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Comparison of glycemic index of spelt and wheat bread in human volunteers

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Abstract

The assessment of the glycemic index (GI) seems to be an important parameter to take into account in order to better understand the physiologic effects of foods with high carbohydrate levels. Among cereals, which are major sources of carbohydrates, spelt (*Triticum spelta* L.) has been considered as particularly interesting from a nutritional point of view. The aim of this study was to evaluate in vivo the GI of white spelt bread in healthy subjects. The wheat (*Triticum aestivum* L.) white bread was used as reference food. To avoid differences in the production of both breads, spelt and wheat breads were baked under the same controlled conditions. Results showed that the glycemic profile of spelt white bread was not different from that of wheat white bread (GI of 93 ± 9). The area under the glycemic curve significantly and negatively correlated to fasting glycemia and carbohydrate intake during evening meals preceding the test. In conclusion, the glycemic response to spelt bread was similar to that of wheat bread. However, in order to avoid more inter-individual variability, our data supports the importance to propose standardised carbohydrate content for the last meal before evaluating the GI of food.

Keywords: Glycemic index; Spelt; Wheat; Bread; Evening meal

1. Introduction

Spelt (*Triticum spelta* L.) is an ancient bread cereal related to wheat (*Triticum aestivum* L.) that has been cultivated for hundreds of years, and that is now being rediscovered in Europe and North America (Abdel Aal, Hucl, & Sosulski, 1995; Abdel Aal, Sosulski, & Hucl, 1998; Ranhotra, Gelroth, Glaser, & Stallknecht, 1996). Today, more spelt-based products are available including flour, bread, breakfast cereals, pasta and crackers. It seems that this cereal has valuable nutritional and/or physiological properties, which could help promoting the consumption of these products. However, no scientific basis for such claims has been established yet.

Because of the high levels of carbohydrates in cereals, the determination of glycemic index (GI) of spelt bread

Abbreviations: AOAC, Association of Official Analytical Chemists; BMI, body mass index; FAO, Food and Agriculture Organisation; GI, glycemic index; HPLC, high precision liquid chromatography; IAUC, incremental area under the curve; MUFA, monounsaturated fatty acid; SEM, standard errors of the mean; WHO, World Health Organisation.

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seemed to be an important criterion to take into account when evaluating the so-called nutritional and physiological advantages of this cereal. The GI concept was proposed for the first time by Jenkins et al. (1981), in order to give complementary information about the chemical composition of carbohydrate-rich foods. This index is defined by the Food and Agriculture Organisation/World Health Organisation (FAO/WHO) as the incremental area under the blood glucose response curve of a 50 g carbohydrate portion of a test food expressed as a percentage of the response to the same amount of carbohydrate from a standard food taken by the same subject (FAO/WHO, 1998).

The regular consumption of foods exhibiting a high GI is associated with the development of some diseases such as type 2 diabetes (Augustin, Franceschi, Jenkins, Kendall, & La Vecchia, 2002; Hodge, English, O'Dea, & Giles, 2004) and certain forms of cancer (Augustin et al., 2001, 2003a, 2003b, 2003c; Franceschi et al., 2001) and to an increased risk of cardiovascular diseases and obesity (Roberts, 2000; Ludwig, 2002). Furthermore, by promoting satiety and promoting fat oxidation at the expense of carbohydrate oxidation (Ball et al., 2003; Warren, Henry, & Simonite, 2003; Wu, Nicholas, Williams, Took, & Hardy, 2003), the intake of low GI foods may benefit weight regulation and be favourable in the treatment of obesity. Consequently, the intake of low GI foods is an important factor for maintaining a healthy diet. Several nutrients are implicated in the drop of the GI such as fat, proteins, α-amylase inhibitors (lectin, phytate), galactose, fructose and viscous fibres (guar, β-glucan) (Augustin et al., 2002). In addition, the oligofructose, a fructan type fermentable fibre, might in addition to its "fibre effect" exert an effect on GI, since it is able to improve glucose homeostasis (Delzenne, 2003).

