Brewers’ spent grain – A new potential ingredient for functional foods

Anca Fărcaș, Maria Tofană, Sonia Socaci*, Elena Mudura, Stăncuța Scrob, Liana Salanță, Vlad Mureșan

Faculty of Food Science and Technology, University of Agricultural Sciences and Veterinary Medicine, 3-5 Mănăștur Street, 400372, Cluj–Napoca, Romania

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Abstract

In the recent times, by-products of plant processing have attracted much attention for their functionality and potential as food ingredients. Brewers’ spent grain is the insoluble residue left over from the production of wort in the brewing industry and represents a valuable source of bioactive ingredients. Typically brewers’ spent grain compositions vary, but always include high levels of dietary fibers, protein and particularly essential amino acids, as well as appreciable levels of minerals, polyphenols, vitamins, and lipids.

The current study aims to expose additional nutritional and economic benefits of brewers’ spent grain as a functional baking ingredient.

Keywords: brewing, natural waste, brewers’ spent grain, human nutrition, bread, functional properties.

1. Introduction

Brewers’ spent grain (BSG), the main low-value solid waste, is the major by-product of the brewing industry. Approximately, 3.4 million metric tons of spent grains from the brewing industry are produced in the European Union every year [7].

This material is basically composed of the malted barley residual compounds and includes:

- the barley grain husk in the greatest proportion,
- minor fractions of pericarp and fragments of endosperm,
- other residual compounds not converted to fermentable sugars by the mashing process [27].

BSG is produced in the largest quantity, corresponding to around 85% of the total generated waste and it is estimated that about 200 tons of wet spent grain with 70 to 80% water content are produced per 10,000 hl of produced beer [16].

The BSG is generally incorporated into animal feeds currently making them a low-value product, maximally marketed between 1 and 6 €/t, or alternatively BSG is composted, incinerated, dumped or anaerobically fermented [9].

In the brewery, malted barley is milled, mixed with water in the mash tun, and the temperature of mash slowly increased from 37 to 78 °C to promote the enzymatic hydrolysis of malt constituents. This enzymatic conversion stage (mashing) produces a sweet liquid known as wort. The insoluble, undegraded part of the malted barley, is allowed to settle to form a bed in the mash tun and the sweet wort filtered through it [17]. After the saccharification process is finished, the clear sweet wort is separated from the solid components - the
spent grain. The wort is then transferred to the wort kettle, while the spent grain is removed from the lauter tun.

Due to its high moisture and fermentable sugars contents, BSG is a very unstable material and is liable to deteriorate rapidly due to microbial activity. Three methods of preserving the spent grain: freeze-drying, oven drying and freezing were evaluated by Bartolome et al. (2002) [5]. Preservation by oven drying or freeze-drying reduces the volume of the product and does not alter its composition while freezing is inappropriate because large volumes must be stored and alterations in the arabinose content may occur. Heating will also kill bacteria or pathogens that maybe found naturally on the grain or picked up during lautering in the mash tun.

Figure 1 shows a simplified schematic representation of the obtaining process of brewers’ spent grain.

Figure 1. Schematic representation of the process to obtain BSG from malt

2. Materials and methods

Recent studies revealed that BSG by-product contains (on a w/w) 22.13 % protein (including exceptionally high levels of essential amino acids), 1.13 % minerals, 131.0 mg/L polyphenols, 28.22 % total fiber and 3.6 % essential fatty acids [26].

Due to its composition, when incorporated into human diets, the BSG may provide a number of benefits such as lowering the risk of certain diseases including cancer, gastrointestinal disorders, diabetics, and coronary heart disease [3,15].

The essential amino acids are representing approximately 30 % of the total protein content. In particular, lysine, which is known to be the limiting amino acid in cereal foods for human nutrition [28], accounts for 14.3 % of the total BSG protein content making it an ideal candidate for bread fortification. Protein bound amino acids also include leucine, valine, alanine, serine, glycine, glutamic acid and aspartic acid in the largest amounts, and tyrosine, proline, threonine, cystine, histidine, isoleucine, methionine, phenylalanine in smaller amounts [14].

Cellulose and hemicellulose together comprise almost 50% (w/w) of the BSG composition, revealing the presence of a large amount of sugars in this material, with xylose, glucose and arabinose being the most abundant [20]. Dietary fibers have been shown to have beneficial effects in the prevention of several diseases, such as cardiovascular diseases, constipation, irritable colon, colon cancer, obesity, and diabetes [24].

Barley is reported to be an excellent source of phenolic compounds including phenolic acids (benzoic and cinnamic acid derivatives), flavonoids, tannins, proanthocyanidins and amino phenolic compounds, which are widely recognized as having important antioxidant and radical scavenging properties [12]. Since most of the phenolic compounds of the barley are contained in the husk, BSG is a potentially valuable source of natural antioxidant compounds.

In 2012, McCarthy [19] has conducted a research on brewers’ spent grains content in phenolic compounds, and finally concluded that it is a suitable target for development as a health promoting food supplement. Specifically, they reported BSG to have DNA-protective effects by acting as powerful antioxidants. BSG contains a relatively high amount of polyphenols (212.85 mg GAE/kg), considering the fact that the sample has a moisture content of 70% [8].

Vitamins such as: biotin, choline, folic acid, niacin, pantethenic acid, riboflavin, thiamine and pyridoxine, are also present in this by-product. Spent grains also contain considerable amounts of minerals present in ashes, such as: calcium, cobalt, copper, iron, magnesium, manganese, phosphorus, potassium, selenium, sodium and sulphur [20].

Lipids found in BSG include triacylglycerols, diacylglycerols, fatty acids (palmitic, oleic and linoleic acids), sterols, sterol esters and sterol
glycosides, plus various hydrocarbons (including alkanes and carotenoids) [6].

