.

The protein preparations applied in the experiment did not deteriorate the sensory attributes of the resultant extrudates as compared to the sample without additives (table 3). Deterioration was only observed for taste and aroma of extrudates with 6% addition of distillery yeast that were characterized by after-taste and aroma of the added preparation. The other examined preparations had no such an intensive taste nor aroma. Extrudates with 6% addition of soybean and potato proteins did not display any negative sensory attributes. Also the color of extrudates was uniform, creamy-yellow, and comparable with the color of extrudates produced without additives. In addition, the protein preparations used in the study did not deteriorate the appearance (structure) of ready products which were homogenous and well-expanded. Scores obtained in the sensory analyses were confirmed by results of assays carried out for the physical parameters of the extrudates (table 4). A worse expansion ratio was observed for extrudates with 6% addition of the potato protein preparation (2.55). All other products were characterized by the expansion ratio ranging from 3.03 (with 6% addition of soybean protein) to 3.54% (with 3% addition of soybean protein preparation). The higher 6% addition of the protein preparations used in the study deteriorated extrudates expansion only to a slight extent.

**Table 3** Physical composition of snacks with 3 and 6 % addition of protein preparations

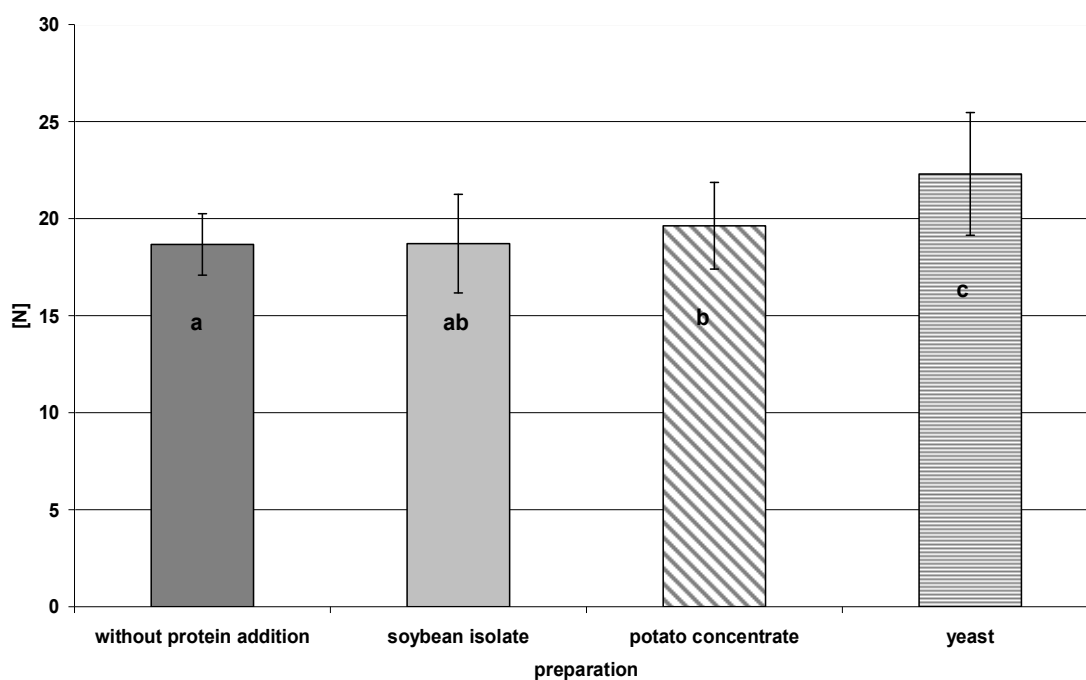
component	SNACKS						
	without protein addition	3% addition of soybean protein	3% addition of potato protein	3% addition of yeast	6% addition of soybean protein %	6% addition of potato protein	6% addition of yeast
bulk mass [g/dm <sup>3</sup> ]	56.90±0.45 <sup>c</sup>	45.70±0.70 <sup>a</sup>	50.20±0.20 <sup>b</sup>	55.60±0.30 <sup>c</sup>	46.30±0.30 <sup>a</sup>	47.10±0.10 <sup>a</sup>	51.00±0.50 <sup>b</sup>
bulk density [g/cm <sup>3</sup> ]	0.11±0.01 <sup>b</sup>	0.11±0.01 <sup>b</sup>	0.11±0.005 <sup>b</sup>	0.12±0.005 <sup>c</sup>	0.10±0.005 <sup>a</sup>	0.11±0.005 <sup>b</sup>	0.11±0.01 <sup>b</sup>
expansion index	3.30±0.11 <sup>cd</sup>	3.54±0.49 <sup>e</sup>	3.49±0.23 <sup>e</sup>	3.35±0.10 <sup>d</sup>	3.03±0.10 <sup>b</sup>	2.55±0.10 <sup>a</sup>	3.21±0.30 <sup>c</sup>
consistance [N]	18.67±0.70 <sup>bcd</sup>	18.71±1.14 <sup>bcd</sup>	19.63±1.0 <sup>cd</sup>	22.30±1.41 <sup>d</sup>	16.40±0.63 <sup>abc</sup>	15.61±0.7 <sup>ab</sup>	13.58±1.0 <sup>a</sup>

