Chemical Composition and Nutritional Value of Emmer Wheat (*Triticum dicoccon* Schrank): a Review

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Abstract

Cereals represent the most important group of crops in the structure of plant production from the economic and agronomic point of view. Cereals are widely consumed and are a valuable sources of delivering components with biological activity to humans. They are one of the most abundant sources of protein and energy and are consumed as bread – a major staple food – in most countries throughout the world. The cultivated hulled wheats emmer, einkorn, and spelt, are among the most ancient *Triticeae* cultivated in the world and have long represented a staple food. However, the move in recent years toward more natural foods and sustainable agriculture and the rediscovery of ancient foods and flavours have brought renewed interest in these neglected species. Emmer wheat (*Triticum dicoccon* Schrank) is rich in resistant starch, minerals, fibre, carotenoids, antioxidant compounds, and poor in fats; it has been recognized as a very healthy cereal and is recommended in the diet for people suffering from allergies, colitis, diabetes and high blood cholesterol. For these reasons, research activities and selection programs are being conducted to assess the genetic, agronomic, nutritional and technological properties of emmer wheat. The main results of studies and the knowledge acquired about the chemical and nutritional composition (protein content, digestible carbohydrates, dietary fibre, lipids, vitamins, and minerals) are reviewed in this paper.

Keywords: chemical composition, emmer wheat, nutritional value, *Triticum dicoccon* Schrank

Introduction

Recent food crises have caused consumers to look for more authentic and safer foods. Organic food production is widely recognised as being friendlier to the environment, more controlled, better for animal welfare and human health (Rembiałkowska, 2007). The increasing popularity of organic agriculture and health food products has led to a renewed interest in hulled wheats species. As the name suggests, the main character that separates the hulled wheats from the free-threshing wheats is the persistent enclosing hull. Hulledness in wheat involves other important characteristics. The thick, tough glumes of hulled wheats give excellent protection to the grains in the field and in storage (Nesbitt and Samuel, 1996).

Hulled wheat (in botanical sense) denotes any wild or cultivated *Triticum* population with nonthreshable grain. Their kernels are covered by tough paleas and spikelet glumes; thus, the threshing product is spikelets, not grains (Feldman, 2001). From a genetic point of view "hulled wheat" represents an *ad hoc* group of *Triticeae,* owning a dominant gene, the Q factor. As threshability is a character selected mostly in cultivation, hulledness is characteristic primarily for neglected, obsolete, spontaneous or wild wheats (Szabó and Hammer, 1996; Luo et al., 2000). The cultivated hulled wheats einkorn (*Triticum monococcum* L., diploid: 2n=2x=14 chromosomes, AA genome), emmer (*Triticum dicoccon* Schrank, tetraploid: 2n=4x=28 chromosomes, AABB genome) and spelt (*Triticum spelta* L., hexaploid: 2n=6x=42 chromosomes, AABBDD genome) (Szabó and Hammer, 1996), known in Italy under the common name of "farro", are among the most ancient *Triticeae* cultivated in the world and have long represented a staple food (Marconi and Cubadda, 2005).

Small amounts of ancient hulled wheat species may still be grown in some countries for traditional foods, but there has been renewed interest in them in recent years as they have been proposed to be rich sources of bioactive components and hence suitabile for producing high value food products with enhanced health benefits (Ruibal-Mendieta et al., 2005; Lachman et al., 2013; Shewry and Hey, 2015).

Cultivated emmer wheat (*Triticum dicoccon* Schrank) is one of the oldest crop in the world and has been a staple crop over millennia (Zohary and Hopf, 1993; Nesbitt and Samuel, 1996; Damania, 1998). It was one of the basic plants in Neolithic agriculture and its domestication was a determining factor for the beginning of agriculture (Zohary, 2004). It was widely cultivated in antiquity, particularly in Egypt, and until recently in a large range of countries. It is now a minor crop, cultivated mainly in isolated, marginal areas where no other crop can be grown economically, where its typical characteristics, such as the ability to adopt to poor and stony soils, resistance to low temperatures, considerable ability to control weeds, and resistance to diseases common to other cereals can be used as advantage. Emmer wheat consequently represents a valuable genetic resource to improve resistance to biotic and abiotic stress in bread wheat and durum wheat (Dorofeev et al., 1979; Castagna et al., 1996; Marconi and Cubadda, 2005; Zaharieva et al., 2010). Some of the ancient wheats have unique composition in secondary components, such as carotenoids and starch, which play a role as functional food ingredients. Emmer is particularly appreciated for its content of resistant starch, fibre, carotenoids, and antioxidant compounds (Serpen et al., 2008).