One of the advantages of using BSG in human diets is that the brewing process uses ingredients approved for human consumption; hence it has the potential for developing new products that can meet full health regulatory approval [18].

The list of potential food applications for BSG is extensive. Trials have demonstrated its incorporation into breads, biscuits, pasta, waffles, pancakes, breakfast cereals and tortillas, amongst many others. However, BSG is too granular for direct addition in food and must first be converted to flour.

Table 1. Properties of BSG flour in foods (data from Huige et al., 1994) [13]

<table>
<thead>
<tr>
<th>Property</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>9%</td>
</tr>
<tr>
<td>Ash</td>
<td>1%</td>
</tr>
<tr>
<td>Protein</td>
<td>6.5%</td>
</tr>
<tr>
<td>Fat</td>
<td>5%</td>
</tr>
<tr>
<td>Fiber</td>
<td>12%</td>
</tr>
<tr>
<td>Starch</td>
<td>70%</td>
</tr>
<tr>
<td>Sugars</td>
<td>3%</td>
</tr>
<tr>
<td>Caloric energy</td>
<td>400 kcal</td>
</tr>
</tbody>
</table>

2.Materials and methods

All the materials (brewer’s spent grain and wheat flour) were supplied by the Microbrewery of the Faculty of Food Science and Technology of UASVM Cluj-Napoca. The BSG used in this work was obtained as a by-products from a mashing process of dark lager beer with 100 % all grain malted barley (Weyermann Specialty Malting Company, Bamberg – Germany) Caramunich and Carafa malts were added in small amount (5-10 %) to obtain dark colour and to enhance flavor characteristics.

Fresh brewers’ spent grain samples were preserved by oven-drying at 78°C for 12 hours. Then, the samples were kilned to 6% moisture content, were grounded into grist using a laboratory milling machine, packed in sealed polyethylene bags and stored at room temperature until used.

The nutritive value of BSG was investigated using near infrared reflectance (NIRS) spectroscopy technology. NIRS is a non-destructive and rapid technique applied increasingly for food quality evaluation in recent years and which has an important role in reducing the costs and saving considerable time by testing all the parameters simultaneously [23]. It is an instrumental technique based on measuring the intensity of reflectance or intensity of transmission of radiation from the near infrared region of the electromagnetic spectrum (800-2500 nm) by the test sample [21,22].

The samples spectra were collected in the NIR regions in reflectance (1100-2500 nm) at 2 nm intervals using a NIR FOSS 5000 system (Denmark). The BSG parameters investigated by analysis of sample spectra were moisture, ash, protein, fat, fiber, starch, sugars and caloric energy.

3.Result and discussions

As BSG is a material rich in dietary fibers and proteins, similar results are expected following its incorporation into bakery products. Ainsworth et al., 2007 reported that the addition of BSG in extruded snacks increased the fiber content of the snacks from 4.8% in the control sample (0% BSG) to 19.8% in samples containing 30% BSG. Also, the addition of 10% spent grain in bread increased the protein by 50 % and essential amino acid content by 10% and doubled the fibers content compared with traditional breads without BSG. In addition, the breads had about 7% less calories than traditional breads [11].

Table 2 presents the chemical composition of dry brewers’ spent grains taken into study compared to that of wheat flour. BSG predominantly consists of the husk-pericarp-seed coat layers that are rich in cellulose, non-cellulosic polysaccharides, lignin, protein and fat [19]. As table 2 shows, proteins, fat and fiber are highly concentrated in the spent grain because most of the barley starch is transform into fermentable sugars during mashing. Additionally, BGS has a higher level of mineral than wheat flour and also a considerable lower caloric content.

The nondigestible oligo- and polysaccharides, known as dietary fiber, are prebiotics because these compounds are resistant to both digestion and absorption in the human small intestine and may suffer partial fermentation in the large intestine. The prebiotics also beneficially affects the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon and thus improving host health [1,2,10]. Thus, the intake of food products rich in dietary fiber has a beneficial effect on gastrointestinal tract, lowers the LDL - cholesterol, attenuates glycemic and insulin response
and reduces the risk of several diseases: coronary heart disease, stroke, hypertension, diabetes, obesity. The recommended intake of dietary fiber is around 28-36 g/day, depending on gender, age and energy intake [4,25]. The high content in fiber of the analyzed BSG flour will determine enrichment in the amount of dietary fiber of bakery products with added BSG flour.

| Table 2. Comparative chemical composition of wheat flour and brewers’ spent grain (% dw) |
|---------------------------------|---------------------------------|
| Wheat flour                     | Brewers’ spent grain            |
| Moisture, %                     | 12.1                            | 5.7                            |
| Protein, %                      | 13.3                            | 18                             |
| Fiber, %                        | 0.6                             | 41.28                          |
| Starch, %                       | 81.06                           | 10.1                           |
| Sugar, %                        | 0.22                            | 16.11                          |
| Fat, %                          | 0.59                            | 6.61                           |
| Ash, %                          | 1.7                             | 3.82                           |
| Energy, cal/100g                | 335.43                          | 228.6                          |

4. Conclusion

Scientific research has revealed that BSG has highly desirable nutritional characteristics from a human dietary standpoint. Typical BSG compositions vary but always include high levels of dietary fiber and protein as well as appreciable levels of minerals, polyphenols, vitamins and lipids. These quality characteristics, in addition to its low cost and high levels of availability, make BSG appropriate as a functional food ingredient.

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Compliance with Ethics Requirements: Authors declare that they respect the journal’s ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human and/or animal subjects (if exists) respect the specific regulations and standards.

References