Legend: a,b,c,d,e – the same letters in rows means homogenous groups

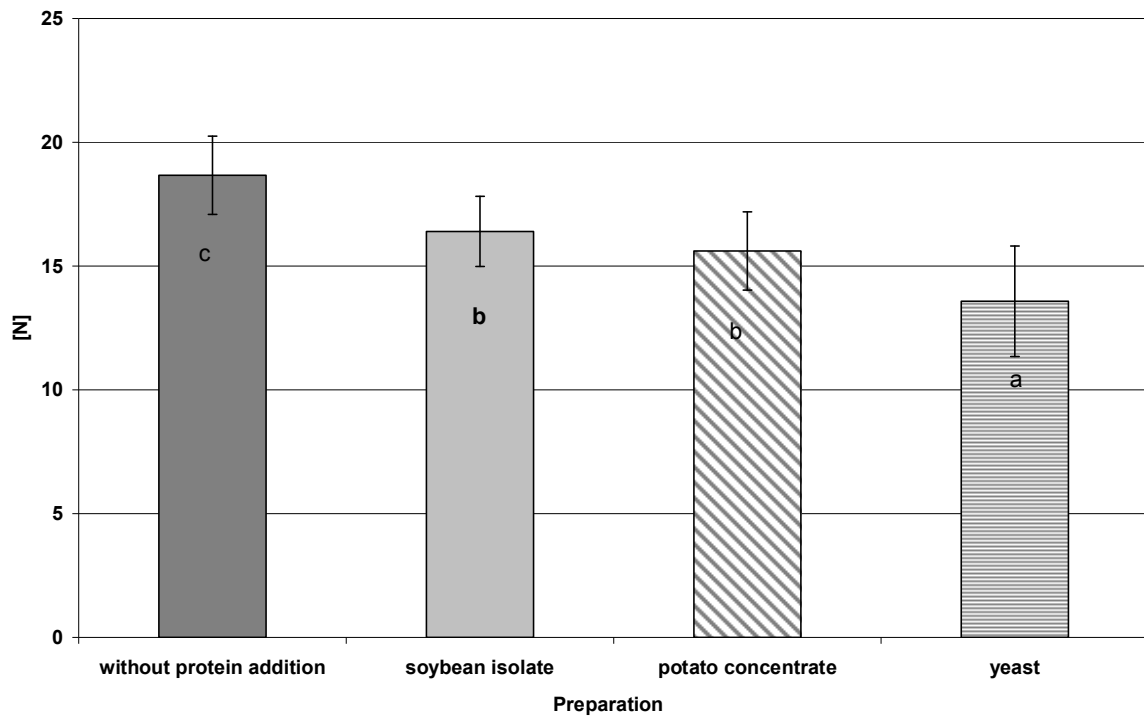


The addition of a protein preparation, especially that containing non-denaturated protein, to extruded products usually results in decreasing the expansion ratio of the ready products, however effects of protein preparations are observed to differ depending on the type of starch applied in the extrusion mixture (Camire *et al.*, 1990; Chen and Yeh 2001; Marshall and Chrastil, 1992). This is most likely due to diversified effects of the protein preparations on the course of the gelatinization process of starch of various origin (Kim and Maga, 1987). The degree of starch gelatinization in the extruded material determines substantially the physical characteristics of the produced extrudates. The proper structure of extrudates does not always reflect the crispy consistency of extruded products. Often products with a similar structure differ considerably in texture (Mohamed, 1990; Pęksa, 2006; Senthil *et al.*, 2002; Singh *et al.*, 1994).