Chemical and Nutritional Composition of Emmer Wheat

Although several articles on emmer wheat chemical composition have appeared in the literature in recent years, there are very few that deal specifically with emmer proximate composition and its variability, which depends on genetic and environmental factors. A study by Marconi and Cubadda (2005) showed the proximate composition of the whole meal and the refined flour of three emmer genotypes. The proximate composition of emmer meal, when compared at the same level of refinement, is similar to that of spelt, durum, and bread wheats.

Protein Content

Proteins are a source of energy and provide essential amino acids. They are concentrated in the cells of the aleurone layer, the pericarp and the germ, with a lower content in endosperm (Fares et al., 2003). Emmer wheat is reported to have higher protein content and a higher participation of the aleurone layer in the kernel than common bread wheat. The few data available in the literature on protein content of emmer wheat show a great variability of this parameter. Differences may be due to the growing place and season, cultivation, fertilizers (Marconi et al., 1999; Puumalainen et al., 2002). If all analyses were performed using Kjeldhal method, the variability could be explained by the growing conditions (environment and nitrogen fertilization) and genetic background that influence protein content (Dupont and Alltenbach, 2003).

Perrino et al. (1993, cit. Cubadda and Marconi, 1995) found high mean values of 17.1% dry basis (db) in fifty emmer accessions, whereas other researchers, on the contrary, found very low values (<10%) in three Italian emmer populations (from Garfagnana, Leonessa and Trivento) cultivated in three different locations (Galterio et al., 1994). Such high variability in protein content was further confirmed by other researchers: Blanco et al. (1990) found in fifty emmer accessions a protein content ranging from 8.7 to 18%, assessments carried out by Cubadda and Marconi (1995) over two years (1992 – 1993) on emmer landraces cultivated in Apulia (southern Italy) determined mean protein content of 20.6 – 21.9%. Prude protein of three emmer wheat varieties cultivated under the conditions of organic farming system in the south region of the Slovak Republic varied between 13.26 and 14.17% (Lacko-Bartošová et al., 2015). Protein content of five spelt wheat varieties cultivated under the same agronomic conditions were higher, in average 16.28% db (Lacko-Bartošová and Rédlová, 2007). Giacintucci et al. (2014) compared spring emmer, winter emmer and common wheat quality and composition of grains and flours. Spring emmer showed a higher crude protein content in grain (14.4%) than winter emmer (11.2%) and common wheat (11.8%). As far as the flours are concerned, spring emmer showed a protein content similar (11.8%) to that of wheat (11.5%), and the winter emmer much lower protein content (10.0%), which indicates that the emmer milling process carried out in a laboratory mill resulted in a reduction of protein content due to the removal of the outer parts of endosperm together with bran.

As was mentioned above, the protein content of hulled wheats (*Triticum dicoccon* Schrank and *Triticum spelta* L.) was consistently higher than those of modern wheats (*Triticum aestivum* L., *Triticum durum* Desf.) cultivated under the same agronomic conditions (Perrino et al., 1993; Galterio et al., 1994; Cubadda and Marconi, 1995; Castagna et al., 1996; Reedy et al., 1998). However, this does not justify the classification of emmer and hulled wheats in general as protein – rich crops since their high protein level (and high content of other nutrients) could be a consequence of low grain yield. In fact, comparing the protein yields ($g*m^{-2}$), the values for emmer are similar or lower than those for modern wheats (Piergovanni et al., 1996). For example, Piergovanni et al. (1996) found that protein yields of emmer (450 kg*ha^{-1}) and spelt (460 kg*ha^{-1}) were lower than that of the control wheats (mean 550 kg*ha^{-1}), although the grain protein contents of the emmer (16.7% db) and spelt (17.1% db) were significantly higher than durum wheats (15.3% db).

