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FOOD INDUSTRY BY-PRODUCTS AS RAW MATERIALS IN THE PRODUCTION OF VALUE-ADDED CORN SNACK PRODUCTS

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Abstract: The addition of brewer's spent grain (BSG), sugar beet pulp (SBP) and apple pomace (AP), on the nutritional properties of directly expanded snack products based on corn grits was investigated. Snack products were produced in a laboratory single screw extruder with the addition of 5, 10 and 15% d. m. of these by-products in corn grits. Chemical composition, total phenolic content, antioxidant activity, dietary fiber, resistant starch, starch damage and pasting properties of the mixtures and extruded samples were determined. Extrusion process and by-product additions had a significant effect on the proximate chemical composition. All three by-products increased contents of both soluble and insoluble dietary fiber, while the extrusion caused a reduction of insoluble fiber and increase of soluble fiber. After the extrusion process starch damage and antioxidant activity increased, while resistant starch content and total polyphenol content decreased. According to obtained results, it can be concluded that the investigated by-products can be used in the production of nutritionally more valuable corn snacks.

Keywords: by-products; extrusion; corn snacks; chemical composition; nutritional value.

Introduction. The development of value-added foods in terms of maintaining and protecting health, improving consumer nutrition and promoting good health and nutrition has been prioritized by numerous researches in recent years. Since the United Nations published Sustainable Development Goals [1], which has been adopted in strategies worldwide, both science and industry have been challenged to look for solutions to utilize by-products of the food industry in such a way that they are first used as food, then as feed and finally for energy production. These by-products are of particular interest because they often contain significantly high amounts of certain compounds (bioactive components, dietary fibers, vitamins, minerals, etc.), which constitute a very valuable raw material for the production and development of new products [2]. One of the most important products are directly expanded cereal-based snacks, which are currently high in carbohydrates, salt and fat and low in overall nutritional value, popular and consumed in large quantities by all generations, from babies to the elderly.

Although numerous studies have been conducted on the use of by-products as cheap and high-value raw materials in the development of new extruded products, most of them are focused on testing the formulations but not the overall sensory and nutritional quality of the developed products [3]. In this context, in our previous studies we investigated the physical and sensory properties of extruded products with added brewer's spent grain (BSG), sugar beet pulp (SBP) and apple pomace (AP) in order to obtain products acceptable for consumption. In first study we investigated influence of by-products addition on physical and sensory properties of corn extrudates, while in the second one, a safety of these products was carried out, manifested by the formation of potentially harmful components (acrylamide and hydroxymethylfurfural). The composition of all three by-products used in this study was presented in our previous research [4] and in other reviews.

AP was used in the production of extruded snacks based on sorghum flour or rice-wheat mixture and the extrudates based on pregelatinized starch combined with cheese whey or other protein sources. BSG was used in content of 10% for the production of barley-based snacks and in the production of extruded broken rice snacks with 15% and 30% of BSG. SBP as a by-product is mainly used for animal feeding, but as a good source of pectin this by-product is recently used for the pectin extraction although pectin extracted from SBP is known to have poor gelling property [5].

The aim of this study was to investigate how the addition of the above-mentioned by-products affect the nutritional value of the developed corn snack products in terms of chemical composition, total phenolic content, antioxidant activity, dietary fiber, resistant starch and starch damage.

Materials and Methods

Preparation of Extruded Corn Snack Products

Raw materials used in this study were: corn grits, brewer's spent grain (BSG), sugar beet pulp (SBP), apple pomace (AP) and pectin (GENU® Pectin 150 USA-SAG type D slow set, CP Kelco A Huber Company, SAD). The chemical composition of raw materials and the procedure of the blend preparation for the extrusion process were described in detailed in our previous article [9]. Briefly, BSG, SBP and AP were added in corn grits in the content of 5%, 10% and 15% d. m. In the case of BSG and SBP, samples with 1% of added pectin were prepared, which resolved the problem of expansion and poor texture properties and enabled the production of sensory acceptable expanded snack products [2].

Table 1. Chemical composition of non-extruded and extruded samples.

