

Effect of Brewer's Spent Grain Addition on Properties of Corn Extrudates with an Increased Dietary Fibre Content

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The effect of brewer's spent grain addition (5, 10, 15 and 20% w/w) on selected properties of extrudates produced from corn grits with various moisture contents (12.5%, 13.5%, 14.5% and 15.5%) was analysed in this study. It was shown that an addition of brewer's spent grain (BSG) to extrudates reduces expansion and increases density of the product. The changes are dependent on raw material moisture content. A higher addition of brewer's spent grain is reflected in higher values of Water Absorption Index (WAI). At a raw material moisture content exceeding 12.5% there is no correlation between the content of brewer's spent grain and WAI. Water Solubility Index (WSI) values decrease with an increasing content of brewer's spent grain in the sample, irrespective of moisture content in the extruded mixture. An addition of BSG to extrudates makes it possible to obtain a product with a high content of dietary fibre, particularly cellulose and hemicellulose fractions. Extrudates produced from a raw material with a moisture content of 12.5% received the highest scores in sensory evaluation. At such a moisture content of the raw material an acceptable product with a 15% brewer's spent grain content was obtained. Higher additions of BSG resulted in a reduced expansion, increased density and lower desirability of the product due to the specific aroma and after-taste of BSG.

INTRODUCTION

Traditionally extruded products are most frequently produced from high-starch raw materials such as maize, rice, wheat, starch or dried potatoes. However, an increasing interest in health-promoting aspects expressed by consumers results in research investigating the applicability of extrusion for the above-mentioned raw materials with additives which essentially improve the nutritive value of products, and at the same time do not deteriorate their sensory properties or even create a new product with novel properties, attractive for consumers [Gumul *et al.*, 2011; Kong *et al.*, 2008; Majcher & Jelen, 2009; Pansawat *et al.*, 2008; Rzedzicki *et al.*, 2004; Rzedzicki & Zarzycki 2007; Schieber *et al.*, 2001; Stojceska *et al.*, 2008a;b, 2009; Su, 2007; Wianecki, 2007]. For economic reasons it may be particularly interesting to apply by-products from other branches of the food industry, which are sources of components of high nutritive value. Brewer's spent grain (BSG) is an example of such a material. It contains high amounts of valuable protein and fat, minerals and fibre substances [Ainsworth *et al.*, 2007; Mussatto *et al.*, 2006; Santos *et al.*, 2003]. Nutrition studies showed that an addition of BSG exerted beneficial health-promoting effects, connected with an increase in faecal mass and shortening of the time of food passage through the alimentary tract [Fastnaught, 2001].

There are many reports on dietary fibre content changes as the effect of extrusion [Fornal *et al.*, 1993; Gumul *et al.*, 2011; Matusz-Mirlak *et al.*, 2007; Rzedzicki & Zarzycki, 2007]. These studies refer mainly to soluble and insoluble dietary fibre, with no differentiation into their individual fractions. BSG is a rich source of insoluble dietary fibre. It is known that its fractions, *i.e.* lignin, cellulose and hemicelluloses, serve different functions in the human organism. Therefore the aim of this study was to investigate the effect of BSG addition and the effect of the extrusion process on the contents of individual fractions of detergent fibre in the product with respect to its sensory properties.

MATERIAL AND METHODS

Material for experiments comprised degermed bran-free corn grits (CG) from a maize mill in Wonieść (Poland) and brewer's spent grain (BSG) from a brewery of Kompania Piwowarska in Poznań (Poland).

Before experiments, BSG was dried in an air flow drier at 60°C, and next ground in a hammer mill (Perten Laboratory Mill 3100) to particle size below 200 µm.

Mixtures of CG and BSG prepared according to Table 1 were wetted to four levels of moisture content a day before the extrusion process.