Bonafaccia et al. (2000) carried out a study on three spelt cultivars (Hercule, Rouquin and Ostro, Italy, 1992–1994) and showed that these cereals have a higher content of protein and soluble dietary fibre than common wheat. The presence of these nutrients may play a role in the decrease of the GI of spelt-based products.

GI value can be calculated by using a mathematical formula based on an in vitro starch hydrolysis assay (Granfeldt, Bjorck, Drews, & Tovar, 1992). By using this test, spelt bread did not differ from wheat bread, in terms of sugar release kinetics; the in vitro predicted GI was 105 (Foster-Powell, Holt, & Brand-Miller, 2002; Skrabanja et al., 2001). Is the GI of spelt vs. wheat bread also similar in vivo? The aim of this study was to evaluate the GI of spelt white bread in vivo, and to compare it with wheat white bread.

2. Materials and methods

2.1. Materials

The spelt grains (*T. spelta* L. cv. Rouquin) and the wheat grains (*T. aestivum* L. cv. Herzog) were cultivated, respectively, in the Belgian Ardennes and the Belgian region of Famenne, during the 2001–2002 growing season. After harvest, grains from both species were milled with a roller mill in 4 breaking and 4 reducing passages and bolted on a planschister through a 100 μm sieve. The spelt and wheat sieved flours produced this way are used for the baking of breads.

2.2. Preparation of breads

Spelt and wheat breads were made and baked with a bread maker (Home bread model, ABKE 41 Moulinex®) and were composed either of spelt flour (525 g) or wheat flour (525 g), water (320 ml), dehydrated yeast (7 g) and salt (6 g).

The nutritional composition of breads has been evaluated after a chemical analysis of both flours by AOAC (2000) methods. Fructans have also been qualitatively and quantitatively evaluated by high performance liquid chromatography (HPLC) in collaboration with Orafti (Tienen, Belgium) (Joye & Hoebregs, 2000). Both breads were weighed after baking to take water loss into account in this calculation.

2.3. Experimental design

Ten healthy subjects (five males and five females) were included in the study. Their ages ranged from 23 to 57 years old and their body mass index (BMI, in kg/m^2) from 18.6 to 25 (Table 1). They were given a food/lifestyle questionnaire before the beginning of the experiment, in order to assess the parameters which could influence glycemic response (physical exercise, time and content of the last meal, the water consumption before the test). The food analysis of the last meal was performed for each subject.

The GI value of spelt bread was determined by using the previously described standard protocol further developed by Wolever, Jenkins, Jenkins, and Josse (1991), and accepted by the FAO/WHO (1998).

Briefly, the subjects were fed with a portion of spelt white bread (test food) or wheat white bread (standard

Table 1
Characteristics of subjects

Subjects	Gender	Years old	Weight (kg)	Height (m)	BMI (kg/m^2)
1	Female	57	56	1.68	19.8
2	Female	45	64	1.60	25
3	Female	46	67	1.69	23.4
4	Female	23	50	1.64	18.6
5	Female	25	54	1.61	20.8
6	Male	51	74	1.77	23.6
7	Male	23	76	1.79	23.7
8	Male	25	73	1.75	23.8
9	Male	26	60	1.71	20.5
10	Male	23	58	1.67	20.7

food) containing 50 g carbohydrates as determined by the AOAC (2000) methods. This quantity represented about 95 g fresh bread.

Both breads were tested three times on each subject on separate days, with intervals of at least three days between measurements performed in the same subject.

The subjects came in the laboratory in the morning after 10–12 h of overnight fast. The only beverage accepted during this fast was water. The blood samples were taken from subject before (0 min) and 15, 30, 45, 60, 90 and 120 min after the start of the meal. The glyceamia was measured by a strip gluco-meter based on glucose-dehydrogenase mediated oxidation of glucose (Accu-chek Sensor, Roche®, Mannheim, Germany). Two glasses of water were given after 60 and 90 min to each subject. A standardised questionnaire was given before, during and after the experiment to analyse the sensation related to hunger, or digestion.

