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Effect of Spelt Pearling on the Contents of Total Dietary Fibre, Wet Gluten, Protein and Starch Fractions

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Abstract

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The important nutritional characteristics of the Rubiota spelt variety, grown in the Czech Republic, were reported. We evaluated the contents of total dietary fibre, protein, wet gluten, total starch, and starch fractions, i.e. rapidly digested starch, slowly digested starch, and resistant starch in pearled grain of spelt and in pearling fines. We measured these properties depending on the degree of kernel abrasion. Small differences were found between the sequential pearling cycles in the pearled spelt but significant differences were observed in the fines. In this study we also compared two methods for determining total and resistant starch.

Keywords: fibre; rapidly digested starch; slowly digested starch; high-performance liquid chromatography

Spelt (*Triticum aestivum* subsp. *spelta*) is an ancient grain, sometimes considered a subspecies of common wheat (*Triticum aestivum*). Spelt is one of the husked hexaploid wheats. It was cultivated by ancient civilisations in Europe and in the Middle East thousands of years ago. In the 20th century spelt was replaced by modern wheat in almost all areas where it had been previously grown. The cultivation of spelt declined substantially, but the recent years, with the expansion of organic farming to grow foods ecologically, have led to its revival. Today spelt is undergoing a renaissance as a niche product in many countries of Europe (Belgium, Germany, Austria, Switzerland, Italy, Spain, Slovenia, and also the Czech Republic). This may be ascribed to the perception of spelt as a natural grain, healthier than common wheat (Bonafacia *et al*. 2000; Skrabanja *et al*. 2001; Abdel-Aal & Rabalski 2008). Spelt is a hulled grain. This is why it must undergo a costly dehulling procedure before further processing. Smaller yields per harvested area and necessary dehulling make spelt more expensive than wheat, but the hull protects the grain from pollutants, insects, and diseases, increases the content of nutrients in the kernel and improves freshness (Campbell 1997; Skrabanja *et al*. 2001; Schober *et al*. 2006). Spelt has a valuable nutritional potential due to its protein content and composition as well as to its lipids and crude fibre (Abdel-Aal *et al*. 1995; Ranhotra *et al*. 1995). Most studies found a higher protein content in spelt than in common wheat. The protein contained in spelt, as reported in the literature, ranges between 12 and 19% (Abdel-Aal *et al.* 1995; Ranhotra *et al*. 1996; Marconi *et al*. 1999, 2002; Bonafaccia *et al*. 2000; Bojňanská & Frančáková 2002).

Wilson *et al*. (2008) noted highly variable protein content in spelt. The degree of nitrogen absorption from the soil depends on the genotype and on the growing conditions. Gluten is the principal protein of the starchy endosperm and its content may vary substantially among respective spelt varieties (Anjum *et al*. 2007). Some studies reveal that the content of wet gluten fluctuates between 30 and 50% (Abdel-Aal *et al.* 1995; Skrabanja *et al*. 2001; Bojňanská & Frančáková 2002; Zielinski *et al*. 2008).

Spelt is reported to contain more lipids (about 3–4%), more concentrated in the germ and the aleurone layer than in the endosperm (Delcour & Hoseney 2010). Most studies indicate that spelt is richer in lipids than common wheat (Abdel-Aal *et*

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al. 1995; Grela 1996; Marconi *et al*. 1999). With regard to fatty acids, studies show that the proportion of oleic acid in fatty acids is higher, but the proportions of linoleic and linolenic acids are lower in spelt than in common wheat. More of saturated fatty acids were observed in common wheat than in spelt (Ruibal-Mendieta *et al*. 2004, 2005).

Spelt contains 10–14.9% total dietary fibre, the main component of which is insoluble fibre (Marconi *et al*. 1999). Most authors found a higher content of total dietary fibre in common wheat than in spelt, but these differences are not statistically significant (Abdel-Aal *et al*. 1995; Ranhotra *et al*. 1995, 1996; Escarnot *et al*. 2010).

Carbohydrates are the main components (59–71%) of the spelt kernel (Belitz & Grosch 1999). Various studies have indicated that there is no great difference in total carbohydrate, starch and sugar contents in spelt flour if compared with whole wheat flour (Abdel-Aal *et al*.1995; Ranhotra *et al*. 1995, 1996; Grela 1996). Predominantly, the spelt kernel contains 61–68% starch, whereas sugars account for 2–3% (Abdel-Aal & Hucl 2005). Bojňanská and Frančáková (2002) found 48.29–66.8% starch in spelt varieties. As for the starch particle-size distribution, Abdel-Aal *et al*. (1999) observed little difference between spelt and modern common wheat.

