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Impact of dietetic tea biscuit formulation on starch digestibility and selected nutritional and sensory characteristics

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A B S T R A C T

In this research, the effects of replacement of 30% of wheat flour in a control biscuit formulation with different whole grain flours (barley, buckwheat, oat, amaranth or soy) or 15% of wheat flour with apple- or oat dietary fibre (DF) were investigated in terms of their impact on the nutritional quality, rates of starch digestibility and sensory characteristics of the final product. Modifications of control formulation resulted in improved macronutrient distribution ranges and increase of dietary fibre (DF) and protein content. Soy- and amaranth enriched samples contained significantly lower rapidly available glucose (RAG) and total starch (TS) content in comparison to control sample. The analysis of starch digestibility showed that the most significant increase of RAG content in the starch fraction was observed in oat- and apple dietary fibre enriched samples defining them as samples with the highest expected glycaemic index (GI). All modifications of control sample resulted in formulations with acceptable sensory characteristics; addition of pure fibre can be considered as significantly less favourable in comparison to whole grain flours especially regarding the taste and texture of the final product.

1. Introduction

Biscuits are favourite food widely consumed mostly due to their pleasant taste, ready to eat nature, accessible cost and availability and longer shelf time (Sudha, Vetrimani, & Leelavathi, 2007) and they can contribute significantly to daily cereal intake. However, in the era of increasing popularity of functional foods and nutraceuticals, new demands have been set for different categories of snack foods including biscuits – maintaining traditional nutritional aspects of foods and exhibiting additional health benefits (Aparicio-Sangulian et al., 2007).

Well established health protecting effects that arise from the long term regular consumption of cereals and grains are mainly associated to the presence of different categories of dietary fibre (DF) (β-glucan, arabinoxylan and complex oligosaccharides) and associated phytochemicals (polyphenols and vitamins) exhibiting a wide range of physiological effects and resulting in disease prevention (Slavin, Jacobs, Marquart, & Wiemer, 2001). Since the majority of mentioned physiologically active compounds are situated in the outer layer of the cereal grain, consumption and development of sensory acceptable whole grain based cereal products with high contents of DF is highly desirable and encouraged. Certain types of dietary fibre (prebiotics) are readily digested by the large bowel microflora to produce short chain fatty acids (SCFA) such as acetate, propionate and butyrate (Wong, de Souza, Kendall, Emam, & Jenkins, 2006). Increased production of SCFA has been linked with improved mechanisms of controlling the initiation of colonic cancer (Leu, Hu, Brown, & Young, 2009) and improvement of colonic resistance to toxic agents in the diet (Hamer et al., 2009).

Additionally, reducing the rate of carbohydrate absorption by lowering the glycaemic index (GI) of the diet may have several health benefits, such as a reduced insulin demand, improved blood glucose control and reduced blood lipid concentrations which are all factors playing important roles in preventing the onset of cardiovascular diseases and diabetes mellitus (Augustin, Franceschi, Jenkins, Kendall, & La Vecchia, 2002) that remain the leading causes of morbidity and mortality. Numerous short-term investigations indicate that consumption of high-GI carbohydrates may also increase hunger and promote overeating relative to consumption of items with a lower GI and higher content of RS. Therefore, current dietary guidelines encourage the consumption of whole grain and lower GI cereals instead of highly refined cereals as a dietary change that may help prevent overeating and obesity (Roberts, 2000). Numerous investigations of *in vitro* amylolytic hydrolysis (Englyst, Kingman, & Cummings, 1992; Granfeldt,

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Bjorck, Drews, & Tovar, 1992; Jenkins et al., 1982) have established the clear relationship between the rate of starch digestion and GI in different types of foods, including plain sweet biscuits (Garsetti et al., 2005). Therefore, the content of rapidly available carbohydrates in foodstuff should be decreased since the consumption of foods rich in easily digestible starch is detrimental to people with impaired glucose tolerance or insulin secretory dysfunction due to consequential postprandial hyperglycaemia and hyperinsulinemia (Willet, Manson, & Liu, 2002). Considering all the above, it is clear that altering the composition of biscuits, in terms of decreasing the rate of starch digestion and consequently GI, presents an important step in improving their functionality and probable health benefits.

