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The recycling of brewer's processing by-product into ready-to-eat snacks using extrusion technology

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Abstract

Brewer's spent grain (BSG) is the main by-product of the brewing industry. The incorporation of BSG into ready-to-eat expanded products and its effects on the textural and functional properties of extrudates have been studied. Dried and milled BSG at levels of 10–30% was added to the formulation mix made of wheat flour, corn starch and other ingredients. The results obtained from the analysis of the extrudates are discussed in terms of the interaction between the ingredients and effects of processing conditions. The samples were processed in a twin-screw extruder with a combination of parameters including constant feeding rate of 25 kg/h, process temperatures 80–120 °C and screw speeds of 150–350 rpm. Pressure, torque and material temperature during extrusion were recorded. The extrudate properties of nutritional and textural characteristics were measured. Image technique investigations provided useful information on internal structure of the extruded products, total cell area, and their contribution to the appearance and texture. It was found that addition of BSG significantly increased protein content, phytic acid and bulk density, decreased sectional expansion index, individual area and total area of the cells. The higher level of BSG resulted in cells with thicker walls with a rougher surface.

Keywords: Snacks; Brewer's spent grain; Extrusion; Expansion

1. Introduction

The food processing industry produces large quantities of waste products. Many of these by-products are usable as raw materials for other purposes. Brewer's spent grain (BSG), the residue left after separation of the wort during the brewing process (Santos et al., 2003) is considered as a lignocellulosic material rich in around 20% protein and 70% fibre and contains about 17% cellulose, 28% non-cellulosic polysaccharides, chiefly arabinoxylans and 28% lignin (Mussatto et al., 2006). Around 3.4 million tonnes of spent grain from the brewing industry are produced in the EU every year (Eurostat data). These plant-derived waste co-products are known to contain significant amounts of valuable components, which remain unexploited waste in the current processes. Because of its high moisture and fermentable sugar content, BSG becomes an environmental problem after a short time (7–10 days) (El-Shafey et al., 2004). It contains a high level of dietary fibre and has a strong potential for being recycled and upgraded for use within the food chain, in products such as high value food additives, composts and animal feeds.

The incorporation of BSG into food products as a source of dietary fibre has been addressed in the literature (Öztürk et al., 2002; Prentice and D'Appolonia, 1977) and it has been suggested to have a role in the prevention of certain diseases (Aman et al., 1994; Hassona, 1993; Zhang et al., 1991). This is reflected by numerous publications such as its incorporation into flour mixed breads (Finley and Hanamoto, 1980; Kawka et al., 1999; Prentice and D'Appolonia, 1977), cookies (Kissell and Prentice, 1979; Öztürk et al., 2002; Prentice et al., 1978), animal and fish feed (Batajoo and Shaver, 1994; Dung et al., 2002).

There is a growing interest to increase the dietary fibre content of extruded products by supplementing with wheat bran, corn bran, oat bran, wheat fibre, sugar beet fibre and beta-glucans (Gaosong and Vasanthan, 2000; Lue et al.,

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1991; Martianez-Tomea et al., 2004; Mendonca et al., 2000; Yanniotis et al., 2007). These types of products are potentially healthier due to the increased fibre, and can be used as a prophylactic product. In extrusion cooking, a high-fibre cereal product under mild conditions affects digestibility of starch, dietary fibre components and phytate in the stomach and small intestine of man (Sandberg et al., 1986). Thus, BSG could be a cheap source of protein and fibre that may provide a number of benefits when incorporated in human diets (Mussatto et al., 2006). Innovative ways are being developed to bring dietary fibre into new appealing high-fibre products that contribute to the recommended dietary fibre intake (National Academy of Science, 2002). The development of new techniques to use this agro-industrial by-product is of a great interest due to the large volumes of spent grain produced. However, reference searches indicate that no research on the incorporation of BSG into extruded products has been published.