Data on the amino acid pattern of emmer wheat show a pattern similar to that of common, durum, and spelt wheat: the main amino acids are glutamic acid (≈30 g*100 g^{-1} protein) and proline (≈10 g*100 g^{-1} protein), and the quantitatively minor amino acids are tryptophan (≈1.30 g*100 g^{-1} protein) and methionine (≈1.5 g*100 g^{-1} protein). From a nutritional point of view, in emmer, as well as in other cereals, lysine is the limiting amino acid (1.40 – 1.94 g*100 g^{-1} protein), followed by threonine (2.57 – 3 g*100 g^{-1} protein) and sometimes methionine (1.5 – 1.7 g*100 g^{-1} protein) (Cubadda and Marconi, 1995; Marconi and Cubadda, 2005; Nowak, et al., 2015). Arzani (2011) reported high lysine content (3.1%) for emmer grains. Higher lysine content (up to 3.65%) was reported by Stehno (2007) in the Czech emmer cultivar Rudico. It is interesting to note that lysine content and the chemical score are higher in whole grain than in flour due to the presence of the aleurone layer, which is rich in albumins and globulins and characterized by a higher content of essential amino acids and lysine. This may have led to emmer and spelt being attributed a higher protein quality than modern wheats, simply because they are mainly used as whole meal or low-refined flours. In fact, when the comparison is between whole meals or meals with the same level of refinement, the amino acid composition of emmer is equivalent to that of modern wheats (Marconi and Cubadda, 2005).

Functional Proteins – Albumins and Globulins are mainly found in the aleurone layer. For this reason, as protein yield increase, the percentage of albumins and globulins decreases, whereas that of gliandins increases. The content of the albumin and globulin fractions in emmer wheat is considerable, representing about 30 – 39% of total proteins (Galterio et al., 1999) compared to 15 – 25% in durum and soft wheat.

Storage Proteins – Gliadins and Glutenins. The average percentages of gliadins and glutenins in whole-meal emmer are about 37% (range 33 – 39%) and 29% (range 27 – 33%) of total protein, respectively (Galterio et al., 1999). Consequently, the high lysine and low gluten content of emmer wheat could complement those of wheat flour, which is poor in lysine but rich in gluten content (Arzani, 2011).

Digestible Carbohydrates

Starch is the main storage carbohydrate in wheat kernels, accounting for 61 – 68% of the grain, whereas sugars account for 2 – 3% (Abdel-Aal and Hucl, 2005; Han et al., 2007; Lacko-Bartošová, 2010; Lacko-Bartošová and Rédlová, 2007). It is a primary functional component in cereal grains, its content and characteristics are known to substantially affect the quality of wheat and its end products. Protein-carbohydrate complex forms the dough structure and is the main source of sugars which are important for baking applications. From a nutritional point of view, starch is rich source of energy and influence the level of glycaemia (Lacko-Bartošová and Rédlová, 2007). Total starch can be divided into rapidly digestible starch (RDS), slowly digestible starch (SDS), and resistant starch (RS). The latter starch fraction is not susceptible to enzymatic hydrolysis and can be included in the dietary fibre (Marconi and Cubadda, 2005).

Total starch is the main nutritional component of the emmer kernels, with values ranging from 52.7 to 56.8% db (Galterio et al., 2003). These values are similar to those of durum wheat, although the lowest values could be attributed to hulled wheats' minor capacity for starch accumulation compared to that of modern wheats.

Konvalina et al. (2008) determined starch content (%) in six varieties of spring emmer wheat, grown at two stations, at the Research Institute of the Crop Production in Prague and at the Faculty of Agriculture in České Budějovice. Starch content was the same in case of all varieties and was very fixed. An average starch content reached 47.7% in Prague and 40.9% in České Budějovice. Galterio et al. (1994) featured higher value of starch content (52.7 – 56.8%), in later studies (Galterio et al. 2003) starch content ranged from 45.7 to 65.1%. The new Davide, Mosé and Padre Pio varieties reveal a starch amount close (54.3 –55.6%) to that of the older population (55.5 – 56.8%), whereas the two varieties of spelt wheat had the lowest starch content (50.0%, resp. 51.5%). As far as starch is concerned it is well known that this component highly contribute to the chemical composition and to nutritional value of cereals. The investigation carried out on the new lines highlighted starch contents ranging from 55.4 to 73.3%.

It is known that starch digestibility may be reduced during processing because of the formation of enzyme resistant starch (RS) (Galterio et al., 2001). As reported by Massaux et al. (2008) inter-species variability in starch content was observed, this could be explained by the genotype and growing season conditions.

