Textural properties of extruded snack products formulated with deboned poultry meat and brewer’s spent grain

J Delic\textsuperscript{1,2}, P Ikonic\textsuperscript{1}, M Jokanovic\textsuperscript{2}, V Banjac\textsuperscript{1}, T Peulic\textsuperscript{1}, B Ikonic\textsuperscript{2}, S Vidosavljevic\textsuperscript{1} and V Stojkov\textsuperscript{1}

\textsuperscript{1} Institute of Food Technology, University of Novi Sad, Bulevar cara Lazara 1, 21000 Novi Sad, Serbia
\textsuperscript{2} Faculty of Technology Novi Sad, University of Novi Sad, Bulevar cara Lazara 1, 21000 Novi Sad, Serbia

E-mail: jovana.delic@fins.uns.ac.rs

Abstract. The incorporation of protein- and fibre-rich ingredients into starch-based extruded snacks is of interest for obtaining healthy products. However, development of this type of product has been limited, since protein and dietary fibre have negative effect on textural properties of extruded snacks. In the present study, response surface methodology was used in order to evaluate the effect of different ratios of mechanically deboned poultry meat (MDPM) and brewer’s spent grain (BSG), as well as screw speeds, on hardness, firmness and crispiness of the extrudates produced. Regression analysis showed that BSG and screw speed had significant effects on all textural parameters, while MDPM had a significant effect only on the crispiness of snack products.

1. Introduction
Extrusion is a complex process consisting of continuous mixing, kneading, cooking, shearing, forming and/or puffing of the material [1]. Numerous products for the snack industry have been obtained by low moisture extrusion processes. Typically, commercial snack products are made of cereal flours and starches, and further seasoned with oil slurries. Thus, the products obtained usually have high fat and carbohydrate contents, and low percentages of proteins and fibres, i.e. are of low nutritional quality [2]. Moreover, in recent years, the prevalence of common diseases associated with poor nutrition, such as obesity, diabetes and cardiovascular disease, is rising, and hence, demand for healthier and nutritionally richer snack products has been evolving [3]. Extruded snack products are often consumed, especially by children and adolescents [4,5], and improvement of their nutritional quality could bring healthy diets closer to these younger populations. Since extrusion is flexible technology, different ingredients could be incorporated in order to improve protein, fibre and mineral contents.

Ingredients that could be used for protein fortification of extruded blends are whey protein, soy concentrate, pea protein, meat, and even insects [6–9]. To increase fibre content, different authors utilized different fibre-rich ingredients, such as wheat bran, rice bran, corn bran, wheat fibre, cauliflower by-products, apple and tomato pomace, etc. [10–12]. However, addition of protein and fibre sources has an influence on textural properties of extruded snack products. Increase of these two components lowers the expansion, and smaller sized pores are formed. Beside taste, the texture is the most important...
parameter regarding consumer acceptability of snack products; hence it is crucial to obtain the desired texture of snacks [13]. Nevertheless, there are limited data explaining the influence of mechanically deboned poultry meat (MDPM) and brewer’s spent grain (BSG) levels on textural properties of corn-based extruded products. MDPM is a low-cost turkey and/or chicken product, produced by mechanical separation of bone and attached skeletal muscle [14]. BSG is a nutritionally valuable by-product of the brewing industry, rich in protein (20%) and fibre (70%) [15]. Furthermore, the texture of snack products is also influenced by processing conditions. It has been suggested that screw speed is the process parameter with the most significant influence on the textural properties [16].

Having in mind the above, the aim of this study was to investigate the influence of different percentages of BSG and MDPM and different screw speeds on the texture of extruded snack products.

2. Materials and Methods

2.1. Raw materials

For the production of extruded snack products, the following four ingredients were used: cornmeal (6.5% protein; 0.59% fat; 0.31% ash; 79.6% carbohydrate; 5.73% dietary fibre), MDPM (15.8% protein; 14.98% fat; 0.95% ash; 0.1% carbohydrate; 0% dietary fibre), BSG and salt. BSG was dried in a convection dryer D-018 Solaris + (Dryer d.o.o. Belgrade Serbia) to meet the target moisture level of around 5.0% and milled in a hammer mill (ABC Inženjering Serbia) equipped with a 1mm sieve. The proximate composition of BSG after drying was: 19.1% protein; 5.58% fat; 4.38% ash; 65.94% carbohydrate; 45.59% dietary fibre.