Extrudates were produced in a single-screw extruder S-45 by Metalchem Gliwice (Poland), where the L:D ratio was 12:1 and material compression rate was 3:1, applying

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TABLE 1. Samples preparation before extrusion-cooking.

| Raw materials composition (w/w %) | | Raw material moisture contents (%) | | | |
|-----------------------------------|-----|------------------------------------|------|------|------|
| Corn grits | BSG | | | | |
| 100 (control sample) | 0 | | | | |
| 95 | 5 | | | | |
| 90 | 10 | 12.5 | 13.5 | 14.5 | 15.5 |
| 85 | 15 | | | | |
| 80 | 20 | | | | |

the following temperatures for individual extruder sections: 140°C/175°C/140°C, at screw rotations of 90/min, and nozzle diameter of 1.5 mm.

Raw materials were evaluated on the basis of protein content (the Kjeldahl method in accordance with [PN-EN ISO 20483:2007]), fat content (according to Soxhlet in accordance with PN-64/A-74039), ash content [PN-ISO 2171:1994], contents of reducing sugars (colorimetrically using of 3,5-dinitrosalicylic acid) and starch content (enzymatic method AACCC 76.13). Detergent dietary fibre and its fractions in the raw material and the product were determined according to the Van Soest method [Van Soest, 1963; Van Soest & Wine 1967], modified by McQueen & Nicholson [1979]. Soluble and Insoluble Dietary Fibre fractions were determined according to Asp [Asp *et al.*, 1983]. All analyses were performed in three replications.

Evaluation of extrudates was performed on the basis of the expansion ratio (ER) (as a ratio of 10 randomly selected extrudate diameters to the diameter of the die nozzle), bulk density, Water Solubility Index (WSI) and Water Absorption Index (WAI) according to Anderson [Anderson *et al.*, 1969].

Sensory evaluation of the extrudates was conducted in a 5-point scale, in accordance with the requirements of the standard PN-ISO 4121:1998, by a panel of 20 individuals. Taste, aroma, colour, texture/porosity, crispiness and overall desirability were evaluated.

Results were statistically verified using Statistica 6.0. Medium values and standard deviations were calculated, in case of continuous variable regression curves and coefficients of determination were established.

RESULTS AND DISCUSSION

Corn grits contain up to 82% starch (Tables 2 and 3), about 9.5% protein, about 6% total dietary fibre, less than 1% fat substances and below 1% ash components. BSG was characterised by starch content of less than 5%, while it contained much more insoluble dietary fibre, protein, fat substances, and minerals.

In the process of extrusion cooking, an increase in the ratio of BSG in the mixture with CG resulted in a reduced expansion of the extruded product. A similar dependence was also reported in studies of Ainsworth *et al.* [2007]. The highest expansion ratio values were recorded for samples produced

TABLE 2. Characteristics of raw materials used in the experiment.

| Raw material | Moisture (%) | Protein (% d.m.) | Lipids (% d.m.) | Ash (% d.m.) | Reducing sugars (% d.m.) | Insoluble Dietary Fibre (%d.m.) | Soluble Dietary fibre (%d.m.) | Starch (% d.m.) |
|--------------|-----------------------|-----------------------|----------------------|----------------------|--------------------------|---------------------------------|-------------------------------|-----------------------|
| Corn grits | 11.40 ±0.20 | 9.52 ±0.10 | 0.98 ±0.05 | 0.34 ±0.01 | 0.72 ±0.02 | 4.72 ±0.08 | 1.14 ±0.04 | 81.70 ±0.83 |
| BSG | 2.79 ±0.24 | 25.49 ±0.66 | 8.53 ±0.03 | 3.76 ±0.17 | 1.70 ±0.03 | 52.46 ±0.81 | 2.51 ±0.06 | 4.56 ±0.42 |

TABLE 3. Detergent fibre and its fractions content in raw materials and extrudates produced with BSG addition (moisture of material to extrusion 12.5%).