The area under the curve for both breads was calculated geometrically as the incremental area under the blood glucose response curve (IAUC) as described by Wolever et al. (1991). Only the area above the fasting concentration was included. The experiment was performed with the agreement of the local ethical committee.

2.4. Statistical analyses

Results were expressed as means with standard errors of the mean (SEM). By using an Excel spreadsheet, the paired Student's *t*-test allowed to compare the different variables of both breads. The Pearson's correlation coefficient (SPSS software) was used for the correlation analysis. The values were considered significant when the *P*-value was inferior to 0.05.

3. Results

3.1. Bread composition

The mean weight of both breads after baking was about 750 g, corresponding to a loss of water of about 100 g. There was no difference between spelt vs. wheat breads concerning this parameter. The nutritional composition of flours and breads is shown in Table 2. Thus, the spelt bread was richer in proteins (8.28 g/100 g for spelt vs. 7.37 g/100 g for wheat) and lipids (1 g/100 g for spelt vs. 0.79 g/100 g for wheat) than wheat bread. The proportion of monounsaturated fatty acids (MUFA) in spelt flour was twice as high that of wheat flour (14.10% of total lipids for spelt vs. 7.9% of total lipids for wheat).

By considering both flours and breads analysis, no difference was observed in the total carbohydrate quantity or in total fibre level. However, a more accurate analysis of fibre showed a lower soluble fibre content in spelt bread vs. wheat bread (1.45 g/100 g for spelt vs. 1.76 g/100 g for wheat). Fructans analysis showed that oligofructose (with a mean number of fructosyl moeties of about 4) represented the major fructosyl oligomer fraction.

Table 2
Nutritional composition of wheat and spelt white flours and wheat and spelt white breads

	Wheat flour	Spelt flour	Wheat bread	Spelt bread
Dry matters	90.58	90.65	65.1	65.2
Proteins	10.53	11.83	7.37	8.28
Lipids				
Total	1.14	1.43	0.79	1.00
Saturated fatty acids (%)	20.67	21.01	20.67	21.01
Mono unsaturated fatty acids (%)	7.9	14.10	7.9	14.10
Poly unsaturated fatty acids (%)	67.04	60.49	67.04	60.49
Carbohydrate				
Total	75.94	74.20	53.16	51.94
Starch	71.84	72.07	50.28	50.45
Sugar	4.10	2.13	2.87	1.49
Fructose	0	0	0	0
Glucose	0.22	0.28	0.15	0.20
Sucrose	0.24	0.24	0.17	0.16
Maltose	3.64	1.61	2.55	1.13
Fibres				
Total	2.52	2.65	1.76	1.86
Insoluble	0	0.58	0	0.41
Soluble	2.52	2.07	1.76	1.45
OFS	0.7	0.9	0.49	0.63
Ash	0.45	0.54	1.15	1.18

The nutritional composition of both breads has been evaluated after a chemical analysis of both flours by AOAC methods. Values are mean of duplicate analysis on the sample and are expressed in g per 100 g of sample.

Quantitative analysis revealed a higher content of oligofructose in spelt flour than wheat flour (0.9 g/100 g for spelt vs. 0.7 g/100 g for wheat). The nutritional composition also showed that wheat bread was richer in maltose than spelt bread (1.61 g/100 g for spelt vs. 3.64 g/100 g for wheat).

3.2. Glycemic response of breads

The glycemic responses to spelt and wheat breads are shown in Fig. 1. The fasting glycemia was similar for each experiment in the same subject with similar means for spelt and wheat breads (4.59 ± 0.15 mM for spelt bread vs. 4.59 ± 0.44 mM for wheat bread). No difference was observed between both breads neither for glycemic peak nor for glycemia 120 min after the meal. The glycemic peaks are observed 45 min after the start of the meal for both breads with a mean of 7.23 ± 0.25 mM for spelt bread and 7.21 ± 0.25 mM for wheat bread. The glycemia value observed 120 min after the spelt bread consumption is also similar to that of wheat bread (5.51 ± 0.21 mM for spelt bread vs. 5.45 ± 0.27 mM for wheat bread). The calculation of IAUC for each subject and for each bread allows evaluating the GI of spelt bread (Table 3). No significant differences between IAUC of both breads were observed leading to a GI of spelt bread of 93 ± 9.

