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MINERAL COMPOSITION OF EMMER WHEAT (*Triticum turgidum* L. VAR. *dicoccum*) LANDRACES

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ABSTRACT

Cereal grains play a key role in human nutrition. Maintaining adequate mineral content in wheat (*Triticum aestivum*) grain is critically important for human nutrition. In this study, mineral elements [11 elements, chrome (Cr), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), selenium (Se), cadmium (Cd) and lead (Pb)] of 10 different local emmer wheat landraces grown in Develi town of Kayseri province were investigated. Experiments were conducted in factorial experimental design with three replications and two factors (10 landraces and 2 grain forms as of bare and spelt). Significant differences were observed in heavy metal contents of different grain forms and landraces. Average Cu, Fe, Mn, Se, Zn, As, Cd, Co, Cr, Ni and Pb contents of ground samples were respectively identified as 3.26, 5.83, 32.69, 0.025, 4.22, 0.027, 0.0382, 0.065, 1.14, 0.786 and 0.065 ppm. Mineral contents of spelt grains were greater than the mineral content of bare grains since the bran covering the grain is rich in minerals. It should be noted that in all emmer wheat samples, all mineral element levels were below the EU maximum allowed levels for cereals and cereal products intended for human consumption. These emmer wheat landraces could be used as parent materials in durum and bread wheat breeding programs.

KEYWORDS:
Hulled wheat, genotypes, mineral content

INTRODUCTION

Hulled wheats with nonfragile spikes and hulled grains were the earliest species domesticated during the Neolithic period. They have played a key role in the phylogenesis of modern wheat. Wild emmer wheat (*Triticum dicoccoides*) is one of the first cereals domesticated in the Fertile Crescent about 10 – 12 thousand years ago [1, 2, 3, 4, 5, 6, 7]. The earliest cultivated forms were einkorn and emmer, which were diploid (genome AA) and tetraploid (genomes AABB) species, respectively. Both species probably is originated from the south-eastern part of Turkey [8]. With high grain carbohydrate content and adaptation capability, wheat is among the most widely grown cereals worldwide. Wheat is used as the primary source of carbohydrate in Turkey. It is used in production of bread, bulgur and macaroni production. Because of this broad range of use and consumption, wheat is included into daily diets of humans.

Wheat cultivars developed through comprehensive breeding programs are mostly poorer in micro elements than the local wheats [9]. Garvin et al [10] experimented 14 red bread wheat cultivars developed between 1873 – 2000 at two locations and reported decreasing zinc and iron contents with the years of registration. Fan et al [11] assessed wheat breeding studies conducted after green revolution and indicated that despite increasing yields, mineral element (Zn, Fe, Cu and Mg) contents of wheat cultivars have been decreasing since 1968. In another study conducted with a local wheat cultivar and short wheat cultivar, 18-29% less Zn, Fe, Cu and Mg contents were reported for short wheat cultivar [9]. In a more recent study conducted with the use of 25 different wheat lines originated from different places, decreasing iron and zinc contents have been reported since the development dates of semi-dwarf cultivars [12].

Nowadays, old wheat cultivars are getting popular since they are quite rich in minerals and nutrients, thus have various health benefits. Then, researchers started to focus on various traits of these old species. The hulled wheat cultivar, so called as "Gacer", has still been cultivated by limited number of farmers in Develi town of Kayseri province of Turkey. Typically, emmer is cultivated on marginal lands, able to survive in harsh environments and poor soils where other species of wheat could not survive. In recent years, given that the ancient species are generally cultivated in organic or traditional low-input farming, the trend towards low-impact and sustainable agriculture, combined with increased attention to the nutritional aspects of food, has led to the rediscovery of regional forgotten crops, especially in Turkey. Notwithstanding lower yields, a significant recovery in the cultivation of these ancient and local wheat cultivars is presently underway [13]. In low-income places, people rely on inexpensive sources of calories, such as cereals and tubers, to meet energy needs [14, 15].