Starch is the major component of digestible carbohydrates in the human diet and, depending on its botanical origin and on the structural type of starch granules, is digested and absorbed at different rates and to different extents in the small intestine. From the viewpoint of digestibility, starch can be divided into three categories: rapidly digestible starch (RDS), slowly digestible starch (SDS) and resistant starch (RS). RSD and SDS are finally completely hydrolysed (Englyst *et al*. 1999).

RS is not degraded by small intestine enzymes and proceeds into the large intestine. Thus it belongs to the polysaccharides that cannot be utilised. These physicochemical properties of starch can be used to provide a description of nutritionally important aspects of food (Bonafaccia *et al*. 2000; Skrabanja *et al*. 2001; Englyst *et al*. 2003; Abdel-Aal & Rabalski 2008).

The content of RS in wheat flour is low, usually it was found not to exceed 1% (Alsaffar 2011; Šárka *et al*. 2013). It can also be influenced by the way of further flour processing (Sajilata *et al*. 2006).

The present paper deals with the impact of spelt pearling on total dietary fibre, wet gluten, total protein and starch fractions and examines their contents in the respective fractions of pearling fines and pearled grain. Another goal of this study was to find the most suitable pearling fraction for further use and specifically for its employment in baked goods.

MATERIAL AND METHOD

Material. Spelt of the Czech variety Rubiota was used for the experiments. It was cultivated in an organic farming environment without any fertilisation. Harvested grain was cleaned and dehulled in the mill. All the impurities were removed in the Petkus K531 seed cleaner (Prokop, Pardubice, Czech Republic).

The grain was then subjected to eight sequential cycles of gradual low-intensity pearling in the Ekonos peeling machine (Prokop, Pardubice, Czech Republic) abrading kernels with the help of grinding wheels). The Ekonos machine works with an engine performance of 1460 rpm (on the vertical shaft 2053 rpm) and the intensity of pearling is regulated by ventilation setting according to the desired degree of pearling.

After each pearling cycle the grain was re-cleaned by Petkus K531 and sieving of the pulverised material was carried out with sieves of mesh sizes 0.485, 0.366, 0.257, and 0.162 mm. Each pearling cycle thus yielded a certain proportion of the pearled grain and also of pearling fines (offal dust arisen from abrading the surface layers of the kernel).

Analytical methods. Wet gluten and protein contents were determined by NIR (near-infrared spectroscopy) using the Inframatic 8600 NIR spectrophotometer (Perten, Hägersten, Sweden). The measurements were performed according to ICC 202.

Total dietary fibre was determined by the enzymatic-gravimetric method AOAC 985.29 using the Bioquant enzyme set (Merck, Darmstadt, Germany). The Fibretec E filtration apparatus (Scan Tech; Foss Tecator AS, Höganäs, Sweden) was used for filtration.

The contents of rapidly available glucose (RAG), slowly available glucose (SAG), total glucose (TG) and free sugar glucose (FSG) were determined by an *in vitro* method according to Englyst *et al*. (1999), with a modification of the HPLC conditions for the determination of released glucose. HPLC system (Watrex, Prague, Czech Republic) together with the refractive index (RI) detector and the analytical column (apHera NH2; Sigma) were used for the HPLC analysis. This method is based on an enzymatic degradation of starch in the sample. The following

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enzymes were used for enzymatic degradation: pepsin, pancreatin (from porcine pancreas), amyloglucosidase (Sigma-Aldrich, St. Louis, USA) and invertin (Merck). RAG was determined as the amount of glucose released during the first 20 min (G20 = RAG) and SAG as the glucose released between 20th and 120th min of enzyme hydrolysis. Total glucose (TG) was determined as the quantity of glucose obtained after total hydrolysis with potassium hydroxide under alkaline conditions. Free sugar glucose (FSG) – including that derived from sucrose – was determined after the extraction procedures and the incubation with invertin. The values obtained in this way were used to calculate RDS, SDS, total starch (TS) and RS according to the following equations: RDS = (RAG – FSG) × 0.9; SDS = SAG × 0.9; RS = (TG – G120) × 0.9; TS = (TG – FSG) × 0.9 (Englyst *et al*. 1999).