In the frameworks of this research new biscuit formulations were developed by substituting a part of wheat flour in control sample (wheat flour based dietetic tea biscuit) with raw materials of different origin. Whole grain raw materials were chosen based on their nutritional quality, accessibility and flavour. In addition to amaranth and soy that are known for their unique protein composition and higher protein content in relation to wheat. Barley flour, oat flour and oat fibre are considered as a desirable functional food ingredients mostly due to high β-glucan content. Apple fibres are characterized by a well balanced portion between soluble and insoluble fraction and high content of associated bioactive compounds (Gorinstein et al., 2001). Buckwheat flour that was traditionally used in Croatia, nowadays has a limited use in human nutrition and was chosen for biscuit supplementation due to its excellent nutritional composition. The major goals were to investigate the impact of conducted recipe changes on the nutritional composition, caloric value and carbohydrate digestibility of experimental biscuits. Since increasing the content of fibre and whole grain raw materials in baked product formulation might result in decreased palatability, coarse texture dry mouth feel or dark colour (Yue & Waring, 1998), sensory analysis has also been conducted in order to ensure acceptable sensory characteristics of novel biscuits. In order to assess the impact of baking on analyzed parameters all analyses were also conducted in fresh dough samples and used for comparison. Attempts of changing the starch hydrolysis rates in biscuits by using whole grain flour are rather rare; recently Agama-Acevedo, Islas-Hernández, Pacheco-Vargas, Osorio-Díaz, and Bello-Pérez (2012) investigated the efficiency of unripe banana flour, while other authors used experimental RS rich products (Aparicio-Sangulian et al., 2007; Laguna, Salvador, Sanz, & Fiszman, 2011). In this research the two approaches were analyzed: effects of replacement of 30% of wheat flour in a biscuit formulation with 5 types of whole grain flours (cereals, pseudocereals and legumes) were compared to those obtained by partial substitution of wheat flour (15%) with purified dietary fibre of different origin.

2. Materials and methods

2.1. Preparation of biscuits

Eight types of biscuits (seven experimental formulations and the reference sample) were evaluated in terms of nutritional quality, sensory characteristics and carbohydrate digestibility. Biscuits were prepared in three series under laboratory conditions in order to ensure the reliability of obtained data. Differences in biscuits' composition are shown in Table 1.

Table 1
Differences in composition of eight investigated laboratory prepared biscuits (percentages are expressed on the basis of the total mass of used flours.

Composition of biscuits				
Sample	Wholemeal wheat flour (%)	White wheat flour (%)	Replacement flour (%)	Pure fibre (%)
Control	60	40	/	/
With oat flour	60	10	30	/
With barley flour	60	10	30	/
With buckwheat flour	60	10	30	/
With amaranth flour	60	10	30	/
With soy flour	60	10	30	/
With oat fibre	60	25	/	15
With apple fibre	60	25	/	15

As presented in Table 1, whole grain- and white wheat flour (Granolio, Zagreb, Croatia) were used as basic flours for biscuit preparation. In experimental samples white wheat flour was partially replaced with whole grain flour of other origin or purified dietary fibre. Oat-, barley-, buckwheat-, and soy flour were purchased at the local market; fibres (Vitacel®oat fibber, type HF 600 and Vitacel®apple fibre, type AF 400-30) were provided from JRS (Rosenberg, Germany) and amaranth was donated by the local grower. During our preliminary investigations, maximal possible amounts of substitute raw materials that still allowed the maintenance of satisfactory dough characteristics were determined and used in sample preparation (30% of whole-grain flour or 15% of purified fibres; expressed as the percentage of the total mass of all used ingredients, except added water). Sugar was substituted with the mixture of artificial sweetener (sucralose) and sugar substitute (isomalt). The content of other raw materials used for biscuit preparation, expressed on the basis of the total mass of all used ingredients, except added water (16 g/100 g vegetable fat; 15 g/100 g of sugar substitute; 0.013 g/100 g of artificial sweetener; 3.5 g/100 g powder skimmed milk; 1 g of ammonium bicarbonate; 0.8 g/100 g of salt; 0.01 g/100 g of flavour) was the same in all investigated samples. The content of water used for dough preparation varied significantly, depending on the recipe of each sample. For the preparation of dough out of 2 kg of raw materials, the content of added water was as follows: 350 mL for biscuit with amaranth flour; 360 mL for reference biscuit, biscuits with barley-, oat- and buckwheat flour; 450 mL for biscuit with soy flour; 620 mL for biscuits with oat fibre and apple fibre. The dough was sheeted using a rolling pin and cut into rectangular pieces (3.5 cm site). Sixteen pieces were placed on a perforated tray and baked in a conventional oven for 6 min at 175 °C. Trays were then turned bringing the side that had been at the back to the front of the oven to ensure homogenous cooking, and baked for a further 6 min at the same. Average thickness of biscuits was 7.8 mm and average mass 10.9 g. 24 biscuits from each prepared series was stored intact for the sensory evaluation. Dough samples to be used for experiments were frozen, vacuumed in polypropylene plastic bags and stored at −10 °C until analysis. After cooling to room temperature, biscuits were milled to pass 0.4 mm mesh and stored in dry plastic containers at +4 °C for further analysis.

2.2. Nutritional analysis

Protein content was determined by the semi-automatic Kjeldahl method according to AACC 46-12 (AACC, 2000) by multiplying the nitrogen content using nitrogen to protein conversion factor of 6.25. Fat content was determined by the Soxhlet AOAC 997.09 method (AOAC, 2000) after 5-h extraction with petroleum ether as the extraction solvent. Moisture content was estimated according to AACC 44-15A method and ash content according to AACC 08-01 method (AACC, 2000). The protein, fat, ash and moisture content were subtracted from the total weight and the difference was considered as total carbohydrates. Total dietary fiber (TDF) were