The maize extrudates produced in the reported experiment were observed to differ significantly in their consistency (table 3, figs. 1, 2).



**Figure 1** Consistence [N] of corn snacks with 3% addition of different protein preparations



**Figure 2** Consistence [N] of corn snacks with 6 % addition of different protein preparation

In the sensory assessment, the worst were extrudates free of additives and to those with 3% addition of potato and yeast protein. Results of instrumental analyses confirmed the scores obtained in the sensory evaluation (table 3). The hardest appeared to be extrudates with 3% addition of yeast protein (22.3 N) and those with 3% addition of potato protein (19.6 N). Consistency of the extrudates was found to be positively affected by the 6% addition of protein preparations (table 4, fig. 2 ), i.e. the higher the protein addition to extrudates, the better their consistency. That dependency was confirmed especially at the higher addition of yeast and potato protein. The shear force needed to cut extrudates with 6% addition of the protein preparation ranged from 13.6 N (extrudates with yeast protein) to 16.4 N (extrudates with soybean protein).

**Table 4** Sensory features of snacks obtained with 3 and 6% addition of protein preparations

feature	SNACKS						
	without protein addition	3% addition of soybean protein	3% addition of potato protein	3% addition of yeast	6% addition of soybean protein	6% addition of potato protein	6% addition of yeast
colour	uniform, cream-yellow	uniform, cream-yellow	uniform, cream-yellow	uniform, cream-yellow	uniform, cream-yellow	uniform, cream-yellow	uniform, cream-yellow
consistence	crispy, with noticeable hard places	crispy	crispy, with noticeable hard places	crispy, with noticeable hard places	crispy, brittle, loose	crispy, brittle, loose	crispy
appearance/ Structure	expanded, uniforme structure	expanded, uniforme structure	expanded, uniforme structure	expanded, uniforme structure	expanded, uniforme structure	expanded, uniforme structure	expanded, uniforme structure
taste	corn taste	corn taste	corn taste	corn taste	corn taste	corn taste	corn taste, slightly noticeable yeast taste
flavour	corn flavour	corn flavour	corn flavour	corn flavour	corn flavour	corn flavour	corn flavour, slightly noticeable of yeast

Results obtained in our study are consistent with findings of other authors (**Camire et al., 1990; Huber, 2001; Lucas and Rooney, 2001; Marshall and Chrastil, 1992**) who claim that the addition of protein in the denaturated form has a negligible effect on the structure, expansion ratio and density of extruded products, yet may significantly modify their texture. It is, probably, linked with considerable inhibition of the formation of complexes between denaturated protein and carbohydrate. Investigations of some authors (**Angeles Liuch et al., 2001; Kim and Maga, 1987; Noguchi et al., 1981**) prove that non-denaturated proteins affect the course of starch gelatinization during the extrusion process, thus modifying texture of ready products and some of their functional properties, e.g. water absorption. Such physical characteristics of extrudates as structure, texture or density are strictly dependent on the type of raw material used, including type and gelatinization degree of starch as well as type and denaturation degree of protein (**Guy, 1992; Lee et al., 2000**). The course of starch

gelatinization in the extrusion process is affected, apart from origin of protein and type of starch, by the addition of salt, NaCl and CaCl<sub>2</sub> in particular.

Findings of some authors (**Angeles Liuch et al., 2001; Kim and Maga, 1987; Marshall and Chrastil, 1992**) indicate that elevating the addition of protein preparations containing non-denaturated protein, e.g. semolina or soybean flour, contributes to increasing the hardness and diminishing the expansion ratio of extrudates. According to **Martinez-Bustos et al. (1998)**, during the extrusion of a mixture of plant materials containing starch and protein products, such as concentrates rich in minerals (calcium in particular), starch-calcium complexes are likely to be formed, that affect the formation of more delicate and crispy consistency of the ready products. This might elucidate the especially favorable consistency of extrudates produced with the addition of a potato protein preparation coagulated with CaCl<sub>2</sub>.

