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Glycaemic response to frozen stored wheat rolls enriched with inulin and oat fibre

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ABSTRACT

The aim of this study was to examine the effect of dietary fibre addition to partially baked and frozen wheat rolls on the glycaemic index (GI).

Healthy humans volunteers ($n = 15$) took part in the study. They were asked to attend six times in the early morning, over three weeks. Each tested four types of wheat rolls – two without dietary fibre addition: (1) fully baked, non-frozen (FBNF), (2) partially baked and frozen (PBF); and two with the addition of 10% dietary fibre: (3) fully baked, non-frozen (FBNF + F), (4) partially baked and frozen (PBF + F). Glucose solution was used as a reference food and tested twice. Blood glucose concentrations were measured before consumption, as well as at 15, 30, 45, 60, 90 and 120 min after the start of the meal. Dietary fibre consisted of oat fibre (75%) and of inulin (25%).

It was concluded that both factors (freezing and fibre), applied to the wheat rolls at the same time, reduced statistically significantly ($P \leq 0.05$) the glycaemic index by 34% – PBF + F (GI = 53 ± 7) compared to control – FBNF roll (GI = 87 ± 11). This effect was not observed when fibre supplementation or frozen storage were applied separately.

1. Introduction

Cereals constitute essential components of the human daily diet and are consumed in various forms, especially in the form of white-wheat bread, brown bread, whole bread, bran enriched bread and multi-cereal bread, among others (Fardet et al., 2006). Nutritionally, they are important sources of carbohydrates, proteins, dietary fibre, also vitamins and minerals. Depending on the flour kind and its extraction rate, bakery goods can be more or less abundant in these compounds. Hence their nutritional value may be differentiated. Glycaemic index is one of carbohydrates' nutritional value determinants. There are evidences that low GI diets are shown to reduce the insulin resistance syndrome, cardiovascular disease, type 2 diabetes and certain cancers (Behall et al., 2006; Cleary et al., 2007; Holm and Björck, 1992). Wheat bread, commonly consumed, is classified as a high GI food (Borczak et al., 2008, 2011; Burton and Lightowler, 2007). At the same time, it is a poor source of dietary fibre, containing typically less than 2.5% of this component (Cleary et al., 2007). Improving the nutritional profile of bread, especially the value of glycaemic index has been of much attention. Several different ways have been proposed to decrease the high glycaemic response of white wheat bread, e.g. the use of high-amylose flours (Grandfeldt et al., 1991; Holm and Björck, 1992), selection of hard-type wheat (semolina) (Grandfeldt et al., 1991), incorporation of intact cereal grains into bread (Holm and Björck, 1992; Liljeberg and Björck, 1994), the addition of soluble fibre (Cavallero et al., 2002), sourdough baking technology and addition of organic acids (Borczak et al., 2011; Katina et al., 2006; Lappi et al., 2010), modification of the traditional baking technology by using freezing treatment (Borczak et al., 2008, 2011; Burton and Lightowler, 2007).

Among dietary fibres, the most popular sources are oats and barley (Claye et al., 1996). Oat fibre is rich in insoluble compounds (~73.6%), especially in hemicelluloses (38.3%), cellulose (26.6%), lignin (21.4%) and insoluble pectin (8.9%). It consists also of the soluble β-glucans (~1.5%) (Claye et al., 1996). Since insoluble fibres have rather greater influence on bowel function, the gel forming soluble fibres are considered to reduce glycaemic response. Notably, there is shown that viscosity of soluble fibres (i.e. β-glucan, pectins, inulin) could influence glucose absorption by several mechanisms: slowing of gastric emptying, decrease of the accessibility of α-amylase to its substrate (starch), slowing down the glucose absorption produced from starch hydrolysis (due to

Abbreviations: BMI, body mass index; CV, coefficient of variation; FBNF, fully baked, non-frozen; F, dietary fibre; GI, glycaemic index; IAUC, incremental area under the curve; PBF, partially baked and frozen; sd, standard deviation.