Dietary Fibre

From a nutritional point of view, it is important to differentiate between soluble and insoluble fibre, since each form is considered to have particular physiological effects and benefits as a constituent of the human diet. Soluble fibre is known for its hypocholesterolaemic effect (Jenkins et al., 1995). In wheat, whole grain flour and its bran fraction are a reliable source of fibre, especially the water-insoluble type (Ranhotra, 1994). In contrast, white flour is not rich in total fibre, but it is relatively rich in soluble fibre.

The whole wheat grain contains between 11.5 and 15.5% db total dietary fibre, with the major components being cell wall components: the polysaccharides arabinoxylan (5.5 – 7.4% db) (Andersson et al., 2013), cellulose (1.67 – 3.05% db) and ß-glucan (0.51 – 0.96% db). However, these components differ in their distribution between the different grain tissues. The outer layers (pericarp and testa) comprise 45 – 50% cell wall material (Barron et al., 2007), with well-characterised outer pericarp being rich in lignin (12%), cellulose (30%) (Shewry and Hey, 2015). Differences in distributions of dietary fibre components are important as they mean that smaller grains may have higher concentrations of fibre components (and other components concentrated in the bran) than larger grains, due to having a higher ratio of bran to flour (Shewry and Hey, 2015).

The whole meal of three emmer genotypes had a total dietary fibre content of about 10 – 12% db, mainly insoluble fractions (85 – 88% of total fibre) (Marconi and Cubadda, 2005). Lower values of total dietary fibre were found by Galterio et al. (1994) in three emmer populations (mean 7.11%), and by Galterio et al. (1999) in another seven emmer populations (mean 8.4% db, range 8.04 – 8.94% db), where the soluble dietary fibre (mean 1.69% db, range 1.57 – 1.84% db) was about 20% of the total dietary fibre. These results are in agreement with Grausgruber et al. (2004), Abdel-Aal et al. (1995), Bonafaccia et al. (2000). The mean value of total dietary fibre was 9.2% db for emmer, 10.8% db for einkorn, 11.18% db for spelt. In the study of Arzani (2011) the content of total dietary fibre was in emmer wheat 2.7 g*100 g^{-1}. The content was higher than in durum wheat (2.4 g*100 g^{-1}) and in common wheat (2.5 g*100 g^{-1}). In the study by Fares et al. (2008) the soluble dietary fibre (SDF) ranged from 1.36 to 2.32%. Regarding SDF, the values found in lines were at the same level as those found by Loje et al. (2003) for einkorn and emmer (0.21 – 1.74%), but lower than those quoted in the study by Bonafaccia et al. (2000) for spelt and common wheat. Lacko-Bartošová and Čurná (2015) found lower values of SDF of four organic emmer wheat varieties. The average SDF was 0.41%, statistical analysis not confirmed significant differences between varieties.

Although only small numbers of samples were analysed in most studies the values for all fractions measured for ancient wheats tend to be lower than those reported in the same studies for bread wheat, although the range is wider in some studies (Shewry and Hey, 2015).

The aleurone cells which form the outer layer of the endosperm are also rich in fibre (35 – 40% db) (Barron et al., 2007), which comprises 29% ß-glucan, 65% arabinoxylan and about 2% each of cellulose and glucomannan (Bacic and Stone, 1981; Shewry and Hey, 2015). As mentioned Demirbas (2005) ß-glucan is a major cell wall carbohydrate which is isolated from cereal grains. Grausgruber et al. (2004) and Gebruers et al. (2008) found that total ß-glucan content varied from 0.3 to 0.4% db in emmer, from 0.23 to 0.90% db in spelt and between 0.25 and 0.48% db in einkorn.

Lipids

Lipids are relatively minor constituents in cereal grains. However, they must be taken into consideration when discussing nutrition, grain storage, and processing. The lipid fraction, particularly minor components such as phytosterols and tocochromanols, can contribute to the characterization of the botanical origin of grain and flour (Piironen et al., 2002). The lipid content of emmer has been reported in very few investigations. Lipids are minor grain constituents, accounting for about 3% of the wheat kernel. They are more concentrated in germ (which contains 28.5% of lipids) and in the aleurone layer (8.0%) than in endosperm (1.5%) (Delcour and Hoseney, 2010). Even though being a 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).

