

NUTRITIONAL VALUE AND BAKING APPLICATIONS OF SPELT WHEAT*

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Abstract. Cereals represent the most important group of crops in the structure of plant production from the economic, agronomic and consumer point of view. Spelt wheat (*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. Spelt is generating increasing interest due to its agronomic, nutritional and medical characteristics. Despite of these spelt bread benefits, spelt is wheat that contains gluten proteins and is capable of provoking wheat allergy and gluten enteropathy. This review describes nutritional composition (proteins, aminoacids, starch, sugars, fiber, lipids, fatty acids, sterol, vitamins, ash and mineral compounds) of spelt wheat and potential using of this cereal for baking application (flour, bread, breakfast cereals, pasta, crackers, nutrition bars, biscuits and some regional specialities).

Key words: spelt wheat, nutrition value, application, cereal technology

INTRODUCTION

At present there is considerable interest in the consumption of alternative crops [Berti et al. 2005]. Spelt wheat (*Triticum aestivum* subsp. *spelta*) is one of the husked hexaploid wheats which possesses the same genomes as bread wheat (*Triticum aestivum* L.) [Yan et al. 2003]. It is an old European crop, grown for centuries, including the first half of this century, in several countries of central Europe (e.g. Belgium, Germany, Austria, Slovenia, and northern parts of Italy), also in Canada and USA [Bonifácia et al. 2000, Rozenberg et al. 2003]. Other small areas of cultivation are still encountered, such as in Spain and in the Czech Republic [Bertin et al. 2004]. For many years, cultivation of spelt declined, but recent interest in use of spelt for ecologically grown foods has led to

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resurgence in its cultivation [Bonifácia et al. 2000, Zieliński et al. 2008]. Spelt wheat is a low-input plant, suitable for growing without the use of pesticides, in harsh ecological conditions and in marginal areas of cultivation [Bonifácia et al. 2000]. Even with low fertilizing spelt wheat gives a good harvest and has a better mineral uptake in comparison with *Triticum aestivum* L. [Bojňanská and Frančáková 2002].

There are few, but marked, differences between spelt and common wheat [Campbell 1997, Onishi et al. 2006]. Compared with wheat, spelt is taller (150 ± 20 cm), has long, lax ears (15 ± 20 cm), a brittle rachis and adherent glumes [Campbell 1997, Yan et al. 2003, Bertin et al. 2001, Onishi et al. 2006]. Spelt is harvested as a hulled grain and must undergo a costly dehulling procedure before being introduced into the milling process [Ranhorta et al. 1995]. The spelt flour is characterised by the yield of about 65% [Zieliński et al. 2008]. It is caused by a tough spelt hull, which makes it more difficult to process than modern wheat and rye varieties. The hull protects the grain from pollutants and insects and enhances the retention of nutrients in the kernel and improves freshness [Ruegger et al. 1990, Abdel-Aal et al. 1997]. The smaller yields per area and the necessary dehulling [Büren et al. 2001] make spelt more expensive than wheat.

CHEMICAL COMPOSITION OF SPELT WHEAT

The nutritive value of spelt wheat is high and it contains all the basic components which are necessary for human beings [Bojňanská and Frančáková 2002]. Differences may be due to the growing place and season, cultivation, fertilizers [Puimalainen et al. 2002]. It is also believed that spelt possesses valuable nutritional potential due to its protein content and composition as well as its lipids, crude fibre [Abdel-Aal et al. 1995, Forssel and Wieser 1995, Ranhorta et al. 1995, 1996 a, Kasarda and D'Ovidio 1999, Wieser 2001, Abdel-Aal and Hucl 2002, Pruska-Kędzior et al. 2008], vitamin and mineral content [Ranhorta et al. 1995].