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a slowing of glucose diffusion) and increase of the unstirred water layer at the surface of the small intestine (Guillon and Champ, 2000). What's more, the consumption of foods containing soluble fibre or resistant starch reduces the risk of chronic disease. Risk factors include reductions in blood glucose and insulin, as well as, improvement of glycaemic control in normoglycaemic and diabetic subjects (Behall et al., 2006; Cleary et al., 2007; Holm and Björck, 1992). On the other hand, there is also accepted that the insoluble dietary fibres may slow gastric emptying through their water binding capacity delaying the absorption of glucose (Asp, 1995).

Taking into account the above mentioned, this paper focused on application of the freezing process to the baking technology in so-called "postponed baking" combined with the addition of dietary fibre, and the impact of these two factors on the glycaemic response of white wheat-flour rolls. Freezing and fibres applied together were not reported in the literature before so that this approach seems to be innovative. It seems to be also very useful, since white wheat-flour rolls are usually preferred by consumers.

The objective of this paper was to investigate the effect of both fibre addition and freezing treatment in the white-flour rolls on postprandial blood glucose in human volunteers.

2. Materials and methods

2.1. Wheat rolls

The material consisted of four types of wheat rolls: (1) fully baked, non-frozen – FBNF; (2) fully baked, non-frozen with dietary fibre – FBNF + F; (3) partially baked and frozen – PBF; and (4) partially baked and frozen with dietary fibre – PBF + F.

The dough for the wheat rolls was prepared using the following ingredients: wheat flour, type 55 – 900 g in the case of FBNF + F and 1000 g for the rest of the tested rolls (Moulins Soufflet, Pornic, France), salt (18 g) (Janikosoda S.A., Janikowo, Poland), yeast (10 g) (SAF – Instant red – Lesaffre Group, Strasbourg, France), dietary fibres (100 g) in which 75 g of insoluble fibre delivered from oat fibre 300 (SunOpta, Bedford MA, USA) and 25 g of soluble fibre – inulin, (Raftiline® HP, Orafti, Tienen, Belgium), Freshbake improver (10 g) (Puratos, Belgium), tap water– 580 g in FBNF and PBF rolls, 590 g in the case of FBNF + F rolls and 540 g in the case of PBF + F rolls. The ingredients were mixed for 9 min in a mixer (DIOSNA SP-12, GETH, Germany), then underwent proofing (60 min, 35 °C, 95% RH) and baking in an electric oven (MIWE, Germany).

The FBNF rolls were baked conventionally (20 min, 230 °C). The PBF rolls were partially baked (190 °C, 3 min, 165 °C, 14 min), frozen in a blast freezer for about 30 min at −30 °C, and then stored in a freezer at −18 °C in airtight containers for 14 days. At the end of the storage period, the rolls were defrosted at room temperature for about 10 min, put in the oven and fully baked (12 min at 230 °C).

All bakings were conducted at the Department of Carbohydrates Technology, Agricultural University in Krakow.

2.2. Chemical analyses of fresh and frozen stored wheat rolls

Chemical analyses (dry matter, protein, lipid, dietary fibre, resistant starch and ash content) of wheat rolls were performed using AOAC standard methods (AOAC, 2006). The content of available carbohydrates (total carbohydrates minus dietary fibre) was evaluated according to FAO/WHO (Table 1). Total carbohydrates (TC) were calculated using the formula:

$$TC = 100 - (\text{proteins} + \text{fat} + \text{water} + \text{ash content})$$ (Cichon and Wądołowska, 2010).

Table 1
Chemical composition of fresh and frozen stored wheat rolls enriched with dietary fibre.