Emmer (*Triticum monococcum*) is among the

ancient wheats and constitute a potential crop for environment-friendly organic farming. As compared to common wheat, emmer is generally more resistant to diseases and has the ability to withstand drought. Emmer is still cultivated on poor soils in Kayseri province of Turkey, where other wheat types fail. The yield of emmer, however, is considerably lower as compared to modern cultivated wheat varieties. However, modern wheat varieties contain very low levels of mineral nutrients and vitamins compared to hulled wheat species such as einkorn (*Triticum monococcum* L. subsp. monococcum) and emmer (*Triticum dicoccum* Schuebl [Schrank], subsp. Dicoccum) [16, 17], known as primitive and first cultivated wheats [18]. Hulled wheat species have been attracting interest of farmers in developed countries for both high nutritional potentials and suitability for low-input and organic farming compared to modern wheats [19]. Minerals are essential not only for plants, but also for humans and animals. Micronutrient malnutrition affects 1⁄3 − ½ of the world population [14]. A major cause of micronutrient malnutrition in low-income populations is lack of access to a variety of foods. Micronutrient deficits are responsible for many health problems, including impairment of the immune system, disturbed physical, mental and cognitive development and increased rates of anemia, morbidity and mortality [20]. Several studies have suggested that ancient wheats have health benefits as compared to modern bread wheat [21]. Additionally, end-users suffering from serious health problems such as obesity, metabolic diseases and chronic diseases have mostly rediscovered the ancient wheat species [7, 13, 22].

In this study, mineral elements [11 elements, chrome (Cr), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), selenium (Se), cadmium (Cd) and lead (Pb)] of 10 different local emmer wheat landraces grown in Develi town of Kayseri province were investigated.

MATERIALS AND METHODS

Grain samples taken from 10 different emmer wheat landraces were used as the material of the present study. These landraces were collected from six different villages of Develi town of Kayseri province. Such landraces are grown only in these villages under traditional farming conditions with N fertilization in the form of ammonium sulfate at 60 kg ha^{-1} and P fertilization in the form of triple superphosphate at 50 kg ha^{-1}. Collected grains were separated into two forms as of bare and spelt. Experiments were conducted in factorial experimental design with three replications and two factors (10 cultivars and 2 grain forms). Dried grain samples were ground and wet-digested in a microwave (Berghof Speedwave, Germany) using 2 ml of 35% H_2O_2 and 5 ml of 65% HNO_3. Following the digestion, chrome (Cr), Manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), selenium (Se), cadmium (Cd) and lead (Pb) contents were determined in an Inductively Coupled Plasma Mass Spectrometry (ICP-MS; Agilent 7500a) device. To check related elemental measurements, reference leaf samples from the National Institute of Standards and Technology (Gaithersburg, MD, USA) were used.

Statistical Analysis: Experimental results were subjected to analysis of variance (ANOVA) and significant means were compared with the use of Duncan's multiple range test at 0.05 significance level. Statistical analyses were performed with the use of SAS software (SAS Inst., 1999).

RESULTS AND DISCUSSION

Significant differences were observed in heavy metal contents of different grain forms and landraces (Table 1, Table 2). Mineral contents of spelt grains were greater than the mineral content of bare grains since the bran covering the grain is rich in minerals. Atar [23] also reported that mineral contents varied with the grain fractions and the cultivars. Therefore, greater trace element and mineral content of emmer wheat could partially be attributed to smaller size of *Triticum monococcum* seeds, which increases the (bran+germ)/endosperm ratio [24].