The starch digestion index (SDI) was calculated as (RDS/TS) × 100% (Abdel-Aal & Rabalski 2008). Resistant starch was determined also by the AOAC method 2002.02 using the Megazyme kit for RS determination.

Each fraction was measured in 4 to 5 replications (for parameters RDS, SDS, TS, and RS).

The Microsoft Excel was used to determine correlations between TS (total starch determined by Megazyme) and TS* [total starch calculated according to Englyst *et al*. (2003)].

RESULTS AND DISCUSSION

Gradual pearling of spelt grain in the Ekonos peeling machine and subsequent cleaning, repeated in eight cycles, provided 8 fractions of pearled spelt and 8 fractions of the abraded material, i.e. pearling fines. Samples of both the pearled grain and the fines were taken for further analysis after each pearling and cleaning cycle.

Table 1 shows the yield of fines in respective pearling cycles (0.4–6.7%, i.e. the percentage of the offal produced by the removal of the surface layers of the grain). The total yield of the fines at the termination of the pearling procedure equalled 28.6%.

Wet gluten and protein contents were determined by NIR (near-infrared spectroscopy) based on the calibrations set up for each parameter. These calibrations, utilising a sample of wheat, were provided by the company servicing the Inframatic device. In the course of spelt pearling the values of both parameters changed only insignificantly, ranging between 33.1% and 35.5% for wet gluten and from 12.0% to 12.9% for protein, being in correlation with the values presented by some other studies. Bojňanská and Frančáková (2002) found spelt varieties to contain 30.6–51.8% wet gluten and 12.49–19.48% protein. Zielinski *et al*. (2008) found the content of wet gluten to range between 30.1 and 37.2% and the protein content between 7.5 and 10.8%, Abdel-Aal *et al*. (1995) 39.2–42.7% and 14.9–16%. respectively. Ranhotra *et al*. (1995) found the protein content to amount to 12.7% and Marconi *et al*. (2002) observed it to range between 12.8% and 16%. The accuracy of some parameters depends not only on the spelt variety, but also on the assay methodology. The NIR method belongs to the less sensitive assay methods, but it finds its use in rapid and simple determinations without the necessity of a demanding sample preparation. It is used e.g. in the evaluation of grain quality in agricultural production.

The content of total dietary fibre (TDF) in pearled spelt grain and in the fines is shown in Table 2. It can

Table 1. Yield of pearling fines (% WT) and moisture (% WT), wet gluten, protein content (% DM) in pearled grain of Rubiota spelt variety

Pearling cycle	Pearling fines yield	Pearled grain		
		moisture	wet gluten	protein
I	0.4	12.2	35.5	12.9
II	1.0	12.3	34.5	12.5
III	2.0	12.3	34.0	12.3
IV	5.7	12.3	34.5	12.5
V	5.0	12.4	34.5	12.5
VI	5.8	12.3	33.5	12.2
VII	6.7	12.1	33.1	12.0
VIII	2.0	12.2	34.8	12.6

Table 2. Total dietary fibre (% DM) in Rubiota spelt variety (raw grain 9.53% DM)

Rearling cycle	Grain	Fines
I	9.14	32.25
II	9.09	30.45
III	8.68	22.84
IV	8.34	16.23
V	9.02	13.73
VI	8.58	10.53
VII	8.70	7.69
VIII	8.51	7.25

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Table 3. Rapidly available glucose (RAG), slowly available glucose (SAG), rapidly digested starch (RDS), slowly digested starch (SDS), and starch digestion index (SDI) values (% WT) of Rubiota spelt variety – fines and pearled grain

Pearling cycle	Fines grain					Pearled grain				
	RAG	SAG	RDS	SDS	SDI	RAG	SAG	RDS	SDS	SDI
I	13.22	13.99	10.35	12.59	40.99	22.38	40.80	19.75	36.72	34.02
II	13.34	17.26	10.43	15.53	39.43	22.66	40.20	19.92	36.18	34.26
III	15.54	19.42	12.4	17.48	39.42	22.05	40.81	19.44	36.73	33.51
IV	18.11	21.02	14.72	18.92	42.13	22.76	42.39	20.02	38.15	33.70
V	21.77	25.12	17.98	22.61	42.51	22.26	42.26	19.72	38.03	33.02
VI	23.43	25.75	19.49	23.18	44.32	22.71	43.24	20.03	38.92	33.35
VII	26.70	29.66	22.42	26.69	44.14	22.82	43.16	20.13	38.84	33.38
VIII	27.15	31.38	22.82	28.24	43.69	23.41	43.03	20.66	38.73	33.97

be seen from the results that progressive pearling causes the TDF content to decrease.