The lipid content of emmer has been reported in very few investigations. There were found an average lipid content of 2.8% db (range 2.4 – 3.0% db) in nine emmer genotypes, similar to that found in twelve spelt genotypes (mean 2.7% db, range 2.5 – 3% db) and in five varieties of durum wheat (2.8% db) but higher than in three cultivars of soft wheat (2.5% db). All the samples were cultivated in the same experimental field under the same agronomical conditions (Marconi and Cubadda, 2005). Piergiovanni et al. (1996) found lower lipid values in fifty accessions of emmer (average 2.0% db; range 1.4 – 2.8% db), in thirty-seven accessions of spelt (mean 2.1% db; range 1.7 – 2.5% db), and in three durum wheat varieties (1.5% db). The lipid content was not significantly different between emmer and spelt. Lacko-Bartošová and Čurná (2014) found lower lipid values in five spelt wheat varieties (mean 1.04% db; range 0.99 – 1.09% db). According to Giacintucii et al. (2014) spring emmer wheat showed a higher lipid content of grain (2.33% db) than winter emmer wheat (1.52% db). As reported by Hanchinal et al. (2005) lipid content in emmer ranged from 1.02 to 3.80%.

The fatty acid composition of emmer compared with those of spelt and modern wheats shows that, as in the reference wheats, the primary fatty acid is lonoleic (C18:2) (60% of total fatty acids), followed by oleic (C18:1) (19% of total fatty acids), palmitic (C16:0) (16% of total fatty acids), linolenic (C18:3) (4% of total fatty acids), and stearic acid (C18:0) (1% of total fatty acids). Oleic acid content (C18:1) was found to be higher in hulled wheats and durum wheats (17 – 19%) than in soft wheat (13%). On the other hand, soft wheat had higher linoleic acid (C18:2) and linolenic acid (C18:3) values. No differences were found in the total unsaturated/saturated fatty acid ratios (TUFA/SFA) and in the polyunsaturated/monounsaturated ratios (PUFA/MUFA) among emmer, spelt, and durum wheats (Marconi and Cubadda, 2005).

Phytosterols may have a role in preventing colon cancer and reducing total serum cholesterol (Piironen et al., 2000). The total and free sterol content of hulled (emmer and spelt) and hulless (soft and durum) wheat species, show that the main sterol was ß-sitosterol, followed by campesterol and stigmasterol. Tetraploid species (emmer and durum wheat) contain significantly larger amounts of sterols and stanols than hexaploid species (spelt and common wheat) (Marconi and Cubadda, 2005).

Vitamins

Tocopherols and tocotrienols, grouped as tocols and recognised as vitamin E, are a class of lipid-soluble antioxidants synthesised only by photosynthetic plants, composed of eight chemical analogues: α-tocopherol, β-tocopherol, γ-tocopherol, δ-tocopherol and their unsaturated tocotrienols: α-tocotrienol, β-tocotrienol, γ-tocotrienol, and δ-tocotrienol (Panfili et al., 2004; Hildago et al., 2006; Okarter et al., 2010; Lachman et al., 2013). No appreciable levels of γ-tocopherol, γ-tocotrienol, δ-tocopherol, or δ-tocotrienol were found in any of the species analyzed. The tocotrienol/tocopherol ratio was much higher in emmer and durum wheat (3.6 and 3.5, respectively) than in spelt and soft wheat (2.0). This ratio could be used as an index to make distinctions between spelt and emmer as well as between durum and soft wheats (Marconi and Cubadda, 2005). As reported by Shewry and Hey (2015) the mean values of total tocols are clearly higher for einkorn than for the other hulled wheat species, with wide range of contents. For example, the amount of total tocols of emmer wheat ranged between 19.7 and 69.85 mg*g^{-1} db, with weighted mean 46.37 mg*g^{-1} db (Lampi et al., 2008; Giambanelli et al., 2013) compared to the weighted mean (69.09 m*g^{-1} db) of einkorn (Hejtmankova et al., 2010) and weighted mean (37.10 mg*g^{-1} db) of spelt (Hussain et al., 2012). As mentioned Stehno et al. (2011) the highest content of E vitamin was measured in variety Tapioszele (1.30 mg*100 g^{-1} db). α – tocopherol, considered the most biologically active form of tocochromanol, varied from a mean value of 7.10 to 10.01 mg*kg^{-1} db in emmer and 15.90 mg*kg^{-1} db in spelt and wheat, respectively. Thus, vitamin E activity in spelt was about 30% more than in emmer. Because most of the tocopherol derivatives are concentrated in the germ and wheat flours contain about 40% of the level in the grain more data are needed on the tocopherol composition in emmer as well as in other ancient grains (Chung, 1991; Abdel-Aal and Hucl, 2005).