| Sample | NDF (% d.m.) | ADF (% d.m.) | Lignin (% d.m.) | Cellulose (% d.m.) | Hemicellulose (% d.m.) |
|-------------------------|------------------------------|----------------------------|----------------------------|----------------------------|------------------------|
| Raw materials | | | | | |
| Corn grits | 3.79 ±0.11 | 2.05 ±0.01 | 0.47 ±0.04 | 1.58 ±0.10 | 1.74 |
| BSG | 51.76 ±0.07 | 22.96 ±0.80 | 5.14 ±0.25 | 17.81 ±0.94 | 28.80 |
| Extrudates | | | | | |
| Corn grits | 4.42 ±0.08 | 3.05 ±0.19 | 0.68 ±0.02 | 2.38 ±0.07 | 1.38 |
| Corn grits with 5% BSG | 6.81 ±0.02 6.19* | 3.96 ±0.11 3.10* | 1.25 ±0.07 0.71* | 2.71 ±0.14 2.39* | 2.85 3.09* |
| Corn grits with 10% BSG | 10.41 ±0.04 8.59* | 5.02 ±0.67 4.14* | 1.46 ±0.01 0.94* | 3.56 ±0.22 3.20* | 5.39 4.44* |
| Corn grits with 15% BSG | 11.20 ±0.09 10.99* | 5.80 ±0.28 5.19* | 1.64 ±0.16 1.17* | 4.16 ±0.13 4.02* | 5.40 5.80* |
| Corn grits with 20% BSG | 12.73 ±0.07 13.38* | 7.03 ±0.27 6.23* | 1.82 ±0.03 1.41* | 5.21 ±0.17 4.83* | 5.70 7.15* |

* – theoretical contents, calculated on the basis of the raw material detergent fibre composition.

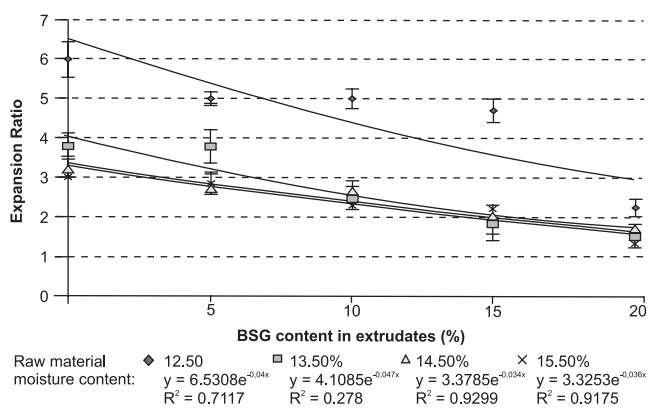


FIGURE 1. The effect of BSG addition on the Expansion Ratio of extrudates.

from the raw material with the lowest moisture content. Figure 1 presents changes in the radial expansion index of extrudates with an increasing share of BSG in the sample, depending on the moisture content of the raw material. The product with a 20% addition of BSG, irrespective of moisture content, had a very low expansion. This may be explained by a high content of dietary fibre in extruded mixtures, a reduced content of starch and an increased content of lipids. At a high temperature and pressure of the extrusion process lipids interact with the amylose fraction, forming indigestible complexes [Galloway *et al.*, 1989; Stojceska *et al.*, 2009]. Starch-lipid complexes are also responsible for an increase of starch gelatinisation temperature, but when found in excess they act as a lubricating agent, resulting in a reduced expansion ratio [Abu-Hardan *et al.*, 2011]. Thus obtained product was characterised by a specific after-taste and aroma of BSG. Increasing the ratio of BSG in extruded products to over 20% requires an addition of flavouring agents, which would eliminate the specific after-taste of brewer's spent grain [Stojceska *et al.*, 2008b], as well as modification of raw material composition to assure adequate expansion.

The extrudates with a 5% and 10% addition of BSG showed a similar density to the control product obtained from corn grits only (Figure 2). At higher addition levels, this value increased. The 20% addition of BSG caused an almost two-fold increase in extrudate density. The lowest density was found for the samples extruded at a 12.5% moisture content.