Spelt is reported to have higher protein content and a higher participation of the aleurone layer in the kernel than common bread wheat [Bojňanská and Frančáková 2002]. Marconi et al. [1999] found in five spelt cultivars 14.3-18.4%, Ranhorta et al. [1995] determined only 12.7%, Loje et al. [2003] 15.4% and Marconi et al. [2002] only 11.4-13.7% of proteins. Abdel-Aal [2007] determined 15.4% of proteins in the laboratory milled wholemeal spelt flour but only 15% in the commercially milled wholemeal spelt flour. Zieliński et al. [2008] found only 7.5-10.8% of proteins in the spelt grains originated from Polish breeding. Bojňanská and Frančáková [2002] described 12.49-19.48% of proteins in the five spelt cultivars (*Rouquin*, *Bauländer Spelz*, *Schwabenkorn*, *Franckenkorn* and *Holstenkorn*). Protein content can be significantly affected by location and agronomic technique [Marconi et al. 1999].

Gluten proteins, representing the major protein fraction of the starchy endosperm, are predominantly responsible for the unique position of wheat amongst cereals [Anjum et al. 2007]. The amount of wet gluten as an indicator is closely connected with the baking quality of bread grains [Bojňanská and Frančáková 2002]. Spelt usually observes a higher yield of wet gluten and higher gluten spreadability, i.e. weaker gluten structure [Schober et al. 2002, 2006, Pruska-Kędzior et al. 2008]. The wet gluten content of spelt can vary a great deal between cultivars. Differences may result from the individual properties of the cultivars as well as from the level of nitrogen fertilizer

added [Schober et al. 2002]. Zieliński et al. [2008] found from 30.1 to 37.2% of wet gluten in the spelt grains originated from Polish breeding, Bojňanská and Frančáková [2002] described 30.6-51.8% in the five spelt cultivars. Gluten, comprising roughly 78-85% of total wheat endosperm protein, is a very large complex composed mainly of polymeric (multiple polypeptide chain) and monomeric (single chain polypeptides) known as glutenins and gliadins, respectively [Shuaib et al. 2007]. Rheological properties of common and spelt wheat dough depend largely on gluten matrix viscoelastic properties, which are predetermined by the qualitative and quantitative composition of monomeric gliadin(s) and polymeric glutenin(s) fractions [Pruska-Kędzior et al. 2008]. There are some essential differences between spelt and common wheat in the number of fractions and molecular masses of α -, γ -, and ω -gliadins as well as HMW (high molecular weight) and LMW (low molecular weight) glutenin subunits (GS) [Radić et al. 1997, Radić-Miehle et al. 1998, Tilman et al. 2003]. RP-HPLC reveals much higher content of total gliadins and lower total glutenins in spelt. The gliadins/glutenins ratio is significantly higher in spelt, and α -gliadins are predominant, followed by γ -gliadins, and LMW-GS; ω -gliadins and HMW-GS are generally minor components [Pruska-Kędzior et al. 2008].

Wheat proteins are known to be low in some amino acids that are considered essential for the human diet, especially lysine (the most deficient amino acid) and threonine (the second limiting amino acid), but they are rich in glutamine and proline, the functional amino acids in dough formation. It was stated that the amino acid composition of the proteins from spelt differs slightly from that of modern bread and pasta wheats [Abdel-Aal and Hucl 2002] and that lysine (and probably other amino acids too) are better assimilated from spelt than from the common wheat [Ranhorta et al. 1995]. Belitz et al. [1989] found that lysine and methionine content were in the range of comparable cultivars of wheat, but the cysteine content was higher in spelt wheat than in common wheat. It was also demonstrated that some spelt wheats were slightly lower in lysine and higher in glutamic acid than those in hard red spring wheat [Abdel-Aal and Hucl 2002].

Starch is the main storage carbohydrate in plants [Han et al. 2007]. Zieliński et al. [2008] found from 71.6 to 85.4% of starch content in the spelt grains originated from Polish breeding and Bojňanská and Frančáková [2002] determined only 48.29-66.8% in the five spelt cultivars (*Rouquin*, *Bauländer Spelz*, *Schwabenkorn*, *Franckenkorn* and *Holstenkorn*). Bonifácia et al. [2000] described that the starch in spelt wheat under-goes hydrolysis more rapidly in the first period; thus products could be used in diets where readily digested carbohydrates are preferred. It was also found that if spelt wheat contains more protein than common wheat, it might be possible that proteins are firmly bound in starch granules, in the matrix. During milling, a greater extent of breakage of starch granules and thus higher starch digestion index is expected in the case of spelt wheat [Bonifácia et al. 2000].