Density of the obtained snacks reached ca. 0.10 g/cm<sup>3</sup>. Both the type of added protein and its origin had no significant effect on that parameter (table 4). In turn, the bulk mass of the extrudates examined was observed to decrease negligibly along with the increasing addition of protein preparations. The lowest bulk mass was recorded for extrudates with 6% addition of potato protein and these with 3% addition of soybean protein, whereas the highest one for the extrudates without additives (56.90 g/ dm<sup>3</sup>). The bulk mass of extrudates containing yeast was similar to that of extrudates without protein preparations.

The bulk mass of expanded products is determined by both their density, shape and size, thus it should be considered for an individual product with a specified shape and size. According to various authors (**Camire et al., 1990; Lee, et al., 2003; Lucas and Rooney, 2001**) the bulk mass of crispy snacks increases along with increasing addition of protein preparations (both those of plant and animal origin), especially those containing non-denaturated proteins, e.g. soybean flour and semolina, high-gluten wheat flour or poultry meat.

## CONCLUSION

The application of 3% and 6% additions of protein preparations in the production of maize extrudates was found to exert a beneficial effect on the chemical composition of the resultant ready products without deteriorating their sensory characteristics. The higher, 6%, addition of proteins to extrudates turned out to significantly reduce contents of fat (by 18%) and ash (by 50%), and to increase total protein content by 26%, on average, in the products examined as

compared to the samples free of additives. The addition of potato protein to extrudates, especially at the higher dose (6%), significantly improved their consistency and texture, simultaneously diminishing the expansion ratio of ready products. The higher (6%) addition of yeast protein applied in the production of extrudates resulted in slight deterioration of their taste and aroma, yet had a positive effect on the structure and expansion ratio of the ready products. The extrudates produced with the addition of soybean protein were characterized by a good expansion ratio, uniform structure, irrespective of preparation dose and simultaneously demonstrated lower bulk mass as compared to the other products obtained in the experiment.

## REFERENCES

- ALMEIDA-DOMINGUEZ, N. G. - VALENCIA, M. E. - HIGUERA-CIAPARA, I. 1990. Formulation of corn-based snacks with high nutritive value: biological and sensory evaluation. In *Journal of Food Science*, 1990, no. 55, p.228-331.
- ANGELES LLUCH, M. - PEREZ-MUNUERA, I. - HERNANDO, I. 2001. Proteins in food structures in „Chemical & Functional Properties of Food Proteins” edited by Z.E. Sikorski, Technomic Publishing Company, Inc 851 New Holland Avenue, 2001, p.13-33.
- BOUTRIF, E. 1994. Recent developments in protein quality evaluation. *Faits nouveaux intéressants l'évaluation de la qualité des protéines. Novedades en la evaluación de la calidad de las proteínas. Nutrient Requirements*. In *Food, Nutrition and Agriculture*, vol.2, 1994, no.3, p.1-7.
- BRÜMMER T. - MEUSER F. - VAN LENGERICH B. - NIEMANN C. 2002. Expansion and functional properties of corn starch extrudates related to their molecular degradation, product temperature and water content. In *Starch*, no. 54, 2002, p. 9-15.
- CAMIRE, M. E. - CAMIRE, A. - KRUMHAR K. 1990. Chemical and nutritional changes in foods during extrusion. In *Critical Reviews Food Science Nutricion*, vol. 29, 1990, no. 1, p. 35-57.
- CHEN, C-M. - YEH, AN-I. 2001. Effect of amylase content on expansion of extruded rice pellet. In *Cereal Chemistry*, vol. 78, 2001, no. 3, p. 261-266.
- DING, Q-B. - AINSWORTH, P. - TUCKER, G. - MARSON, H. 2004. The effect of extrusion conditions on the physicochemical properties and sensory characteristic of rice-based expanded snack. In *Journal of Food Engineering*, 2004, no. 66, p. 283-289.
- EPPENDORFER, W. H. - EGGUM, B. O. 1994. Dietary fibre, starch, amino acid and nutritive value of potatoes as affected by sulfur, nitrogen, phosphorus, potassium, calcium and