The gradual reduction of the TDF content in pearl fractions I to VIII was very low, from 9.14 to 8.51%, whereas in the fines its drop was quite conspicious, from 32.25 to 7.25%, the value in fraction VIII approaching those found in the pearled spelt. The changes in TDF were caused by the gradual attrition of the surface layers of the kernel. The content of TDF in the unpearled grain amounted 9.53% and generally correlated with other studies, or was slightly lower. Ranhotra *et al.* (1996) found the range of TDF to be 10.1–11.6%, Marconi *et al.* (1999) 10.5–14.9%, Abdel-Aal *et al.* (1995) 9.8–10.3%, and Escarnot *et al.* (2010) 8.5–11.9%. Compared with common wheat, most studies presented lower TDF values for spelt. However, the differences were not statistically significant.

Table 3 shows the values of RAG, SAG, RDS, SDS, and SDI for pearling fines and for pearled grain. It can be seen from the results that in the fines the values of these starch fractions changed noticeably, whereas in pearled spelt these changes were only minor and the degree of grain abrasion influenced the starch fraction values only to a small extent. The studies by Abdel-Aal and Rabalski (2008) and Bonafaccia *et al.* (2000) mentioned the possible influence of the method of grain grinding, suggesting that the more intensive grinding contributes to the disintegration of starch granules, which thus become more easily accessible to the enzymes. So far this theory has not manifested itself markedly in our results. The hypothesis by Englyst *et al.* (1999) claims that the RAG value predicts the glycaemic response to foods. According to these authors the RAG content in common wheat flour equals 35%. It seems clear from our results that the RAG value for spelt grain was lower (22.38–24.09%), but significantly higher when compared with the results published by Abdel-Aal and Rabalski (2008). These authors found the RAG values for spelt to range between 6.3 and 9.2%, depending on whether that spelt was ground in the laboratory or at an industrial facility.

The RAG value assayed includes the quantity of free glucose, glucose released from sucrose, and glucose from RDS or starch digested after 20 min incubation with digestive enzymes under defined conditions. The relative standard deviations (RSD) ranged from 2.1% to 5.3% for RAG, SAG, and TG. The starch digestion

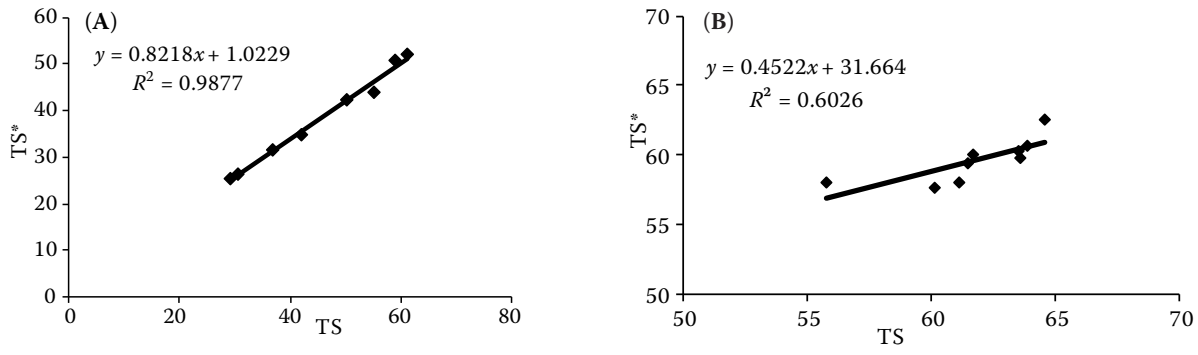

Figure1. Correlation between TS (WT %) and TS*(WT %) for (**A**) pearling fines and (**B**) pearled grain of spelt

