Effect of Spelt Wheat Flour and Kernel on Bread Composition and Nutritional Characteristics

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Spelt wheat seeds (*Triticum aestivum* subsp. *spelta* cv. Ostro) were used to obtain white spelt flour (64.5% yield), wholemeal spelt flour (100% yield), and scalded spelt wheat kernels. From these materials, white spelt wheat bread (WSB), wholemeal spelt wheat bread (WMSB), and spelt wheat bread with scalded spelt wheat kernels (SSKB) were made and were compared to the reference white wheat bread (WWB). The spelt wheat flours and breads contained more proteins in comparison to wheat flour and bread. Among the samples the highest rate of starch hydrolysis was noticed in WSB. During the first 30 min of incubation this particular bread was shown to have significantly more ($P < 0.05$) rapidly digestible starch than the WMSB and later on also more starch than in WWB and SSKB, respectively. The WMSB had the lowest hydrolysis index (HI = 95.7). However, the result did not differ significantly from that in the reference common wheat bread. On the other hand, the most refined spelt wheat flour resulted in a bread product (WSB) that was statistically withdrawn ($P < 0.05$) as one with the highest HI (112.6).

Keywords: *Bread; fiber; gluten; scalded kernels; spelt wheat; starch*

INTRODUCTION

At present, there is considerable interest in the consumption of alternative crops, including cereals. However, most of the alternative plants have been already widely used in ancient times.

Spelt (*Triticum aestivum* subsp. *spelta*) is among the earliest cultivated wheat species (*1*). The findings of individual spelt wheat grains date from the early Neolithic (~5600−4300 B.C.), whereas the first signs of its storage occur from the early Bronze Age (2300−800 B.C.). It is also reported that spelt reached its highest presence in the early Medieval period (260−1000 A.D.) (*2*).

The main drawback of spelt wheat is that the hulls remain on the threshed grain and thus limit the use of spelt wheat primarily to animal feeds (*1*, *3*). Among wheat species intended for human consumption, there was a selection for free-threshed, compact-eared, and high-yielding forms. However, according to Ohtsuka (*4*), the cultivation of two types of spelt has survived in some countries of central and southeastern Europe. This seems to be connected with the better resistance of spelt to harsh climatic and soil conditions (*2*).

On the basis of the morphological characteristics of grain, spelt is also resistant to pests and diseases and is thus suited to trends in ecological cultivation. However, the chemical composition suggests that spelt wheat may not offer any significant advantage in comparison to common wheat (*5*, *6*). Moreover, the baking properties of spelt flour were found to be inferior as compared to those of common wheat flour (*3*, *5*, *7*). The nutritional properties of spelt wheat have been less investigated. Considering starch as the main plant metabolite in spelt wheat, from the nutritional point of view this component is therefore a subject of great importance. The recent FAO/WHO consultation on carbohydrates strongly advocates an increased consumption of foods that promote a lower rate of glucose delivery to the blood (*8*). The glycemic index (GI) as a method for assessing and classifying the glycemic responses to starchy foods (*9*) is now widely accepted. On the basis of several studies, it has become increasingly clear that in a long-term perspective low-GI diets have metabolic advantages, particularly in diabetes and hyperlipidemia (*10*−*14*). There are some discrepancies as to whether the carbohydrates of spelt wheat have "lente" characteristics and can thus be an appropriate source for diabetic patients. Widely accessible, but not scientifically supported sources (*15*−*17*), report a reduced digestion of spelt wheat starch and smaller fluctuations in blood glucose concentrations, respectively. However, following a recent in vitro study, this issue was not confirmed (*18*).

In Slovenia, spelt was grown until the middle of the 20th century. Currently, as in other European countries, there is a renewal of interest in products made of spelt wheat. The purpose of the present study was twofold. The first aim was to estimate the yield of experimental sowing and to follow the main parameters of grain and flour quality. The second was to study the nutritional characteristics of designed spelt wheat breads with special emphasis on the rate of starch hydrolysis and on the dietary fiber content as compared to the reference white wheat bread.

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MATERIALS AND METHODS

Materials. The spelt wheat seeds (*T. aestivum* subsp. *spelta* cv. Ostro) were sown on November 5, 1997, in Vipava (Slovenia) and harvested on July 16, 1998. No fertilization or other chemicals were applied. For baking the experimental bread samples, white spelt flour (64.5% yield), wholemeal spelt flour (100% yield), and scalded spelt wheat kernels were used. For comparison, a commercial white wheat flour (Mlinotest, Ajdovscina) was used.