Marconi et al. [2002] found fewer reducing sugars in the spelt flours (0.29-0.39%) than in the semolina samples (0.48-0.53%). The nutritional composition also showed that wheat bread is richer in maltose than spelt bread (1.61 g per 100 g for spelt vs. 3.64 g per 100 g for wheat) [Marques et al. 2007].

Total fiber content in spelt cultivars varied from 10.5% db (dry basis) (*Ebners Rotkorn*) to 14.9% db (*Triventina*) [Marconi et al. 1999]. These values are in agreement with data obtained by Ranhotra et al. [1996 a, b]. However, from a nutritional point of view, it is important to differentiate between soluble and insoluble fiber, since each

form is considered to have particular physiological effects and benefits as a constituent of the human diet [Jenkins et al. 1995]. Soluble fiber contents shows a wide variability in spelt cultivars, ranging from 1.2% db (*Balmegg*) to 2.4% db (*Oberkulmer*) and 2.5% db (*Rouquin*), which represented 8.7, 21.1, and 19.7% of total dietary fiber content, respectively [Marconi et al. 1999]. Bonifácia et al. [2000] found in 3 spelt cultivars higher content of soluble dietary fiber (1.7-1.8% dmb-dry matter basis) in comparison to the common wheat (1.4% dmb). Insoluble dietary fiber was the major fiber component in the wheat species, soluble fiber representing only 17% of total dietary fiber [Abdel-Aal et al. 1995]. Ranhorta et al. [1996 b] determined in the 15 spelt cultivars (in average 8.1 g per 100 g) lower content of insoluble fiber than in the common wheat (10.5 g per 100 g). Bonifácia et al. [2000] found in 3 spelt cultivars in average higher content of insoluble dietary fiber (11.2-12.1% dmb) in comparison to the common wheat (11.4% dmb). Analysis of fibre also showed a lower soluble fibre content in spelt bread vs. wheat bread (1.45 g per 100 g for spelt vs. 1.76 g per 100 g for wheat) [Marques et al. 2007].

β -glucan is a major cell wall carbohydrate which is isolated from cereal grains [Demirbas 2005]. Marconi et al. [1999] found that total β -glucan content in five spelt wheat cultivars was low (1.16% db, mean value) and was similar to that of common wheats. These results are in agreement with authors Demirbas [2005] and Loje et al. [2003] that determined in spelt wheat from 0.6 to 1.2% and 0.7% of β -glucan.

Even though being minor constituent, cereal lipids are quite a complex family of components, present both as free and bound to various other constituents in the cereal, including proteins and starch [Ruibal-Mendieta et al. 2002]. Results of Ruibal-Mendieta et al. [2005] showed that, on average, spelt wholemeals and milling fractions were higher in lipids and unsaturated fatty acids as compared to wheat, whereas tocopherol content was lower in spelt, suggesting that the higher lipid content of spelt may not be related to a higher germ proportion. Ruibal-Mendieta et al. [2002] stated that spelt differs from winter wheat by higher free and total lipid content (on average, 1.3 times and 1.2 times respectively). Marconi et al. [1999] and Grela [1996] determined high lipid content in different spelt cultivars of the five spelt cultivars (by mean = 4.4% db and 3.8% db). These findings could suggest that the germ was present in higher proportions in the kernels of spelt than in those of common wheats [Marconi et al. 1999]. Another hypothesis is that in spelt, the lipid content of the aleurone layer (also a lipid-rich fraction of the kernel) could be higher than that of wheat [Ruibal-Mendieta et al. 2002]. Spelt has also higher unsaturated fatty acid/palmitic acid ratio than wheat, which results from a nearly double level of oleic acid [Ruibal-Mendieta et al. 2005]. The proportion of monounsaturated fatty acids in the spelt flour was found twice as high than of wheat flour [Marques et al. 2007]. Ranhorta et al. [1995] concluded that because spelt grain has a little higher in fat and utilizable carbohydrates (starch and sugars), it contains about 3% more energy (324 vs. 315 kcal per 100 g) than hard red wheat grain. These authors [Ranhorta et al. 1996 b] also showed that energy content for another spelt wheat cultivars was slightly higher (in average about 321 kcal per 100 g) as a common wheat (318 kcal per 100 g).