2.2 Experimental design and data analysis

The independent variables selected for the study were: MDPM content (X1), 4, 8 and 12%; BSG content (X2), 10, 20 and 30%, and; screw speed (X3), 500, 700 and 900 rpm. The actual values are presented in Table 1. The response variables were: hardness, firmness and crispiness. Using Response Surface Methodology (RSM), based on a Box-Behnken design, a second-order polynomial regression model (Equation 1) was established to fit the experimental data (P < 0.05). In Equation 1, b0 represents the intercept (constant), b1 the linear, bii the quadratic and bij the interaction effect of the factors, and Y represents response. From the fitted equations, response surfaces were generated.

\[ Y = b_0 + \sum b_i X_i + \sum b_{ii} X_i^2 + \sum \sum b_{ij} X_i X_j \]  \hspace{1cm} (1)

2.3 Sample preparation and extrusion process

The blends were prepared following experimental design (Table 1) by mixing cornmeal, MDPM and BSG in appropriate proportions in a bowl cutter SMZ 20/82 (Alexanderwerk, Germany). Each mixture contained 2% salt, and moisture content was set to 18%. The extrusion process was performed using a co-rotating twin-screw extruder of 880 mm length (model BTSK30, Buhler, Uzwil, Switzerland) of L/D ratio 28:1. The temperature profile was set at 100°C (zone 2-4) and 120°C (zone 6-7). Extrusion was conducted at a constant feed rate of 50 kg/h, with the three different screw speeds. At the end of the extruder, a circular die with an aperture diameter of 4 mm and six knives rotating with a constant speed of 350 rpm were mounted. After extrusion, snacks were dried for half an hour at room temperature, sealed in paper and plastic bags and stored.

2.4 Textural properties

Textural properties (hardness, firmness and crispiness) were analysed using a TA.XT2 Texture Analyser (Texture Technologies Corp., Scarsdale, NY/ Stable Microsystems, Godalming UK) equipped with 250 kg load cell. Hardness and firmness of the extrudates were measured in 15 probes according to methods described by Paula and Conti-Silva [17] – a compression test (aluminium cylinder probe of diameter 25 mm) and a cut test (Warner-Bratzler V-shaped cutting blade). Measurements of crispiness were repeated five times, using 5-blade Kramer shear cell [18].

854 (2021) 012020 doi:10.1088/1755-1315/854/1/012020
Table 1. Experimental design for extrusion experiments with coded and actual variable levels

| Run | X1  | X2  | X3  |
|-----|-----|-----|-----|
| 1   | 4 (-1) | 10 (-1) | 700 (0) |
| 2   | 12 (+1) | 10 (-1) | 700 (0) |
| 3   | 4 (-1) | 30 (+1) | 700 (0) |
| 4   | 12 (+1) | 30 (+1) | 700 (0) |
| 5   | 4 (-1) | 20 (0) | 500 (-1) |
| 6   | 12 (+1) | 20 (0) | 500 (-1) |
| 7   | 4 (-1) | 20 (0) | 900 (+1) |
| 8   | 12 (+1) | 20 (0) | 900 (+1) |
| 9   | 8 (0) | 10 (-1) | 500 (-1) |
| 10  | 8 (0) | 30 (+1) | 500 (-1) |
| 11  | 8 (0) | 10 (-1) | 900 (+1) |
| 12  | 8 (0) | 30 (+1) | 900 (+1) |
| 13  | 8 (0) | 20 (0) | 700 (0) |
| 14  | 8 (0) | 20 (0) | 700 (0) |
| 15  | 8 (0) | 20 (0) | 700 (0) |

3. Results and Discussion

The regression coefficients and analysis of variance for the analysed responses in hardness, firmness and crispiness are presented in Table 2. All the evaluated parameters showed an adequate adjustment with values of R² in range of 0.91 to 0.99, and coefficients of variation between 4.71 and 9.08. None of the models showed significant lack of fit, indicating that all the second order polynomial models correlated well with the measured data.