Components [% f.m.]	FBNF	FBNF + F	PBF	PBF + F
Dry matter	70.2 ± 0.0^{a}	68.5 ± 0.0^{b}	70.6 ± 0.0^{c}	69.0 ± 0.0^{d}
Protein	8.8 ± 0.0^{a}	7.2 ± 0.2^{b}	8.9 ± 0.7^{a}	9.3 ± 0.3^{a}
Fat	0.8 ± 0.1^{a}	1.0 ± 0.0^{b}	0.4 ± 0.0^{c}	1.0 ± 0.0^{b}
Total carbohydrates	58.6 ± 0.1^{a}	58.7 ± 0.2^{a}	59.2 ± 0.6^{a}	57.2 ± 0.1^{b}
Available carbohydrates	55.9 ± 0.1^{a}	50.9 ± 0.3^{b}	56.0 ± 0.6^{a}	49.3 ± 0.1^{c}
Dietary fibre				
Total	2.9 ± 0.0^{a}	7.8 ± 0.0^{b}	3.2 ± 0.0^{c}	7.9 ± 0.0^{d}
Soluble	1.2 ± 0.0^{a}	1.4 ± 0.0^{b}	1.1 ± 0.1^{a}	1.7 ± 0.0^{c}
Insoluble	1.7 ± 0.1^{a}	6.4 ± 0.0^{b}	2.1 ± 0.1^{c}	6.6 ± 0.0^{d}
Resistant starch	1.3 ± 0.0^{a}	1.1 ± 0.2^{ab}	1.5 ± 0.0^{b}	1.3 ± 0.1^{ab}
Ash	2.0 ± 0.2^{ab}	1.6 ± 0.0^{ac}	2.0 ± 0.1^{b}	1.5 ± 0.1^{c}

FBNF – fully baked–non frozen, FBNF + F fully baked–non frozen with fibre, PBF – partially baked and frozen, PBF + F – partially baked and frozen with fibre, f.m. – fresh matter. Different letters in rows show significantly different values at $P \leq 0.05$.

Values are obtained by means of duplicate analysis and are expressed as g per 100 g of fresh sample.

The weight of the rolls and the content of the portion given to each participant were calculated on the basis of the chemical composition thus obtained. Thus, the weight of rolls that contained 50 g of available carbohydrates was 88 g, 93 g, 86 g and 94 g for FBNF, FBNF + F, PBF and PBF + F, respectively.

2.3. Subjects

Fifteen healthy volunteers (non-smoking, restricted alcohol consumption, aged between 18 and 40, normal activity) according to FAO/WHO criteria (Brouns et al., 2005; FAO/WHO, 1998), two men and thirteen women, aged (mean ± sd) 23.1 ± 1.2 years, with an average body mass index (BMI) (mean ± sd) of 21.8 ± 2.70 kg/m^2, height (mean ± sd) 1.68 ± 0.1, weight (mean ± sd) 61.8 ± 9.2, took part in the test. They were recruited from among students of the Agricultural University in Krakow. The Regional Chamber of Bioethics Committee approved the experimental procedure and the participants signed their consent to attending. Each volunteer was medically examined before the tests.

2.4. Evaluation of glycaemic index (GI)

Subjects were asked to attend six times in the morning over a period of three weeks (on Mondays and Thursdays). In order to reduce intra- and inter-individual variability, the volunteers were instructed to fast for 10–12 h before the test, as well as to avoid intense physical activity, and alcohol consumption, and to restrict the time spent ingesting the test food. Every participant tested once the four different wheat rolls and twice the reference food, as recommended by FAO/WHO (1998). Each roll was tested on a separate day in a random order, with at least a two-day gap between each glycaemic index evaluation, in order to minimize carry-over effects. The rolls were served with 250 ml of low-mineralized water. Subjects were asked to eat the test wheat rolls within 15 min and to consume the reference food in 10 min (Brouns et al., 2005). Pure glucose was used as the reference food. The amount of 50 g of glucose was dissolved in 250 ml of low-mineralized water, just before the start of the test, and served to the volunteers.

Blood glucose concentrations were measured before consumption as well as at 15, 30, 45, 60, 90 and 120 min after the start of the meal. Finger-prick blood samples were taken for capillary blood glucose analysis. Glucose concentration was measured by