Ruibal-Mendieta et al. [2004] concluded that spelt and winter wheat exhibit not only similar sterol profiles (β -sitosterol, campesterol, Δ^5 - and Δ^7 -avenasterol, stigmasterol and cholesterol (unsaturated), and sitostanol and campestanol (saturated) but also similar sterol contents, as studied in saponified samples.

Spelt wheat is reported to have high vitamin content. Differences in composition of B vitamins among the wheats are not large, especially for thiamine, which amounted to about 0.6 mg per 100 g. Riboflavin is relatively high in einkorn and common wheat (about 0.5 mg per 100 g) but was low (0.15 mg per 100 g) in the spelt accessions. On the other hand, spelt cultivars PGR8801 and RL5407 had higher concentrations of niacin (5.5 mg per 100 g) compared to einkorn, spelt SK0263, and common wheat (2.5 mg per 100 g) [Abdel-Aal et al. 1995]. Ranhorta et al. [1995] analysed three B vitamins, thiamine, riboflavin and niacin and found that only niacin was higher (5%) in spelt wheat compared with hard red winter wheat. Among the fat-soluble vitamins, there are no significant differences among wheats in contents of vitamin A, E, and D [Abdel-Aal et al. 1995]. Piergiovanni et al. [1996] found in the 37 wheat accessions from 2 to 4.2 ppm of carotene on dry basis. Abdel-Aal [1995] showed that spelt wheat accessions were significantly higher content of β -carotene and retinol equivalent than hard red spring wheat.

Furthermore, a parameter as simple as ash content allows the discrimination of spelt from wheat milling products [Ruibal-Mendieta et al. 2005]. Zieliński et al. [2008] found from 0.43 to 0.61% of ash content in the spelt flours (with extraction rate of 65-70%) originated from Polish breeding. Bojňanská and Frančáková [2002] determined 1.79-2.36% of ash in the five spelt cultivars. Ruibal-Mendieta et al. [2005] presented higher ash content in dehulled spelt (1.83%) in comparison with wheat (1.49%). The high ash content is due to the high content of macro- and microelements [Forssell and Wieser 1995, Ruibal-Mendieta et al. 2005, Zieliński et al. 2008]. Compared to wheat, spelt has, on average, 30-60% higher concentrations of Fe, Zn, Cu, Mg, and P, which is most pronounced in fine bran and coarse bran, where cereal minerals are naturally concentrated [Ruibal-Mendieta et al. 2005]. Ranhorta et al. [1995] found that spelt grain was higher in P (by 19%), Fe (by 20%), K (by 7%) and Zn (by 91%) in comparison to the hard red winter wheat. In contrast to minerals, and especially P, the phytic acid content tends to be 40% lower in spelt than in wheat, as indicated by our data obtained in fine brans, where aleurone cells, which naturally contain phytic acid [Lopez et al. 2002], are the most concentrated [Ruibal-Mendieta et al. 2005].