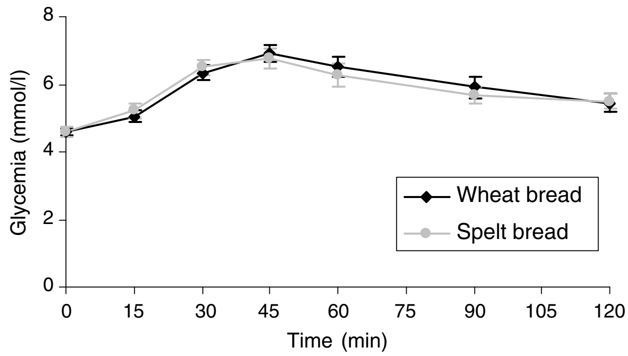

Fig. 1. Profile of glycemia after consumption either wheat bread or spelt bread. Profile of glycemia (mmol/l) for 120 min after consumption of spelt white bread or wheat white bread containing 50 g carbohydrates. Values are means ± SEM.

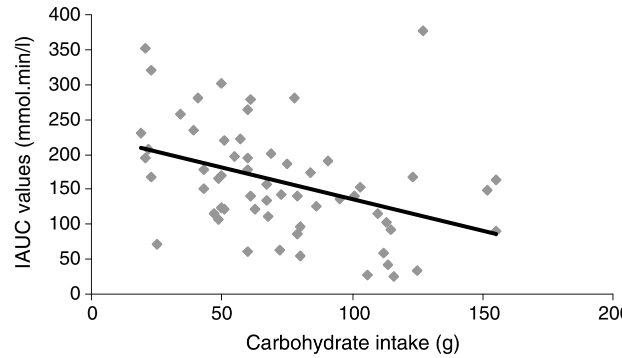

Fig. 2. Correlation between carbohydrate intake of the last meal before the experiment and the IAUC values. Negative correlation between carbohydrate intake (grams) of the last meal before the experiment and the IAUC values (mmol min/l) measured in all subjects for all experimental conditions (6 IAUC evaluation per subject; $n = 10$ volunteers; $r = -0.397$, $P < 0.01$).

4. Results of questionnaires

4.1. Effect of spelt and wheat breads on the satiety

Questionnaire results showed no difference between the two breads for satiety, or for sensation related to digestion (data not shown).

4.2. Correlation analysis with the IAUC values

For each subject, the food analysis allowed evaluation of the nutrient intake of the last meal before doing the test (data not shown). The correlation analysis showed that the carbohydrate intake of the meal preceding the test influences the IAUC value (Fig. 2) ($r = -0.397$, $P < 0.01$): the higher the carbohydrate intake, the lower the IAUC values. No significant relation was observed between the last intake of lipids or fibres and the IAUC values (data not shown). A negative correlation was also found between the fasting glycemia values and the IAUC values (Fig. 3) ($r = -0.353$, $P < 0.01$). The carbohydrate intake of the last meal before the experiment was not significantly associated with the fasting glycemia values (Fig. 4).

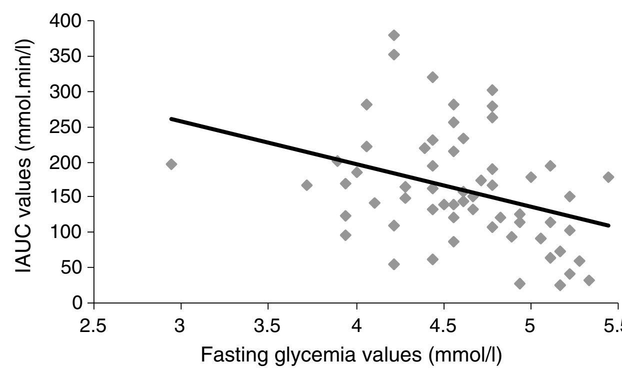

Fig. 3. Correlation between fasting glycemia and IAUC for glycemia. Negative correlation between the fasting glycemia values (mmol/l) and the IAUC values (mmol min/l) measured in all subjects for all experimental conditions (6 IAUC evaluation per subject; $n = 10$ volunteer; $r = -0.353$, $P < 0.01$).