Wheat grains are recognized as important dietary sources of B vitamins. The B vitamin complex comprises eight water-soluble components which often occur together in the same foods and were initially considered to be a single component. Wheat, and in particular wholegrain is an important source of B vitamins: thiamine (B_1), riboflavin (B_2), niacin (B_3), pyridoxine (B_6) and folates (B_9) (Shewry and Hey, 2015). For example, Hoppner et al. (1968) demonstrated that two common spring wheat cultivars grown at sixteen locations in two years contained 0.5 mg*100 g^{-1}, 0.2 mg*100 g^{-1}, and 6.8 mg*100 g^{-1} of thiamin, riboflavin, and niacin, respectively. These niacin and thiamine levels would provide a substantial proportion of the human requirements in balanced diets, but the riboflavin level would not supplement deficiencies in other components of the diet. As was reported by Stehno et al. (2011) a higher content of vitamins thiamine and riboflavin was ascertained in variety Rudico, grown under organic farming system in the Czech Republic during two years of experiments. The content of thiamine reached value 0.44 mg*100 g^{-1} db, riboflavin content was 0.135 mg*100 g^{-1} db in comparison to variety May – Emmer (0.33 mg*100 g^{-1} db; 0.108 mg*100 g^{-1} db, respectively). Also the highest contents of other vitamins (niacin, pantothenic acid and pyridoxine) were found in the Rudico variety. Only folates have been compared in ancient wheat and modern wheat species – as a part of the HEALTHGRAIN project. This showed slightly higher contents in durum wheat (0.74 mg*g^{-1} db) and emmer (0.69 mg*g^{-1} db) compared to the other species (0.56 – 0.58 mg*g^{-1} db). However, the limited numbers of lines analysed of all species except bread wheat and the single growth environment should be borne in mind in drawing conclusions (Piironen et al., 2008).

Carotenoids are a group of compounds that are both nutritionally and technologically important, since they influence the chromatic characteristics of the meal. Carotenoides occur in two major forms, the oxygen-containing xanthophylls (which include lutein, β-cryptoxanthin and zeaxanthin) and the unoxygenated carotenes (which include α-carotene and β-carotene). Some carotenoids, notably β-carotene, are converted to vitamin A (retinol) in mammals, and hence are also referred to as provitamin A (Shewry and Hey, 2015).

The predominant compound found in all hulled species is lutein, and this is higher in einkorn, emmer (90% of total carotenoids) and durum wheat than in bread wheat (Lafiandra et al., 2012). The highest content of lutein was reported for einkorn, with a mean of 7.28 mg*g^{-1} db (Giambanelli et al., 2013; Lachman et al., 2013). Lower content was reported in emmer, with a range from 0.451 to 5.21 mg*g^{-1} db (mean of 2.72 mg*g^{-1} db) compared with 1.55 mg*g^{-1} db of bread wheat and 1.68 mg*g^{-1} db of spelt (Carpentier et al., 2009; Stringham et al., 2010; Shewry and Hey, 2015). Total carotenoids were lower in emmer (2.34 mg*kg^{-1} db) and, as expected, in spelt (1.58 mg*kg^{-1} db) and soft wheat (1.49 mg*kg^{-1} db) than in durum wheat (3.05 mg*kg^{-1} db) (Panfili et al., 2004; Marconi and Cubadda, 2005). Piergiovanni et al. (1996) found that the carotenoid values in emmer (mean 2.9 mg*kg^{-1} db, range 2.0 – 4.2 mg*kg^{-1} db) and in spelt (mean 3.4 mg*kg^{-1} db, range 2.2 – 5.0 mg*kg^{-1} db) were lower than in durum wheat (4.7 mg*kg^{-1} db). On the other hand, Somma et al. (2004, cit. Marconi and Cubadda, 2005) did not find any significant differences between the carotenoid contents of emmer and durum wheat (6.17 mg*kg^{-1} db vs. 6.34 mg*kg^{-1} db, respectively).

Minerals

Minerals are important components required by humans in their daily food. Minerals are divided into two groups: (i) macro minerals, which are needed in large amounts, e.g., calcium (Ca), magnesium (Mg) and potassium (K), etc., (ii) micro minerals or trace elements, which are required in smaller quantities, e.g., copper (Cu), zinc (Zn), iron (Fe), boron (B), selenium (Se) (Martinez-Ballesta et al., 2010). Due to the high consumption of emmer wheat in a variety of food products all over the world, emmer is considered an important source of minerals (Hussain et al., 2010).