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Table 4. RS and TS values (% WT) of Rubiota spelt variety – fines and pearled grain

Pearling cycle	Fines				Pearled grain			
	RS	TS	RS*	TS*	RS	TS	RS*	TS*
I	0.26	29.19	1.65	25.25	0.98	55.79	1.50	57.95
II	0.24	30.50	1.49	26.45	1.31	60.15	1.66	57.63
III	0.28	36.72	1.58	31.46	1.25	61.11	1.83	58.01
IV	0.30	42.13	1.31	34.94	0.70	61.45	1.18	59.41
V	0.26	50.25	1.70	42.30	0.70	63.60	1.79	59.54
VI	0.32	55.23	1.30	43.97	0.74	63.55	1.36	60.31
VII	0.38	58.95	1.67	50.79	0.45	61.67	1.84	60.81
VIII	0.26	61.12	1.16	52.23	0.50	63.90	1.27	60.67

RS, TS – resistant and total starch determined by Megazyme; RS*, TS* – resistant and total starch calculated according to Englyst *et al.* (2003)

index (SDI), which is the ratio between RDS and TS, was calculated for each fraction. Progressive abrasion only increased the SDI very slightly (pearled grain 34.02–35.07%; fines 40.99–43.69%).

In another part of our study we compared two methodologies of TS and RS assay in pearling fines and in pearled spelt in the course of pearling (Table 4).

These parameters were determined by the method using the Megazyme kit, and also calculated from the contents of starch fractions according to Englyst *et al.* (1999). It can be seen from the results that the TS values obtained by the Megazyme method slightly differed from the calculated values. The pearling fines showed a very good correlation (R^2 = 0.9877), whereas a weaker correlation (R^2 = 0.6026) was found in the pearled grain (Figure 1).

The relative standard deviations for values obtained by the Megazyme kit were rather high. For RS of the pearling fines they ranged from 1.9 to 14.1% (average 8.8% RDS) and for RS of the pearling grain they ranged from 7.6 to 22.0% (average 14.8% RDS).

In some fractions the RS values calculated according to Englyst *et al.* (2003) were higher than the values determined with the help of the kit. These differences can be explained by high sensitivity to the accuracy of both these methods, and by the fact that they are very demanding. The methodology of determining RS with the help of the Megazyme kit states that RS values below 2% can be burdened with a more substantial error because, in addition to very high sensitivity, the method utilizes very low sample weights.

A comparison of these two methods for the determination of resistant starch in several matrices was presented by Moore *et al.* (2014). In their presentation the authors concluded that the method proposed by Englyst *et al.* (2003) yielded higher results than the determination methodology using the Megazyme kit.

The study by Abdel-Aal and Rabalski (2008) presents the RS value equalling 3.25% in a single variety of laboratory-scale pearled spelt and 4.12% in commercially pearled spelt, which is significantly more than found in our work. However, these authors suggest that the variation of the RS content in various spelt varieties can be wider, also because of their genome, and that some of the spelt materials used may represent spelt hybrids exhibiting RS values lower than 1%. However, it is necessary to point out that the analytical parameters of pearls and fines presented in that study could be influenced by the method of attrition.

CONCLUSIONS

The purpose of this study was to characterise the Czech spelt variety Rubiota in terms of certain important nutrients and to observe how these substances change in response to eight cycles of grain pearling in the Ekonos peeling machine, with the aim to find the most suitable level of pearling for the potential incorporation of pearled grain into spelt products. On the basis of the analytical data obtained and presented in this study we came to the conclusion that in the course of progressive pearling the values of observed grain parameters (total dietary fibre, proteins, starch fractions) changed only very slightly and hence the degree of grain abrasion did not have any principal and marked effect in the choice of the most suitable level of pearling. Beside the pearled

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grain, we also observed the changes of the fibre and starch fractions in the fines, which showed somewhat more explicit changes in their parameters (TDF, RDS, SDS, and TS). In this connection it is worth considering the possibility of adding a reasonable amount of the fines to baked goods to introduce an interesting nutritional benefit in the form of increased dietary fibre and reduced glycaemic index, without impairing their palatability. This study, focused on the starch fraction analysis, provides an impetus to continue exploring this topic, and to describe grain pearling and milling more precisely, and also to evaluate suitable comparative analytical methods, namely the assay of respective starch fractions in raw materials as well as in final products.

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