Table 2. Regression coefficient and analysis of variance for textural properties of extruded snack products

| Coefficient | Hardness | Firmness | Crispiness |
|-------------|----------|----------|------------|
| Intercept   | 13.71*   | 67.45*   | 169.42*    |
| b₁          | < -0.01  | 2.25     | -5.01*     |
| b₂          | 0.23*    | 2.70*    | -6.19*     |
| b₃          | -0.01*   | -0.04*   | -0.01*     |
| b₁₂         | < 0.01   | < -0.01  | 0.11       |
| b₁₃         | < 0.01   | < 0.01   | < -0.01*   |
| b₂₂         | < 0.01   | < 0.01   | < -0.01*   |
| b₂₃         | < 0.01   | < -0.01* | 0.14*      |
| P of F (model) | 0.03    | < 0.01   | < 0.01     |
| Lack of fit | 0.60     | 0.33     | 0.05       |
| R²          | 0.91     | 0.97     | 0.99       |
| CV (%)      | 9.08     | 6.96     | 4.71       |

The effects of the process variables on hardness, firmness and crispiness are shown in Figure 1 (A, B, C, respectively). Hardness and firmness showed similar response plots. The values of hardness and firmness ranged from 5.82 to 10.76 kg and from 38.28 to 78.24 N, respectively. These textural parameters did not change with MDPM increase, while increase of the percentage of BSG in the snacks promoted hardness. These results were in accordance with results of Stojceska et al. [12], showing that inclusion of BSG, a fibre-rich material, caused a rise of extrudates’ hardness. It has been shown that
increase of fibre content results in less expanded and more compact structure, thus increased hardness and firmness [7]. Furthermore, some authors suggested that proteins also cause less expansion of extruded products [19], while others showed that addition of proteins in certain amounts can actually increase expansion of extrudates [20]. In the present research, MDPM as a source of protein did not have any significant influence on hardness and firmness, but only on crispiness. Hardness and firmness were negatively influenced by screw speed, i.e. they decreased as screw speed rose, similar to reports published earlier [9,12]. The crispiness of our extrudates varied between 64.25 and 135.1 (peak counts), and it was also slightly influenced by the percentage of MDPM in the snacks. Crispiness was negatively correlated with BSG, especially observed at high screw speeds. These results confirm the suggestion that fibre and protein often lead to less crispy products [7]. Furthermore, addition of fibre and proteins results in less starch in the mixture, which is the ingredient most responsible for the puffing of the snack [21], and more expanded products are characterized by lower hardness and higher crispiness [11]. Screw speed had a mild positive effect on crispiness of extrudates, which became more intensive when the percentage of BSG was low.

![Figure 1](image_url)

**Figure 1.** Response surface plots for the effect of MDPM, BSG and screw speed on the hardness (A), firmness (B), crispiness (C)

### 4. Conclusion

Response surface plots showed that hardness and firmness were highly influenced by BSG and screw speed, while hardness and firmness did not change significantly with the percentage of MDPM in the snack mixtures. Hardness and firmness increased with addition of BSG, but decreased with rising screw speed. On the other hand, crispiness was affected by all three independent variables. BSG had the most intensive effect on crispiness. A greater percentage of BSG in snack mixtures led to less crispy product, while increase of screw speed, when snack mixture contained 10% BSG, had a positive effect on crispiness. The presented study is encouraging for the development of healthy alternatives to the currently available commercial snack products that have poor nutritional value.

### Acknowledgements

This work was supported by Ministry of Education, Science and Technological Development of the Republic of Serbia, contract number 451-03-9/2021-14/200222 and 451-03-9/2021-14/200134.
References

[1] Navale S A, Swami S B and Thakor N J 2015 Extrusion cooking technology for foods: A review J. Ready to Eat Food 2 66–80

[2] Jumpertz R, Venti C A, Le D S, Michaels J, Parrington S, Krakoff J and Votrubá S 2013 Food label accuracy of common snack foods Obesity 21 164–9

[3] Buttriss J L and Benelam B 2010 Nutrition and health claims: the role of food composition data Eur. J. Clin. Nutr. 64 S8–13

[4] Hess J M, Jonnalagadda S S and Slavin J L 2016 What is a snack, why do we snack, and how can we choose better snacks? A review of the definitions of snacking, motivations to snack, contributions to dietary intake, and recommendations for improvement Adv. Nutr. 7 466–75

