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Effect of wheat bran addition on *in vitro* starch digestibility, physico-mechanical and sensory properties of biscuits

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A B S T R A C T

Biscuits contain high amount of fat and sugar thus having high calorie but low nutrient density. Wheat bran is a good source of dietary fibre (DF) and protein and is thus a good candidate for nutritional enrichment of cereal foods. The aim of this study was to understand the effect of bran incorporation and particle size reduction on biscuit microstructure, texture and *in vitro* starch digestibility. Five different biscuits containing 5–15% DF were produced. Two different particle sized wheat brans were used: coarse (450 μm) and fine (68 μm). Bran particle size reduction increased the elastic modulus and hardness of biscuits. Biscuits containing fine bran had visually more compact structure without any surface or internal defects than those with coarse bran. Fine bran containing sample had the highest hardness value. Sensory evaluation showed that roughness and breakdown of biscuits in the mouth was significant for the coarse bran with highest level of bran addition. The instrumental elastic modulus, stress and hardness were closely related to sensory hardness and strength to break. Increasing DF content from 5 to 15% increased hydrolysis index by 16%, from 32 to 37.

1. Introduction

Biscuits are one of the popular cereal food categories, consumed as breakfast items and as snacks. The major constituents are typically wheat flour, sucrose and fat, making biscuits a rather energy dense cereal food. Use of refined ingredients makes biscuits lack those components of grain that are supposed to be protective of health: DF and phytochemicals (Fardet, 2010). On the other hand, biscuits are known to have low GI and high amount of slowly digestible starch *in vitro*, characteristics that are related to incompletely gelatinized starch and also the high amount fat in the formulation (Garsetti et al., 2005). The production steps during biscuit manufacturing hinder starch gelatinization and the majority of starch remains in intact form which results in low GI (Garsetti et al., 2005). In contrast, Englyst et al. (2003) found that some biscuits had negligible quantities of slowly available glucose and in turn high GI due to differences in processing technologies.

In biscuit structure, gas cells of various size and shape are embedded in a matrix of starch, fat and sugar (Baltsavias et al., 1999a). The proportion of fat to sugar and the particle size of the materials influence the mechanical properties of short dough biscuits (Luyten and van Vliet, 1990). Sugar addition results in highly cohesive structure and crisp texture whereas fat addition gives a friable texture easy to break, as well as structural integrity, lubrication, and increased air incorporation in biscuit dough making (Maache-Rezzoug et al., 1998; Rodríguez-García et al., 2013). Short dough biscuits such as digestives are particularly ductile when strain sets up unevenly within the biscuit structure (Saleem et al., 2005). Regardless of the amounts of fat and sugar, the rate of starch gelatinization in biscuits is small due to the low water content and the low baking temperature (Baltsavias et al., 1999b). The physical state of starch has a major effect on its digestibility, as mentioned above starch gelatinization is restricted in biscuits because of high levels of fat and low water amount; the presence of ungelatinized starch results in softer texture (Manley, 2000). However, biscuit recipes with high water and low sugar levels exhibit starch gelatinization to a larger extent (Delcour and Hoseney, 2010). The rate of starch gelatinization impacts the magnitude and duration of glycaemic response. There are also other food factors which influence starch degradation in the gastrointestinal tract, such as food structure, and type and amount of DF (Englyst et al., 2003). There has been various attempts to

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predict the glycaemic response of foods by evaluating the rate and extent of starch digestibility *in vitro* (Brennan et al., 1996; Garsetti et al., 2005; Dona et al., 2010).

In order to improve the nutritional quality of biscuits, various DF ingredients have been studied, such as inulin, β-glucan, potato fibre, mango peel, wheat bran (Brennan and Samyue, 2004; Ajila et al., 2008; Marangoni and Poli, 2008). Soluble DF reduced starch digestibility by changing the microstructure of food or by limiting water availability as a consequence of soluble non-starch polysaccharide hydration which will restrict starch gelatinization. Malting of cassava flour with legumes decreased *in vitro* starch digestibility of cassava flour biscuits enriched with wheat and rice bran (Jisha et al., 2010).

It is a food engineering challenge to increase the DF content of biscuits without affecting structural and sensory characteristics, such as texture, colour and taste. There is limited research available in the literature focussing on DF addition and its effect on biscuit quality, characteristics, texture, and *in vitro* starch digestibility. Thus, the aim of this study was to understand the effect of wheat bran incorporation and particle size reduction on microstructure, texture and *in vitro* starch digestibility of digestive type wheat biscuits.

2. Materials and methods

Short-type biscuits represent the most enjoyed type of biscuit by consumer worldwide. The process commonly used to form this type of biscuit is rotary moulding baked in conventional ovens. Of this category, a digestive-type biscuit was chosen, which includes a relatively high proportion of wholemeal flour in the recipe. This was chosen, partly because of its popularity in the U.K. market, and now more widespread availability in Europe and Worldwide. Digestive biscuits could be described as flat round golden brown coloured biscuits with a distinct flavour/aroma of baked wheat, sweet and slightly salty, crisp initial bite and crumbles quickly to form a slow paste texture.