Sample	NON-EXTRUDED				
	Dry Matter (%)	Protein (% d. m.)	Fat (% d. m.)	Ash (% d. m.)	Raw Carbohydrates (% d. m.)
Corn grits	85.25 ± 0.04 b	7.91 ± 0.05 d	1.33 ± 0.02 e	0.41 ± 0.02 a	90.35 ± 0.05 f
Corn + 5% BSG	85.11 ± 0.02 a	8.94 ± 0.06 f	1.52 ± 0.03 g	0.67 ± 0.01 e	88.87 ± 0.11 c
Corn + 10% BSG	85.78 ± 0.03 e	9.68 ± 0.07 g	1.47 ± 0.00 f	0.77 ± 0.01 f	88.08 ± 0.08 b
Corn + 15% BSG	85.39 ± 0.06 c	11.08 ± 0.14 h	1.91 ± 0.02 h	0.93 ± 0.01 h	86.08 ± 0.11 a
Corn + 5% SBP	85.19 ± 0.02 b	7.80 ± 0.10 d	1.18 ± 0.01 d	0.81 ± 0.03 g	90.21 ± 0.12 f
Corn + 10% SBP	85.05 ± 0.02 a	7.83 ± 0.14 d	1.04 ± 0.01 b, c	1.30 ± 0.02 i	89.83 ± 0.18 e
Corn + 15% SBP	85.20 ± 0.05 b	8.08 ± 0.01 e	0.99 ± 0.01 a	1.64 ± 0.01 j	89.29 ± 0.03 d
Corn + 5% AP	85.57 ± 0.03 d	7.57 ± 0.05 c	1.18 ± 0.01 d	0.46 ± 0.00 b	90.79 ± 0.07 g
Corn + 10% AP	85.35 ± 0.00 c	7.30 ± 0.09 b	1.07 ± 0.03 c	0.53 ± 0.03 c	91.10 ± 0.08 h
Corn + 15% AP	85.42 ± 0.02 c	7.07 ± 0.05 a	1.00 ± 0.01 a,b	0.62 ± 0.02 d	91.31 ± 0.03 i

The blends with 15% moisture content were extruded in a laboratory single-screw extruder (Brabender GmbH, Model 19/20DN, Duisburg, Germany) according to Ačkar et al. [3], at the temperature profile: 135/170/170 °C, using a screw with a compression ratio of 4:1, and a round die head with 4 mm nozzle diameter. The obtained snacks were air-dried overnight at ambient temperature, milled in a laboratory mill (IKA MF10, Staufen, Germany) with a 1 mm sieve and stored in sealed plastic bags at 4 °C until further analysis.

Chemical Composition

The chemical composition of non-extruded samples and obtained extrudates were determined according to standard methods for moisture content (ISO 6540), protein (ISO 5983-2), fat (ISO 6492) and ash (ISO 5984), while the contents of raw carbohydrates were calculated by difference.

Results and Discussion

3.1. Chemical Composition

Brewer's spent grain (BSG), sugar beet pulp (SBP) and apple pomace (AP) as food industry by-products used in this study for the development of new value-added corn snack products represent a great potential due to their chemical composition presented in our previous article. The influence of the addition of BSG, SBP and AP in corn grits and the effect of the extrusion process on the chemical composition is shown in Table 1.

Increasing the proportion of BSG and SBP in the mixtures, the protein content increased, and the increase was more pronounced with the addition of BSG. Thus, the protein content in the mixture with 15% BSG was 11.08% ± 0.14% d. m., and in the mixture with 15% SBP was 8.08% ± 0.01% d. m., compared to the corn grits, in which the protein content was 7.91% ± 0.05% d. m. On the other hand, the addition of AP to the mixture proportionally reduced the protein content, so the lowest protein content was recorded in the mixture containing 15% AP (7.07% ± 0.05% d. m.). The fat content decreased with the addition of AP and SBP to the mixture, while the increase in fat content was recorded in the mixtures with the addition of BSG. The lowest fat content was in the sample with 15% SBP (0.99% ± 0.01% d. m.), and the highest in the sample with 15% BSG (1.91% ± 0.02% d. m.). The ash content was increased by the addition of all by-products in proportion to the added content, with the highest value recorded for the mixture containing 15% SBP (1.64% ± 0.01% d. m.). The content of raw carbohydrates decreased with the addition of BSG and SBP to corn grits, while the opposite trend was observed in mixtures with AP, so the mixture with 15% AP had the highest content of raw carbohydrates (91.31% ± 0.03% d. m.).

From the results obtained for the extruded samples, it is visible that the extrusion process resulted in a decrease in the values of protein and fat content for all samples, while the ash content increased, but this increase was not so high. This trend of decreasing protein and fat content and not so high increase in ash content after the extrusion process is consistent with previous studies. In short, the most significant change in proteins during the extrusion process is denaturation due to the applied high temperatures, pressure and shear. Sobota et al.concluded that the extrusion process resulted in a decrease of protein content, which is in accordance with the results of our study. The lack of nitrogen content due to the extrusion process is explained by Stanley as the effect of the formation of isopeptide bonds between the ε-amine group of lysine and the amide groups of asparagines or glutamine, which is associated with ammonia release. Furthermore, the reaction of lysine with reducing sugars formed during the extrusion is also stated. As for fats, their proportion is reduced mainly by loss at the die after leaving the extruder and by the formation of fat complexes with starch and proteins . In agreement with the effect of extrusion on the reduction of protein and fat content, the content of raw carbohydrates increased in all samples after the extrusion process, so that the highest content was recorded in the extruded sample with 15% AP (91.88% ± 0.02% d. m.). The results obtained in this research are in accordance with previous studies, where it was found that the content of protein, fat and ash in extruded products increases with the addition of used by-products [6,31,32,33].