Bread Making. *White Spelt Wheat Bread (WSB).* The ingredients, 3000 g of white spelt flour, 53 g of salt, 90 g of yeast, and 1720 g of water, were mixed into a dough and raised for 30 min. After the dough had been formed into a loaf, a second rising for 45 min followed. Baking was performed at 225 °C for 40 min.

Wholemeal Spelt Wheat Bread (WMSB). The ingredients, 3000 g of wholemeal spelt flour, 60 g of salt, 90 g of yeast, and 1870 g of water, were mixed and risen for 40 and then 25 min, respectively. Baking was performed at 225 °C for 60 min.

Scalded Spelt Wheat Kernel Bread (SSKB). The ingredients included 3000 g of white spelt wheat flour, 747 g of whole spelt kernels, 53 g of salt, 90 g of yeast, and 1720 g of water. The spelt kernels were scalded with boiled water and after 3 h added to the mixture for making the dough. The dough was raised for 30 min and the loaf for 45 min. The same baking conditions as for the WSB were used.

Reference White Wheat Bread (WWB). Bread from white wheat flour was made in a baking machine as described previously by Liljeberg and Björck (*19*).

All types of bread were sliced, the crusts removed, and the slices frozen. Before analysis, the slices were thawed at room temperature.

Methods. *The Falling Number* (FN) was evaluated by an FN 2000 apparatus (Falling Number, Huddinge, Sweden) according to Method ICC/No. 107 (*20*). The FN test is used to determine the level of α-amylase activity. Specifically, the FN is the number of seconds required to stir and allow the stirrer to fall a measured distance through a hot aqueous flour gel undergoing liquefaction. A high FN indicates low α-amylase activity, whereas in flours with high enzymatic activity, lower FN values are obtained.

Gluten Tests. Gluten is the natural protein in the wheat endosperm that gives structure, elasticity, and sponginess to the dough. This retains the gas and steam from baking and is critical for the technological quality of wheat and flour. The wet gluten content is the amount of gluten prepared with the standardized method in the gluten washer. Gluten tests were performed by the Glutomatic system (Falling Number, Huddinge, Sweden) according to Method 106/2 (Standard No. 137/1) (*20*).

Alveograph characteristics were studied by Chopin alveograph (*21*). The principle is based on measurement of the air pressure required to inflate a bubble of dough, which is prepared from flour, salt, and water in the mixer. The recorded parameters were the configuration ratio of the curve (P/L) and the strength of the flour (W). P/L indicates the relation between the tenacity and spreading capacity of the dough, whereas W expresses the strength of the flour and the quality of the protein network.

Chemical Analyses of the Test Products. Prior to analysis, a portion of each bread was air-dried and milled in a Cyclotec mill (Tecator) to a particle size <0.8 mm. Protein analysis in flours and products was performed by using the Kjeldahl method (979.09) (*22*), using a nitrogen-to-protein conversion factor of 5.7.

The total starch in the flours and in the breads was determined enzymatically following solubilization in alkali according to a method described by Tovar et al. (*23*); however, before the alkali treatment (4 mol/L KOH) the samples were soaked in a phosphate buffer (0.1 mol/L; pH 6.0). By omitting the alkali treatment (*24*), the starch corrected for retrograded amylose (used for HI standardization) in the milled material was also determined.

Table 1. Main Quality Parameters of Wheat and Spelt Wheat Flours

material	total starch (%, dmb)	proteins (%, dmb)	wet gluten (%)	strength W[a]	P/L[b]	FN[c] (s)
white wheat flour	81.3	11.1	28.0	280	0.7	250
white spelt flour	76.3	12.5	39.7	160	0.8	240
wholemeal spelt flour	63.2	14.0	41.5	64	0.2	240

[a] W, alveograph work of deformation. [b] P/L, alveograph ratio of the curve. [c] FN, Falling Number.

The enzymatic–gravimetric method was used for the determination of total, soluble, and insoluble dietary fiber (Bioquant kit, 1.12979, Merck).

All chemical analyses were performed on two independent samples.