In some practices of alternative medicine, spelt wheat have been proposed for inclusion in the diet of patients being treated for health problems such as [Abdel-Aal et al. 2002] colitis ulcerosa, neurodermitis and others allergies [Ranhorta et al. 1995, Zieliński et al. 2008], high blood cholesterol [Rozenberg et al. 2003, Zieliński et al. 2008] rheumatoid arthritis, depression and cancer [Abdel-Aal et al. 2002]. Despite of these spelt benefits, spelt is wheat that contains gluten proteins and is capable of provoking wheat allergy and gluten enteropathy [Zieliński et al. 2008]. Spelt is not safe grain for people with celiac disease [Kasarda and D'Ovidio 1999]. In gluten-sensitive patients was not confirmed, in accordance with the fact that spelt tested positive for gluten [Friedman et al. 1994, Ranhorta et al. 1996 b, Wieser 2000, Piergiovanni and Volpe 2003, Sandberg et al. 2003] and that α -type gliadin from spelt and wheat shared >95% homology [Kasarda and D'Ovidio 1999, Ruibal-Mendieta et al. 2005].

BAKING APPLICATIONS OF SPELT WHEAT

Spelt has shown good potential in a variety of end-uses [Abdel-Aal and Hulc 2002] depending on genotype, cultivar and processing conditions [Abdel-Aal et al. 1998, Abdel Aal 2007]. This cereal is intended both for animal feeding (as a ground grain) [Ranhorta et al. 1995, Büren et al. 2001] and human consumption [Rozenberg et al. 2003, Büren et al. 2001, Zieliński et al. 2008]. Today, more spelt-based products are available including flour, bread, breakfast cereals, pasta, crackers [Marques et al. 2007] and number of regional specialties (e.g., the Grünkern of southern Germany) [Büren et al. 2001].

Grünkern is spelt that has been harvested with thrashers while the grain is still green and subsequently dried in big ovens. It originates from Southern Germany. Traditionally, Grünkern has been used in soups (Grünkern Suppe), as starches, sauces, puddings and pastries. The sensory properties have been described as 'smoky' and 'rich in aroma' [Puumalainen et al. 2002].

Spelt flour is usually available in health-food stores [Zieliński et al. 2008] at prices up to 50% above the price of comparable wheat flour in these stores [Büren et al. 2001]. In the United States, spelt flour and resultant breads and pasta products are now promoted and marketed in some states (Michigan and Ohio) [Ranhorta et al. 1995]. Spelt and wheat flours are often mixed in some cases for an improved baking quality [Radić-Miehle et al. 1998, Bojňanská and Frančáková 2002].

The use of spelt in bread production is possible: bread with the addition of spelt flour is characteristic by a strong bread smell, excellent taste and it stay longer fresh and soft [Bojňanská and Frančáková 2002]. This cereal shows behaviour different from modern wheat in baking [Schober et al. 2002]. Dough made from spelt flours is characterised by lower stability, less elasticity, and higher extensibility than common wheat dough. Spelt dough is very soft and sticky after kneading; thus, handling spelt dough is more difficult, and the loaf volume is generally lower than modern wheat cultivars [Abdel-Aal et al. 1997, Schober et al. 2002, Zanetti et al. 2001, Pruska-Kędzior et al. 2008, Bonifácia et al. 2000, Schober et al. 2002]. For the technological treatment-flour from spelt wheat requires in comparison with flours from common wheat the addition of ascorbic acid because of the strength of the gluten structure and the reduction of dough extensibility [Bojňanská and Frančáková 2002]. If the rest period of spelt dough is prolonged from 30 min to several hours, the loaf volume describes and no ascorbic acid is used [Schober et al. 2002].

In southern Germany, such spelt speciality breads do exist traditionally (e.g., Oberschwäbische Seelen, a kind of longish roll, weighing ≈ 80 g, with an irregular shape and crumb structure and a crisp crust). Seelen are usually sprinkled with salt and caraway seeds [Schober et al. 2002].

Ranhorta et al. [1995] found that bread made from spelt wheat showed lower volume and had a rather open coarse texture compared to the wheat bread. These authors concluded that spelt bread would probably be acceptable if promoted as speciality bread. Abdel-Aal et al. [1997] made bread from spelt flour only, but such bread had worse volume, texture and crumb colour in comparison to bread made from hard red spring wheat. The sensory aspect of such bread was evaluated as average. Bojňanská

and Frančáková [2002] tested baking quality of five spelt cultivars and for bread preparation recommended cultivar *Holstenkorn* because breads made from these cultivars had excellent taste and good crumbing. Abdel-Aal [2007] appraised slight differences between organic spelt and common wheat bread and sour dough bread products in protein digestibility.