Table 3
Incremental area under the blood glucose response curve (IAUC) of spelt and wheat breads and glycemic index (GI) value of spelt bread

	Spelt bread				Wheat bread				GI
	IAUC 1	IAUC 2	IAUC 3	Mean	IAUC 1	IAUC 2	IAUC 3	Mean	
F1	239	281	190	237	133	132	379	215	110
F2	320	195	219	245	278	179	351	269	91
F3	257	281	195	244	302	263	230	265	92
F4	141	61	169	124	165	55	96	105	118
F5	202	186	196	195	222	124	176	174	112
H1	73	64	152	96	120	157	179	152	63
H2	115	125	90	110	216	93	122	144	76
H3	28	33	41	34	152	103	25	93	37
H4	168	86	173	142	140	116	142	133	107
H5	122	140	149	137	110	163	59	111	123
Mean ± SEM									93 ± 9

IAUC 1,2,3 correspond to measurement performed at three separate days (see Section 2). GI corresponds of the ratio of the mean Spelt bread/mean Wheat bread × 100. There is no significant difference between IAUC of both breads (P-value > 0,05; paired student's test).

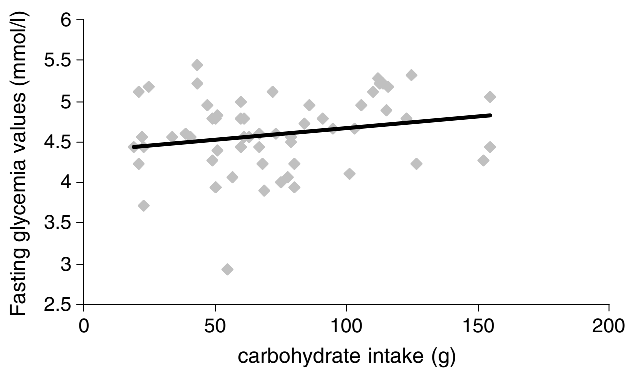

Fig. 4. Relationship between carbohydrate intake of the last meal before the experiment and fasting glycemia. Relationship between carbohydrate intake (grams) of the last meal before the experiment and the fasting glycemia (mmol/l) measured in all subjects for all experimental conditions (6 evaluations of fasting glycemia per subject; $n = 10$ volunteers). Non significant correlation ($r = 0.211$, $P > 0.05$).

5. Discussion

A study carried out by Bonafaccia et al. (2000) showed that spelt cultivars compared to common wheat had a higher content of some nutrients implicated in the drop of GI, such as proteins and soluble fibres. Those two parameters were not different in the spelt and wheat flours used in the present experiment. For the first time, the fructans present in both breads were determined and we found that oligofructose content was higher in spelt than in wheat flour. Oligofructose has been recognised as a dietary fibre which is largely fermented in the caeco-colon, and produces several effects in the gastrointestinal tract (prebiotic effect, decrease in pH, increased absorption of minerals, etc.), but also in the systemic circulation (decrease in triglyceridemia, in glycemia, in uremia, etc.), this phenomenon being linked to its fermentation pattern (Delzenne, 2003). Moreover, the spelt flour was two times less rich in maltose – a carbohydrate responsible for a rapid increase in glycemia, and richer in MUFA than wheat flour, two nutrients susceptible to influence GI in an opposite way.