In Vitro Rate of Starch Hydrolysis and HI. The rate of starch hydrolysis in the bread samples was followed by a dialysis procedure (*25*). Six subjects chewed the bread samples [corresponding to 1 g of starch, determined according to the method of Holm et al. (24)] 15 times for 15 s. The sodium/potassium phosphate buffer ($KH_2PO_4 + Na_2HPO_4 \times 2H_2O$; pH 6.9) was then used to dilute the samples. Thereafter, pepsin ([pepsin] = 50 mg/mL buffer, EC 3.4.23.1, 2000 FIP-U/g; Merck) was added to the samples. The pH was adjusted to 1.5 with 2 mol/L HCl, followed by incubation at 37 °C for 30 min. Before porcine pancreatic α-amylase ([α-amylase] = 110 units/mL of buffer, EC 3.2.1.1, 790 units/mg of protein; Sigma) was added, the pH was readjusted to 6.9 with 1 mol/L NaOH. The sample was brought to 30 mL with a sodium/potassium-phosphate buffer and transferred into dialysis tubings (Spectra Por No. 2, width = 45 mm, MWCO 12000–14000). Each bag was placed into a beaker containing 800 mL of sodium/potassium phosphate buffer and stirred during the incubation (3 h, 37 °C). Every 30 min, aliquots of 1 mL were withdrawn in duplicates for analysis of the reducing sugar content with the 3,5-dinitrosalicylic acid (DNS). A standard curve was prepared using maltose. The hydrolysis index (HI) was calculated as follows: for each product, the area under the hydrolysis curve (0–180 min) was expressed as a percentage of the corresponding area obtained after hydrolysis of the reference WWB chewed by the same person. To predict the glycemic index (GI) from the HI in spelt wheat products, the equation introduced by Granfeldt (*31*) was used: GI = 0.862(HI) + 8.198.

Statistical Analysis. The results are expressed as means ± SEM. The in vitro rate of starch hydrolysis was statistically evaluated by one-way ANOVA using the SPSS/PC+ program (SPSS Inc., Chicago, IL). Comparisons of the means were performed by Duncan's test. A value of $P < 0.05$ was considered to be significant.

RESULTS AND DISCUSSION

The general characteristics of the material used in this study are listed in Table 1. The highest value of starch was determined in commercial wheat flour, whereas spelt wheat samples contained more proteins in comparison to wheat flour. However, the percentage of proteins in wholemeal spelt flour (cv. Ostro; extraction rate = 100%) was slightly lower (14%, dmb) than in the milled grains of the same cultivar (17%, dmb) obtained recently by Bonafaccia et al. (*18*).

The wet gluten content of white spelt flour was 39.7%, and that of the wholemeal spelt flour was 41.5%. The gluten index as a percentage of the wet gluten that remains on the standard sieve after centrifugation of wholemeal spelt flour was 10% and that of white spelt flour, 10%.

The strength measured as a W value in joules × 10^4 —analyzed by Chopin alveograph—of the white spelt flour was 160; however, that of the wholemeal spelt flour

Table 2. Contents of Starch, Proteins, and Dietary Fiber in Wheat and Spelt Wheat Bread Products

bread product	total starch (%, dmb)	proteins (%, dmb)	dietary fiber (%, dmb)		
			total	soluble	insoluble
WWB	81.2	12.4	3.9	1.1	2.8
WSB	76.3	12.7	4.6	1.6	3.0
WMSB	63.6	14.0	11.7	4.0	7.7
SSKB	74.3	12.9	7.4	3.1	4.3

Table 3. Percentage of Starch Hydrolyzed within 0–180 min[a]

time (min)	WWB	WSB	WMSB	SSKB
30	11.3 ± 0.42[ab]	12.8 ± 0.52[b]	11.0 ± 0.64[a]	11.6 ± 0.91[ab]
60	25.1 ± 0.74[a]	29.1 ± 0.64[b]	23.9 ± 1.41[a]	25.8 ± 0.61[a]
90	36.0 ± 0.99[a]	41.0 ± 0.78[b]	34.3 ± 2.14[a]	37.0 ± 0.97[a]
120	44.4 ± 1.06[a]	49.8 ± 0.85[b]	42.5 ± 2.50[a]	45.0 ± 1.01[a]
150	50.8 ± 0.97[a]	56.4 ± 0.73[b]	48.7 ± 2.68[a]	51.3 ± 1.02[a]
180	55.5 ± 1.12[a]	61.3 ± 0.86[b]	53.6 ± 2.84[a]	55.5 ± 1.07[a]

[a] Values are means ± SEM, $n = 6$. Values on the same row, followed by different letters, are significantly different ($P < 0.05$).

was 64. The low result in wholemeal spelt flour may be due to bran particles, which cause the early breakdown of alveograph bubbles. In the same way the low P/L value in wholemeal spelt wheat could also be explained. The Falling Number in white spelt wheat flour is similar to that of wholemeal spelt flour and white wheat flour, which means that in none of the samples studied were there any problems during growing or postharvesting conditions.