Radić-Miehle et al. [1998] suggested that spelt flours are, in general, rather suitable for pasta production. At present, there are limited and incomplete data on the ability of spelt to produce alimentary pasta of suitable quality [Marconi et al. 1999]. Protein content emerged as the key factor in the pasta making performance of spelt [Marconi et al. 2002]. Marconi et al. [1999, 2002] demonstrated that as long as protein content is >13.5% (corresponding to 15% protein content in grains) and high drying temperatures are used, spelt flours can be processed in manufacturing pasta with satisfactory cooking quality. Otherwise, the vital gluten extracted from spelt flour can be successfully used to increase flour protein content and to improve pasta making potential of those spelt samples characterized by low protein content. Marconi and Carcea [2001] described that the relative lack of yellow colour coupled with a redder tinge of spelt pasta was not a problem for consumers because users of whole meal, health, or organic foods are prepared to accept pasta that is not amber yellow.

Ruibal-Mendieta et al. [2002] presented that spelt fine bran is a particularly suitable raw material for nutrition bars because it combines high mineral and unsaturated fatty acid contents, a low proportion of P in the form of phytic acid, a slightly sweet taste, and a composition still rich enough in starch to manufacture biscuit-like bars. Abdel-Aal et al. [1998] showed that from hard spelt wheat can be prepared a flaked breakfast cereal with appealing flavour and texture. Abdel-Aal [2007] described using of spelt wheat for preparation of bread, sour dough bread, biscuits, cookies and muffins. Hempel et al. [2007] presented application of spelt for manufacture of prebiotic wafer crackers containing inulin syrup. Abdel-Aal et al. [1998] suggest using of spelt flour for making two-layer flat breads.

These food applications show diverse use of spelt; and reasonable quality of spelt products can be achieved by choosing the right cultivar and/or by manipulating processing conditions [Abdel-Aal 2007].

CONCLUSION

The expansion of the cultivation of spelt largely depends on the possibility of using it in the production of various products such as pasta, flakes, etc., with good sensorial and nutritional properties [Abdel-Aal et al. 1998, Marconi et al. 2002]. Further, spelt wheat and its products could serve as an abundant source of protein and, lastly, a great proportion of soluble fibre emerges in the final spelt wheat product [Bonifácia et al. 2000]. Now that consumers are increasingly interested in health and their knowledge of the relationship between diet and well-being has raised, wheat spelt is likely, to gain interest and popularity [Zieliński et al. 2008]. As the consumption of spelt food products is steadily increasing, there is a need to evaluate their nutritional quality in comparison with normal wheat products [Abdel-Aal 2007].

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WARTOŚĆ ODŻYWCZA I PRZYDATNOŚĆ WYPIEKOWA PSZENICY ORKISZ

Streszczenie. Pszenica orkisz (*Triticum spelta* L.) jest od dawna znaną rośliną zbożową spokrewnioną z pszenicą (*Triticum aestivum* L.). Była ona uprawiana już setki lat temu i obecnie jest „odkrywana” na nowo w Europie i Ameryce Północnej. Wzbudza duże zainteresowanie ze względu na jej właściwości zdrowotne i żywieniowe. Pszenica orkisz jest przydatna do wyrobu chleba, ale zawiera gluten i może być przyczyną groźnych uczuleń. Przegląd opisuje podstawowy skład tego zboża (białka, aminokwasy, skrobia, cukry, włókna, tłuszcze, kwasy tłuszczowe, sterole, witaminy i składniki mineralne) oraz jego przydatność w piekarnictwie (mąki, chleby, płatki śniadaniowe, makarony, batony odżywcze, biszkopty oraz niektóre specjały regionalne).

Słowa kluczowe: pszenica, orkisz, wartość odżywcza, zboża, pieczywa

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