- water stress. In *Acta Agriculture Scandinavica, Section B – Plant Soil Science*, 1994, p. 107-115.
- GUY, R. 1992. Creating texture and flavour in extruded products. In *Food Technology International*, 1992, no. 7, p. 57-60.
- HARPER, J.M. 1986. Extrusion texturisation in foods. In *Food Technology*, vol. 40, 1986, p. 70-76.
- HUBER, G. 2001. Snack foods from cooking extruders. In *Snack Food Processing edited by Lusas E.W., Rooney L.W. CRC Press*, 2001, p. 315-367.
- KAPOOR, A. C. - DESBOROUGH, S. L. - LI, P. H. 1975. Potato tuber proteins and their nutritional quality. In *Potato Research*, 1975, no. 18, p. 469-478.
- KIM, C. H. - MAGA J. A. 1987. Properties of extruded whey protein concentrate and cereal flour blends. In *Lebensmittel Wissenschaft und Technologie*, 1987, no. 20, p. 311.
- LEE, E. Y. - LIM, K. I. - LIM, J-K. -LIM, S-T. 2000. Effects of gelatinization and moisture content of extruded starch pellets on morphology and physical properties of microwave-expanded products. In *Cereal Chemistry*, vol. 77, 2000, no. 6, p. 769-773.
- LEE, S. O. - MIN, J. S. - KIM, I. S. - LEE, M. 2003. Physical evaluation of popped cereal snack with spent hen meat. In *Meat Science*, 2003, no. 64, p. 383-390.
- LUSAS, E. W. - ROONEY, L. W. 2001. Snack Food Processing, In *CRC Press*, 2001, p.300-314.
- MARSHALL, W. E. - CHRASTIL J. 1992. Interaction of food proteins with starch. Biochemistry of food proteins (B.J.F. Hudson). *Elsevier Applied Science Publi. (Borking Essex)*, 1992, p. 75-97.
- MARTINEZ-BUSTOS, F. - CHANG, Y. K. - BANNWART, A. C. - RODRIGEZ, M. E. - GUEDES, P. A. - GAIOTTI, E. R. 1998. Effects of calcium hydroxide and processing conditions on corn meal extrudates. In *Cereal Chemistry*, vol. 75, 1998, no. 6, p. 796-801.
- MOHAMED, S. 1990. Factors affecting extrusion characteristic of expanded starch – based products. In *Journal of Food Processing and Preservation*, 1990, no. 14, p. 437-452.
- NOGUCHI, A. - KUGIMIYA, W. - HAQUE, Z. - SAIKO, K. 1981. Physical and chemical characteristic of extruded rice flour and rice flour fortified with soyabean protein isolate. In *Journal of Food Science*, 1981, no. 47, p. 240-245.
- OBUCHOWSKI, W. - MICHNIEWICZ, J. 1993. Extrusion. The possibilities on products properties influence. In *Przemysł Zbożowo-Młynarski*, 1993, no. 11, p. 5-7.
- PEKSA, A. 2006. Quality assessment of potato protein preparations obtained under different

technological conditions and their suitability for extruded products processing. In *Zeszyty Naukowe Akademii Rolniczej we Wrocławiu, Dissertations*, 206, no. 533, p. 101.

PN-ISO 2171:1994. Cereal grain and products. Total ash determination (in Polish).

SCHIEBER, A. - STINZING, F. C. - CARLE, R. 2001. By-products of plant food processing as a source of functional compounds-recent developments. In *Trends in Food Science and Technology*, 2001, no. 12, p. 401-413.

SENTHIL, A. - RAVI, R. - BHAT, K. K. - SEETHALAKSHMI, M. K. 2002. Studies on the quality of fried snacks based on blends of wheat flour and soya flour. In *Food Quality and Preference*, 2002, no. 13, p. 267-273.

SINGH, J. - HOSENEY, R. C. - FAUBION, J. M. 1994. Effect of dough properties on extrusion - formed and baked snack. In *Cereal Chemistry*, vol. 71, 1994, no. 5, p. 417-422.

STANISZ, A. 1998. *Easy statistic course. StatSoft Sp. z o.o.*, Kraków, 1998, p. 362 (in Polish).

ŚWIDERSKI, F. 2003. *Żywność wygodna i żywność funkcjonalna*. WNT, Warszawa, 2003, p. 390 (in Polish).

TEPPER, B. J. - TRAIL, A. C. 1998. Taste or health: a study on consumer acceptance of corn chips. In *Food Quality*, vol. 9, 1998, no. 4, p. 267-272.

WALKER, G.M. 1998. *Yeast Physiology and Biotechnology*. Wiley-VCH Verlag GmbH, 1998, p. 320.