According to the results, the estimated technological quality of spelt wheat flours is less suitable than the quality of commercial white wheat flour. This is in agreement with the results obtained previously for Hercule spelt wheat (*18*).

In relation to the contents of total starch and proteins, the bread products did not differ from the corresponding starting material (Table 2). It was found that WSB contained more total dietary fiber (4.6%, dmb) than the reference WWB (3.9%, dmb). However, the difference was not significant. Taking flat pita bread made of spelt wheat flour (extraction rate = 73%) as the most comparable previously evaluated product (4.0% total dietary fiber, dmb), our result for fiber content in WSB is in accordance with that reported by Abdel-Aal et al. (*3*). The range obtained in the series of spelt wheat bread products (4.6–11.7%, dmb) also corresponded to that published by Bonafaccia et al. (*18*). In the case cited, the values for total dietary fiber (dmb) in breads made of white spelt flour (cv. Hercule, yield = 71%) and that of wholemeal spelt wheat flour (same cultivar, yield = 100%) were 4.4 and 12.4%, respectively.

The average rates of starch hydrolysis in spelt wheat breads following the enzyme incubation in the dialysis system are shown in Table 3. Considering the ratios between the area under hydrolysis curve of the particular spelt bread and of the reference WWB, the calculated HI and predicted GI values for different spelt products are given in Table 4.

Between the two spelt wheat breads (WMSB and SSKB) and the reference WWB there were no statistical differences in the course of starch hydrolysis. Moreover, at each time point the selected dialysis procedure gave similar results and after 180 min yielded ∼45% residual starch.

Among the samples, the highest rate of starch hydrolysis was noticed in WSB. During the first 30 min of incubation this particular bread was shown to have significantly more ($P < 0.05$) rapidly digestible starch than the WMSB and later on also more starch than in WWB and SSKB, respectively.

Table 4. HI and Predicted GI Values[a]

bread product	HI	predicted GI
WWB	100[a]	100
WSB	112.6 ± 1.74[b]	105
WMSB	95.7 ± 4.84[a]	91
SSKB	101.6 ± 2.77[a]	96

[a] Values are means ± SEM, $n = 6$. Values in the same column, followed by different letters, are significantly different ($P < 0.05$).

When the HI value was calculated, the WMSB had the lowest (95.7). However, the result did not differ significantly from that in the reference common wheat bread. On the other hand, the most refined spelt wheat flour resulted in the bread product (WSB) that was statistically withdrawn ($P < 0.05$) as one with the highest HI (112.6). Considering the total dietary fiber content in WSB and WMSB (Table 2), respectively, the increase of 7% would reduce the HI value by 17 units (Table 4).

The characteristic of spelt wheat starch as compared to that of common wheat is in accordance with the study of Bonafaccia et al. (*18*). There was reported a higher starch digestion index (SDI)—calculated as the ratio between rapidly digested and total starch (percent), in spelt wheat bread (SDI = 80)—than in common wheat bread (SDI = 68). The high digestion index of spelt wheat could be connected with the fact that in spelt wheat samples there is more protein. The extensive protein matrix in the endosperm may cause a greater extent of mechanical damaging of starch grains during the milling procedure (*26*). Concerning the HI or GI values in spelt wheat products, there are no other comparable data available in the literature. The predicted GI values for spelt wheat products (GI = 91–105) were in the range of those of other flour-based breads, the majority of breakfast cereals, rice, or potato products (*25*, *27*, *28*). As judged from our results, spelt wheat breads are not expected to improve glycemia in diabetic patients or to offer the metabolic advantages related to the reduced starch digestion pattern in individuals. However, with regard to the characteristics of starch, one may conclude that spelt wheat products such as those studied are more suitable in diets when readily digested carbohydrates are preferred. Thus, they can be used for individuals after strenuous physical activity or work, when the exhausted stores of glycogen need to be replenished (*29*, *30*), or in the design of foods for infants or patients with a sensitive gastrointestinal tract.

However, spelt wheat bread has somewhat less total starch in comparison to wheat bread. Consciously chosen breads can also serve as an alternative source of cereal proteins and dietary fiber. One of the main advantages of spelt wheat remains that it could be relatively easily grown without the use of chemicals.

ABBREVIATIONS USED

dmb, dry matter basis; DNS, 3,5-dinitrosalicylic acid; FN, falling number; HI, hydrolysis index; P/L, alveograph ratio of the curve; SDI, starch digestion index; SEM, standard error of mean; SSKB, scalded spelt wheat kernel bread; W, alveograph work of deformation;

WMSB, wholemeal spelt wheat bread; WSB, white spelt wheat bread; WWB, white wheat bread.

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