[5] Youngner N A, Blake C E, Davison K K, Blaine R E, Ganter C, Orloski A and Fisher J O 2016 “What do you think of when I say the word ‘snack’?” Towards a cohesive definition among low-income caregivers of preschool-age children Appetite 98 35–40

[6] Azzollini D, Derossi A, Fogliano V, Lakemond C M and Severini C 2018 Effects of formulation and process conditions on microstructure, texture and digestibility of extruded insect-rich snacks Innov. Food Sci. Emerg. Technol. 45 344–53

[7] Lobato L P, Aníbal D, Lazaretti M M and Grossmann M V E 2011 Extruded puffed functional ingredient with oat bran and soy flour LWT - Food Sci. Technol. 44 933–9

[8] Rhee K S, Cho S H and Pradahn A M 1999 Composition, storage stability and sensory properties of expanded extrudates from blends of corn starch and goat meat, lamb, mutton, spent fowl meat, or beef Meat Sci. 52 (2) 135–41

[9] Félix-Medina J V., Montes-Ávila J, Reyes- Moreno C, Perales- Sánchez J X K, Gómez- Favela M A, Aguilar-Palauzelos E and Gutiérrez-Dorado R 2020 Second-generation snacks with high nutritional and antioxidant value produced by an optimized extrusion process from corn/common bean flours mixtures LWT 124 109172

[10] Basilio-Atencio J, Condezo-Hoyos L and Repo- Carrasco-Valencia R 2020 Effect of extrusion cooking on the physical-chemical properties of whole kiwicha (Amaranthus caudatus L) flour variety centenario: Process optimization LWT 128 109426

[11] Ačkar Đ, Jozinović A, Babić J, Miličević B, Panak Balentić J and Šubarić D 2018 Resolving the problem of poor expansion in corn extrudates enriched with food industry by-products Innov. Food Sci. Emerg. Technol. 47 517–24

[12] Stojcenska V, Ainsworth P, Plunkett A and Ibanoğlu S 2008 The recycling of brewer’s processing by-product into ready-to-eat snacks using extrusion technology J. Cereal Sci. 47 (3) 469–79

[13] Philipp C, Buckow R, Silcock P and Oey I 2017 Instrumental and sensory properties of pea protein-fortified extruded rice snacks Food Res. Int. 102 658–65

[14] Pereira A G T, Ramos E M, Teixeira J T, Cardoso G P, Ramos A de L S and Fontes P R 2011 Effects of the addition of mechanically deboned poultry meat and collagen fibers on quality characteristics of frankfurter-type sausages Meat Sci. DOI: 10.5713/ajas.17.0471

[15] Mussatto S I, Dragone G and Roberto I C 2006 Brewers’ spent grain: Generation, characteristics and potential applications J. Cereal Sci. 43 (1) 1–14

[16] Neder-Suárez D, Quintero-Ramos A, Meléndez-Pizarro C O, de Jesús Zazueta-Morales J, Paraguay-Delgado F and Ruiz-Gutiérrez M G 2021 Evaluation of the physicochemical properties of third-generation snacks made from blue corn, black beans, and sweet chard produced by extrusion LWT 146 111414

[17] Paula A M and Conti-Silva A C 2014 Texture profile and correlation between sensory and instrumental analyses on extruded snacks J. Food Eng. 121 9–14

[18] Oliveira L C, Schmiele M and Steel C J 2017 Development of whole grain wheat flour extruded cereal and process impacts on color, expansion, and dry and bowl-life texture LWT - Food Sci. Technol. 75 261–70

[19] Philipp C, Oey I, Silcock P, Beck S M and Buckow R 2017 Impact of protein content on physical and microstructural properties of extruded rice starch-pea protein snacks J. Food Eng. 212
[20] Robin F, Théoduloz C, Gianfrancesco A, Pineau N, Schuchmann H P and Palzer S 2011 Starch transformation in bran-enriched extruded wheat flour Carbohydr. Polym. 85 65–74
[21] Ainsworth P, İbanoğlu Ş, Plunkett A, İbanoğlu E and Stojceska V 2007 Effect of brewers spent grain addition and screw speed on the selected physical and nutritional properties of an extruded snack J. Food Eng. 81 702–9