Dietary Fiber

The by-products used to fortify corn snack products in this study were selected in part because of the high fiber content found in the literature [34,35,36], and confirmed by the results shown in our previous study [9]. Namely, all by-products had significantly higher content of total, soluble and insoluble dietary fiber (TDF, SDF and IDF), compared to the corn grits. While corn grits contained 3.39% ± 0.01% d. m. of TDF, this content was >10 times higher in AP (40.47% ± 0.26% d. m.), >15 times higher in BSG (60.56% ± 0.53% d. m.) and >20 times higher in SBP (70.98% ± 0.29% d. m.) [9]. The results for dietary fiber content in non-extruded mixtures and produced snack products are shown in the Table 2. The obtained results show that by increasing the amount of added by-products in the mixtures, the content of IDF and SDF increased proportionally, with BSG having the most significant influence on the increase of IDF content (11.22% ± 0.07% d. m., for the mixture with 15% of BSG), and SBP on the SDF content (3.45% ± 0.08% d. m., for the mixture with 15% SBP). Despite the fact that the addition of AP increased the fiber content less than other by-products, the values obtained were significantly higher compared to corn grits, which is confirmed by the fact that the TDF content doubled already with the addition of 10% AP. The effect of higher fiber increment in the case of SBP and BSG is also related to the fact that in the application of these two by-products also 1% d. m. of pectin was added, which belongs to the group of SDF.

The extrusion process had the same effect on all samples, regardless of the type of by-product used. Namely, a decrease in the IDF content and an increase in the SDF content was found. Since the decrease in the IDF content was more pronounced than the increase in the SDF content in all cases, this also affected the decrease in the TDF content in all extrudates. However, it should be emphasized that even after these changes due to the extrusion process, the obtained extrudates with satisfactory expansion and sensory acceptability had a significantly higher content of dietary fiber compared to the control sample of extruded corn grits. Namely, while the extruded sample of corn grits had 2.36% ± 0.03% d. m. of TDF content, extrudates with BSG and SBP had double the amount of TDF content already at 5% added by-products (5.13% ± 0.08% d. m. and 5.56% ± 0.21% d. m., respectively), and a similar trend was observed with the addition of AP, where the sample with 5% AP had 4.57% ± 0.05% d. m. of TDF content.

Previous studies have shown that the extrusion process generally reduces the content of IDF, with the usual accompanying increase in the content of SDF, which would imply that a conversion from insoluble to soluble fibers occurs during the extrusion process [4]. Such results have been obtained by Sobota et al.

Table 2. The dietary fiber content in non-extruded and extruded samples.

Table 2. The dietary fiber content in non-extruded and extruded samples.

Sample	NON-EXTRUDED		
	IDF (% d. m.)	SDF (% d. m.)	TDF (% d. m.)
Corn grits	3.18 ± 0.03 a	0.21 ± 0.04 a	3.39 ± 0.01 a
Corn + 5% BSG	5.98 ± 0.05 d	1.29 ± 0.09 c	7.26 ± 0.04 d
Corn + 10% BSG	8.72 ± 0.07 g	1.44 ± 0.12 c	10.16 ± 0.20 g
Corn + 15% BSG	11.22 ± 0.07 i	1.64 ± 0.06 d	12.86 ± 0.01 i
Corn + 5% SBP	5.69 ± 0.17 c	1.97 ± 0.11 e	7.66 ± 0.06 e
Corn + 10% SBP	8.34 ± 0.10 f	2.51 ± 0.03 f	10.85 ± 0.13 h
Corn + 15% SBP	10.70 ± 0.10 h	3.45 ± 0.08 g	14.15 ± 0.18 j
Corn + 5% AP	4.44 ± 0.07 b	0.75 ± 0.09 b	5.19 ± 0.02 b
Corn + 10% AP	5.62 ± 0.07 c	1.29 ± 0.02 c	6.91 ± 0.08 c
Corn + 15% AP	6.89 ± 0.05 e	1.92 ± 0.02 e	8.80 ± 0.07 f

Pérez-Navarrete et al. and Jing and Chi, which particularly point out the increase in IDF content after the extrusion process. Therefore, the results of this research are in accordance with all the above studies. Furthermore, in terms of the impact of the by-products used in this study on the increase in fiber content, the obtained results are also consistent with previous studies. Namely, the addition of BSG increased the dietary fiber content in the production of wheat bread and in various extruded produts. So, Kirjoranta et al. used 10% of BSG in the production of barley based snacks and concluded that obtained extruded were “high fiber”. Similarly, the “high fiber” extrudates were developed with application of 20–40% BSG in extruded products based on rice flour and wheat semolina mixture . The use of sugar beet fiber increased the content of dietary fiber in spaghetti production and corn extrudates. The same effect has also been reported with the use of AP in cake making and in corn extrudates. Additionally, the results obtained in our research are in agreement with the results obtained in the preparation of rice-wheat based extruded samples with AP (10–30%), where it was found that the addition of AP increased the TDF content [5]. In addition, incorporation of 22% AP in snacks based on pregelatinized starch the dietary fiber content increased from 0.8 g/100 g in the control sample to 14 g/100 g in the sample containing AP [6].

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