Mineral content of emmer analysed by Hanchinal et al. (2005), range from 1.14 to 2.46%, and was lower than in durum wheat. Piergiovanni et al. (2009) reported higher mineral content in the emmer cultivar Farvento. Farvento grains also had higher concentration in selenium, important antioxidant factor. Genc and MacDonald (2008) identified domesticated emmer wheat accessions with greater zinc concentration than in modern durum and bread wheat genotypes. Ortiz-Monasterio and Graham (2000) reported high zinc concentration in the accessions selected from the landrace Amarello de Barba Branca from Portugal and landrace from the Krasnodar Ostrada Province, Russia. Zhao et al. (2009) conducted a survey where variation in mineral micronutrient concentration in grain of wheat lines of diverse origin was determined. The concentrations of seventeen minerals in grain were determined. Data of three trace elements (Fe, Zn, and Se) that are of particular importance to human nutrition were as follows: among the 150 bread lines, grain iron concentration varied from 28.9 to 50.8 mg*kg^{-1}, grain zinc from 13.5 to 34.5mg*kg^{-1} and grain selenium from 33 to 238 µg*kg^{-1}. Emmer wheat was characterized by higher concentration of iron in grain (mean 34.1 mg*kg^{-1}), zinc (mean 22.8 mg*kg^{-1}) and selenium (ranging from 150.6 to 325.8 µg*kg^{-1}). Higher concentrations of iron than in emmer was detected in spelt (mean 45.9 mg*kg^{-1}) or in einkorn (mean 45.9 mg*kg^{-1}, ranging from 38.2 to 55.5 mg*kg^{-1}). The concentration of zinc was at the same level: 22.4 mg*kg^{-1} for einkorn, 22.8 mg*kg^{-1} for emmer and 22.9 mg*kg^{-1} for spelt. The highest concentration of selenium was detected in einkorn (mean 278.9 µg*kg^{-1}).

The mineral composition of ten emmer and ten spelt accessions was evaluated and compared to that of two common wheat cultivars and three durum cultivars grown in the same experimental field in Southern Italy. Emmer and spelt wheat differed from common and durum wheat cultivars in having higher levels of lithium, magnesium, phosphorus, selenium, and zinc. The highest levels for all minerals tested were found in spelt accessions, suggesting a higher uptake in spelt (Piergiovanni et al., 1997; Abdel-Aal and Hucl, 2005).

The ash content in emmer was usually higher (>2.0% db) than in durum and soft wheat (1.7 – 1.8% db) (Piergiovanni et al., 1996; Galterio et al., 1999; Lacko-

Bartošová and Čurná, 2015). The low ash content of modern wheat cultivars is the result of selection, in order to increase the milling yield (Rasmusson et al., 1971). Therefore, this parameter could be an indicator of the primitiveness of hulled wheats. Piergiovanni et al. (1996) found an ash content ranging from 1.75% to 2.33% db (mean value 2.00% db) in 50 emmer accessions.

Conclusions

The move in recent years toward more natural foods and sustainable agriculture and the rediscovery of ancient foods and flavours have brought renewed interest in hulled neglected species. Emmer wheat, a minor cereal today, should know a new development due to the nutritional value of its grain, the special taste of its products, and its characters of resistance to pests and disease. Limited data are available on the contents and compositions of chemical and nutritional value of ancient wheat, specifically of emmer wheat. Nevertheless, the data that are available show that emmer wheat differs from modern wheat species in some components. The notable difference from bread wheat is high content of the carotenoid lutein in emmer and einkorn. Carotenoids have been selected against bread wheat due to their colour. The higher nutritional value of emmer wheat is attributed to higher fibre and antioxidant compound concentrations, high protein digestibility, high resistant-starch content and slower carbohydrates in vitro digestibility. The low glycaemic index value and high satiety value of emmer wheat make it particularly suitable for special diets, e.g. diabetes. Most of these qualities are related to a high total dietary fibre, which is associated with reduced rate of starch digestion. Increasing interest in natural and organic products has led to an emmer rediscovery not only for its nutritional and health properties but also because it is suitable for low input and organic farming systems. Further research is needed to elucidate the physical, chemical, and nutritional properties of emmer grain and to address its beneficial health effects.

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