2.1. Raw materials

Wheat flour (Heygates Flour Mills, Northampton, UK), wholemeal, coarse and fine bran (ADM, Brentwood, UK), palm oil (Britannia Food Ingredients, East Yorkshire, UK), sugar (British Sugars, Suffolk, UK), glucose syrup (Ragus, Slough, UK), malic acid, salt, soda and ammonium bicarbonate were used as raw materials (Glacia Chemicals, UK). Particle size analysis of coarse and fine bran was made by Malvern Mastersizer 3000-model (Malvern Instruments, Worcestershire, UK) and the mean particle size was 450 μm and 68 μm for coarse and fine bran, respectively. Coarse bran contained 47 ± 0.2% total dietary fibre, 13.2 ± 0.8% starch, 18 ± 0.1% protein, 3.39 ± 0.0% fat, 5 ± 0.03% ash whereas fine bran contained 45 ± 0.3% fibre, 22.3 ± 0.2% starch, 16.2 ± 0.0% protein, 3.4 ± 0.0% fat, 4.2 ± 0.04% ash.

2.2. Chemical analysis

Analyses of the chemical composition of raw materials were made as follows: total protein content by AACC method no. 46–11A (AACC, 2003), fat by AOAC method no. 922.06 (AOAC, 2000), total starch by AACC method no. 76.13 (AACC, 1999), total dietary fibre by AOAC method no. 985.29 (AOAC, 1990), ash gravimetrically by burning at 550 °C in a muffle furnace, and moisture content by drying the samples in an oven at 105 °C for 3 h. Total protein, fat and ash contents were analysed in triplicate while total starch and fibre analyses were done in quadruplicate.

2.3. Preparation of biscuits

Biscuit samples were prepared by supplementation of the ingredient mix with coarse (**CB5**, 5% bran (1:11.9, bran:flour), **CB15**, 15% bran(3:11.9, bran:flour), **CB30**, 30% bran (6:6.9, bran:flour)) and fine bran (**FB15**, 15% bran (3:11.9, bran:flour)**)** including a standard biscuit recipe without bran addition (**control**). In all recipes, the sum of flour and bran kept constant at 60.2%, the amount of other ingredients were as follows; palm oil (17.3%), sugar (11.7%), glucose syrup (1.6%); malic acid (1.1%); salt (0.3%); soda (1%); ammonium bicarbonate (0.1%). Water levels were determined according to the dough consistency measurements done at United Biscuits. The amount of water added was 6.5% for control, 7.4% for (CB5, CB15 and FB15) and 9.4% for CB30. Biscuits were manufactured according to recipes using the processing equipment at United Biscuits pilot plant. Doughs were mixed with a Duramol blade vertical mixer with 30 lt capacity. The mixing process was a typical 2 stage process: Stage 1 was a "cream-up" phase where sugar, fat and water were mixed together at 55 rpm for 90 s followed by stage 2 called "dough-up phase" where all the other ingredients were added with biscuit flour and wholemeal flour to form dough at 55 rpm for 120 s at room temperature (24–26 °C).

After mixing, the dough was then rested for 20 min in sealed plastic tubs. Dough pieces were rotary moulded in circular moulds with 72 mm × 72 mm axes dimensions (length and width), 3.5 mm depth and 18 docking pins. The moulded dough pieces were placed on a wire mesh oven band. Dough piece weight was 168 ± 0.2, 171 ± 0.2, 168 ± 0.5, 166 ± 0.0, and 164 ± 0.0 for Control, FB15, CB5, CB15 and CB30 samples, respectively. Baking was carried out after 20 min resting time using a pilot-scale direct gas fired forced convection oven (Spooner & Vicars Bakery Systems, Merseyside, UK) with three zones (250–290–285 °C). Baking time was 330 s.

2.4. Pasting properties

The effects of bran supplementation and particle size reduction on the pasting properties (gelatinization, pasting, and setback properties) of the biscuit flour mix were assessed using a Rapid ViscoAnalyzer (RVA) (RVA-Super4, Newport Scientific, Australia). Flour-bran blends (3.5 g, 14% moisture basis) were transferred into aluminium cups and 25 ± 0.1 ml of distilled water was added. The suspension was heated to 50 °C, stirred at 160 rpm for 10 s, then held at 50 °C for up to 1 min, and heated to 95 °C in 3 min 42 s. The temperature was held at 95 °C for 2 min 30 s, and finally the gelled sample was cooled to 50 °C in 3 min 48 s, and held at 50 °C for 2 min. The peak viscosity (maximum viscosity during heating and holding at 95 °C), final viscosity (viscosity at the end of the testing profile), setback (the drop in apparent viscosity from peak viscosity) and breakdown (hot paste) viscosity were determined from the pasting curve using Thermocline v. 2.2 software.

2.5. Analysis of water extractable arabinoxylans (WEAX)

Water extractable arabinoxylans were determined for FB15, CB15 and CB30 samples by adding only 0.525 g coarse and fine bran in 25 ml water for FB15 and CB15 samples and 1.05 g coarse bran for CB30 sample. The bran ratios and extraction protocol were selected to mimic the RVA conditions which were described above. The aim of this analysis was to understand the role and contribution of WEAX from coarse and fine bran samples on RVA pasting profiles. The contents of WEAX in the water extracts were determined by a colourimetric phloroglucinol method (Douglas, 1981) using xylose as a standard. Free pentose sugars were corrected by a factor of 0.88 to anhydro sugars. Detailed description of the adapted protocol can be found in Santala et al. (2013).