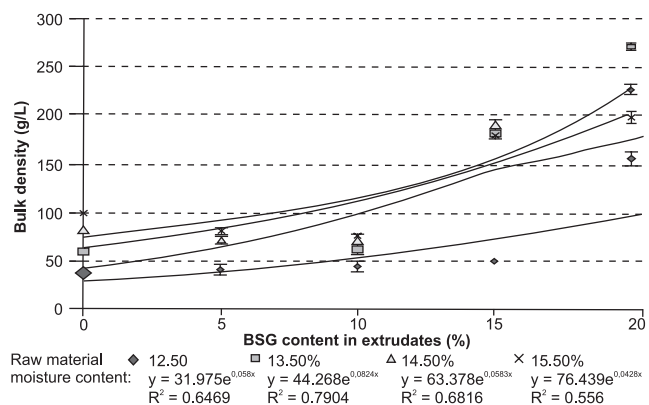


FIGURE 2. The effect of BSG addition on bulk density of extrudates.

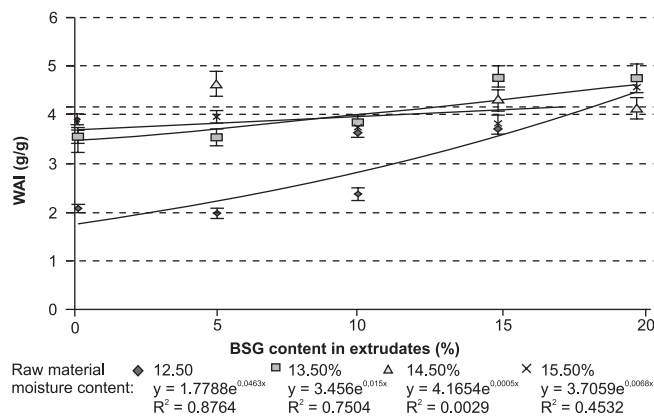


FIGURE 3. The effect of BSG addition on Water Absorption Index (WAI) values of extrudates.

Extrusion cooking results in higher Water Absorption Indexes (WAI) when compared with the raw material, but it was found that extrusion cooking of the raw material at a low moisture content yielded a product with a lower water absorption rate (Figure 3). A positive correlation between the raw material moisture content and WAI of extrudates was recorded by Stojceska *et al.* [2009] and Robin *et al.* [2011]. At the lowest moisture content of the raw material a positive correlation was shown between BSG content and water absorption of the product. In case of a higher moisture content of the raw material used in extrusion the correlation coefficients were not statistically significant ($p < 0.05$).

The comparison of the amount of water-soluble substances (expressed by means of the water solubility index WSI) illustrates the degree of degradation of high-molecular compounds under the influence of extrusion (Figure 4). This factor may be used as a degree of the raw material transformation during processing. According to Kirby *et al.* [1988], an increase in WSI was caused, to a considerable extent, by starch degradation, expressed in a reduction of molecular mass of this polymer. The intensity of mechanical shear in the processing, increasing with a decreasing moisture content of the raw material, results in a statistically significant increase of the WSI value [Colonna *et al.*, 1989]. A similar dependence was shown in studies of Robin *et al.* [2011], as well as Stojceska *et al.* [2009]. On the other hand, lower WSI values of the extrudates, corresponding to an increasing ad-

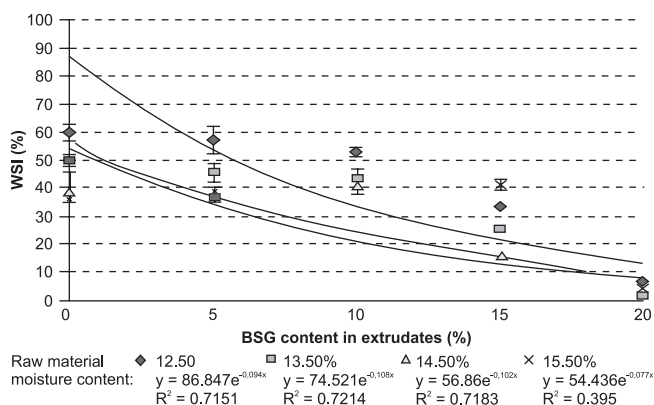


FIGURE 4. The effect of BSG addition on Water Solubility Index (WSI) of extrudates.