The presence of MUFA in higher quantity could influence the GI of bread. In fact, Gatti et al. (1992) have found a reduction in postprandial glucose responses to wheat bread after the addition of olive oil (rich in MUFA) and corn oil (polyunsaturated fatty acids), but not butter (saturated fatty acids). However, a recent study performed by Maclntosh, Holt, and Brand-Miller (2003) has shown that substitution of monounsaturated or polyunsaturated fatty acids by saturated fatty acids does not improve acute postprandial hyperglycaemia. The question thus remains open: are the differences in maltose, MUFA, and/or fructans content observed in spelt vs. wheat bread sufficient to lessen the glucose response?

By using a test based on the in vitro starch hydrolysis assay, the GI of spelt bread did not differ from wheat bread (Foster-Powell et al., 2002; Skrabanja et al., 2001). However, it is not yet known if the in vitro method is a reliable means to evaluate the GI of all types of foods. Some factors could affect the post-prandial glycemia in vivo without modifying the rate of starch hydrolysis in vitro.

Furthermore, most of the spelt-based foods are not prepared with spelt cereal above and a previous study in our laboratory has shown that no bread commercially available on the Belgian market place with denomination "spelt bread" was made with pure spelt flour. As a general rule, the baker uses a mix of spelt and wheat flour to facilitate the baking of bread. In order to compare spelt and wheat bread with equal composition, both breads were baked in our laboratory under the same conditions with authentic spelt or wheat flour manufactured in the same mill. At the end of this experiment and according to the in vitro study, our results showed that spelt bread GI was close to 100, which is the GI attributed to wheat bread. However, GI values variability between subjects and within the same subject was very high. Under one study performed by Wolever et al. (2003), GI values were not significantly related to the method used for glucose measurement or subject characteristics. Furthermore, capillary blood glucose was less variable than venous plasma glucose. These observed differences led us to look for other factors which could modulate IAUC values and influence GI values. According to correlation analysis, our results suggest that the IAUC values are significantly associated to fasting glycemia values and carbohydrate intake during the last evening meal before the experiment. However, the fasting glycemia was not correlated to the carbohydrate amount ingested the previous day, which suggests that these two observations are independent. Consequently, the GI value does not depend only on glucose availability in the food, but also on the fasting glycemia and the carbohydrate quantity ingested in the previous meal. Furthermore, it seems that the GI was not due to the appearance of glucose in the blood, but to glucose removal by tissue (Schenk, Davidson, Zderic, Byerley, & Coyle, 2003). The GI of two breakfast cereals was different despite no significant differences in the rate of glucose entry into the blood. This suggests that the GI depends more on glucose metabolism than glucose absorption. This could explain the influence of the last carbohydrate intake or the fasting glycemia on the GI.

In fact, it seems that a high-carbohydrate evening meal improves glucose tolerance after an oral glucose tolerance test (OGTT) the next morning. A high nocturnal insulin concentration should prime the system and the subject should be more insulin sensitive, enhancing insulin-dependent glucose disposal and inhibiting hepatic glucose production (Robertson, Henderson, Vist, & Rumsey, 2002).

Henceforth, in order to avoid more variability, we suggest to include in the method a standardised carbohydrate quantity in the evening meal before the experiment.

According to the glycemic profile observed after bread intakes, no effect of spelt bread on satiety compared to wheat bread was noticed. Indeed, the postprandial glycemia could be negatively correlated to the sensation of hunger. However, a study carried out by Bard et al. (2003) showed the effect of spelt bread on satiety compared to wheat bread. Yet, the authors have not used spelt and wheat breads baked with a standardised recipe. Furthermore, they have not given an indication of the origin of the flour used to bake these breads. Could the presence of additives or other substances such as sucrose or emulsifiers influence the results? In fact, thanks to their small-scale production, spelt breads are often exempt of bread improvers that may be responsible of a more important satiety effect.

In conclusion, the spelt bread has a GI of 93 and its glycemic profile was not different than that of wheat bread. Consequently, we suggest that the differences in nutrients contents such as fibres, fructans, or fatty acids in the spelt bread compared to wheat bread are not physiologically relevant, at least in term of GI modulation. Furthermore, the IAUC values seem to be correlated to fasting glycemia and carbohydrate intake of the evening meal before the test. Those parameters will have to be taken into account in the evaluation of GI.

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