The primary objective of this study was to exploit the use of food processing waste i.e. BSG and incorporate it into a ready-to-eat extruded snack. The second objective was to investigate the effects of BSG, corn starch and screw speed on selected physical and nutritional properties of the snacks. Product quality can vary depending on the extruder type, screw configuration, feed moisture, and temperature profile in the barrel, screw speed and feed rate.

2. Materials and methods

The ingredients used for the ready-to-eat snack preparation were wheat flour with composition (w/w) of 12.6% protein, 1.3% fat, 0.9% sugar, 77.3% starch and 0.9% fibre (Smiths Flours Mills, Worksop, UK); corn starch (w/w) with moisture content of 12% and composition of 80% amylopectin, 20% amylase and 88% carbohydrates (Cerestar, A Cargill Company, Manchester, UK); yogurt powder (db) with 5.5% moisture content, 4.8% protein, 1.0% fat and 88% carbohydrates (Fisue Food Ingredients, Milton Keynes, UK); onion powder (db) with 6% moisture content, 1.2% protein, 0.2% fat and 92.6% carbohydrates (Fisue Food Ingredients, Milton Keynes, UK), tomato powder (w/w) with the composition of 14.1% protein, 55.7% carbohydrates, 3% fat and 12.3% fibre (Fisue Food Ingredients, Milton Keynes, UK), yeast (Fermipan, Gist-Bracades, Holland), dill and mint (Chat Moss Herbs, Manchester, UK); paprika and salt (purchased from a local supermarket in Manchester).

A commercial sample of BSG with composition of 75% moisture, 1% ash, 4.8% protein, 16% fibre, 2.1% fat and 1.1% carbohydrates content was supplied by the Joseph Holts Brewery (Manchester, UK).

2.1. Preparation of dry BSG

The source of BSG was based on brewing of barley and hops and is the remains after extraction of the wort, before fermentation. The BSG was refrigerated immediately after collection and then dried the following day at 150 °C for 4 h in the Teknitronic reel oven (Teknigas Ltd., Sussex, England) to a moisture content of 5–7%. The dried sample was finely milled using 1, 0.5 and 0.25 mesh screens, packed and then sealed in polyethylene bags and kept at room temperature until use. The composition of dried BSG was 20.30% protein, 53.39% fibre, 8.32% fat and 10.76% carbohydrates content.

2.2. Preparation of sample

Ingredient formulations for extrusion products are given in Table 1. Dry weight of BSG at levels of 10%, 20% and 30%, were added to each mix on a sample weight basis. All the ingredients were weighed and then mixed in a Hobart NCM mixer (Process Plant and Machinery Ltd., UK) for 20 min. Forty-six samples in total were prepared. After mixing, the samples were stored in polyethylene bags at room temperature for 24 h before extruding.

The moisture content of all the samples was estimated using the oven method (AOAC method, 1984) and later adjusted by pumping water into the extruder.

2.3. Extrusion experiments

Extrusion trials were performed using a Werner and Pfleiderer Continua 37 co-rotating twin-screw extruder (Stuttgart, Germany). The barrel diameter and L/D ratio were 37 mm and 27:1, respectively. A screw configuration that was a standard design for processing cereals and flour-based products was used. This screw profile was made up of conveying self-wiping elements except for a section consisting of short reverse and forwarding elements to improve mixing and apply shear to the material being extruded while restricting flow and building up pressure. The exit diameter of the circular die was 4 mm. The temperature of the extruder barrel and the moisture of the feed material were kept constant at 120 and 80 °C and 14% db, respectively. A twin-screw volumetric feeder (Rospen, Gloucestershire, UK) was used for feeding the dry mixture to the extruder and a Watson–Marlow 505 DI pump (Cornwall, UK) which was used to control the solid feed and water inputs respectively.

Table 1
Formulations for extrudate development

Formulations	Wheat flour (g/100 g)	Starch (g/100 g)	Other ingredients[a] (g/100 g)	BSG (%)
1	88	0	12	0–30
2	62	26	12	0–30
3	44	44	12	0–30
4	26	62	12	0–30
5	0	88	12	0–30

[a]Yogurt, onion powder, tomato powder, yeast, paprika, dill, mint and salt.