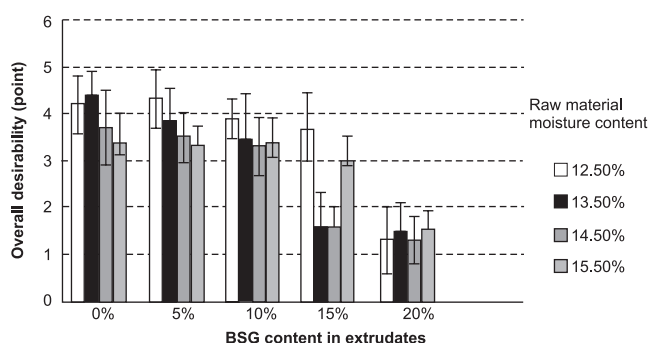


FIGURE 5. Overall desirability of extrudates on the basis of sensory evaluation of products.

dition of brewer's spent grain, indicate that this component significantly reduces the intensity of mechanical processing of the material in the extruder (Figure 4). Relatively low contents of high-molecular biopolymers such as starch, high contents of insoluble fibre, as well as high contents of fat in BSG may lower the pressure and mechanical stress intensity during extrusion. It should be noticed that extruded products are highly processed foodstuffs with high WSI values as a result of the specific character of the process, *i.e.* intensive mechanical shear, high pressure and temperature of the process. From the nutritional point of view, high WSI values are not always desirable, since they indicate a rapid digestion process and next intestinal absorption [Singh, 2010; Altan, 2009]. This may lead to a rapid increase in postprandial blood glucose concentration. Therefore an addition of brewer's spent grain has an advantageous effect on a reduction of this index.

Unfortunately, an increase of BSG content in the extrudate to over 15% deteriorates its sensory attractiveness (Figure 5). Desirability of the product was also dependent on extrusion conditions. The highest scores were given to the products made of the raw material with a moisture content of 12.5%. At such a moisture content high quality was found for extrudates with BSG contents up to 15%. Among extrudates produced from the raw material with a 14.5% moisture content good sensory evaluation scores were given to the samples with BSG contents of 5% and 10%, while at a 15.5% moisture content all of the products with BSG addition received a positive score.

An addition of BSG to corn grits significantly increased contents of all dietary fibre fractions in the extrudates (Table 2). Addition of 10% brewer's spent grain, acceptable from the sensory point of view (extrusion at a 12.5% moisture content), increased almost three times the contents of all fractions of dietary fibre. The highest proportions were recorded for fractions of hemicelluloses and cellulose. In this study a higher content of all forms of dietary fibre after extrusion (samples with a 0–15% BSG addition) was found in comparison to their theoretical contents, calculated on the basis of the raw material composition. Higher contents of total dietary fibre after extrusion were recorded also in other studies [Matuszak-Mirlak *et al.*, 2007; Stojceska *et al.*, 2009; Vasanthan *et al.*, 2002]. This is probably caused by the formation of resistant starch during extrusion and interactions of partly degraded substances, leading to the formation of new complexes resistant to digestion.

As a result, a 10% or even 15% addition of BSG may be applied to obtain a good quality extruded snack rich in dietary fibre. The application of higher BSG additions is possible, but requires other ingredients to be introduced to the formulation that would enhance expansion and mask the specific aroma and taste of BSG.

CONCLUSION

BSG is characterised by high contents of the dietary fibre fraction. Therefore it may be a valuable source of these nutrients in food. An addition of BSG up to 10% does not significantly change sensory attributes of the product, while it increases the amount of various forms of dietary fibre by almost 3 times. Sensory and physicochemical properties of the extrudates produced with an addition of BSG depend both on the amount of added BSG and moisture content of the raw material used in extrusion. The most advantageous attributes of the product were obtained at a relatively low (12.5–13.5%) moisture content of the processed material.

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