Copper (Cu): Copper concentrations of bare and spelt wheat grains varied between 2.55 - 4.01 ppm with an average value of 3.26 ppm. The highest copper concentrations were observed in Yenice (4.01 ppm) and Ebce1 (3.58 ppm) landraces and the lowest copper concentrations were observed in Sahmelik1 (2.55 ppm), Aysepinari2 (2.63 ppm) and Sahmelik3 (2.79 ppm) landraces (Table 1). Landrace genetics resulted in different mineral contents. Mineral contents greatly vary with the genotypes [25]. Besides genetics, such variations in mineral contents could also be attributed to environmental factors and genotype x environment interactions [26]. Average copper content of wheat grains was reported as 4.0 mg / kg^{-1} [27], 6.4 mg / kg^{-1} [28], 9.0 mg / kg^{-1} [16] and 7.4 mg / kg^{-1} [23]. Present findings on copper contents were close to findings of Suchowilska et al [27], but quite lower than the others. Such differences were mainly attributed to differences in genotypes, environmental factors and cultural practices [28].

Iron (Fe): Iron concentrations of bare and spelt wheat grains varied between 3.75 - 7.77 ppm with an average value of 5.83 ppm. The highest iron concentration (7.77 ppm) was observed in Ebce1 landrace and the lowest iron concentration (3.75 ppm) was observed in Aysepinari1 landrace (Table 1). Iron

contents varied with the landraces. Genotype and environmental factors greatly influence wheat mineral contents [26, 28, 29, 30, 31].

Ozkan et al [28] reported average iron content of einkorn wheat as 47.04 mg, which was quite greater than the present value. Such a great difference could be attributed to the cultivar [32], soil, climate and cultural practices [30]. On the other hand, Kleese et al [33] indicated that iron contents of wheat genotypes did not vary significantly with the years and locations.

Manganese (Mn): Manganese concentrations of bare and spelt wheat grains varied between 26.30 - 38.59 ppm with an average value of 32.69 ppm. The highest manganese concentrations were observed in Yenice (38.59 ppm), Ebce1 (36.48 ppm) and Kiziloren (36.10 ppm) landraces; the lowest manganese concentrations were observed in Sahmelik1 (26.30 ppm) and Sahmelik3 (27.22 ppm) landraces (Table 1).

Average manganese content of hulled wheat grains was reported as 28.0 mg / kg^{-1} [27], 34 mg / kg^{-1} [34], 44 mg / kg^{-1} [35] and 49.3 mg / kg^{-1} [28]. Differences from the present findings were attributed to differences in cultivars and ecology [23, 36]. Significant effects of genotype x environment interactions on Mn contents were also reported [36].

Selenium (Se): Selenium concentrations of bare and spelt wheat grains varied between 0.002 - 0.086 ppm with an average value of 0.025 ppm. The greatest selenium concentrations were observed in Ebce2 (0.086 ppm), Ebce1 (0.044 ppm) and Sahmelik2 (0.034 ppm) landraces and the lowest selenium concentrations were observed in Aysepinari1 (0.002 ppm) and Yenice (0.005 ppm) landraces (Table 1). Selenium contents varied significantly with the emmer wheat landraces. Previous researchers also reported significant variations in undesirable metal contents of different wheat cultivars [26, 30, 37]. Abdel-Aal and Rabalski [38] reported Se concentrations of emmer wheats as between 0.050 – 0.055 mg/kg^{-1} (mean, 52.3 mg/kg^{-1}), which was twice as much of the present value. Tekin et al [39] conducted a study with 49 spelt wheat lines similar with the present landraces and reported average Se content of wheat lines as 0.05 mg/kg. Previous studies reported varying selenium contents. Some found no evidence for genetic variability among the wheat cultivars for Se density in grain [40], while others found higher concentrations of Se, Zn in hulled wheat (*Triticum spelta* L. and *Triticum dicoccum* Schrank) grown together with modern bread wheats (*Triticum aestivum* L.) [41].

Zinc (Zn): Zinc concentrations of bare and spelt wheat grains varied between 0.02 - 11.73 ppm with an average value of 4.22 ppm. The highest zinc concentrations were observed in Aysepinari1 (11.73 ppm) and Gumusoren (10.74 ppm) landraces; the lowest zinc concentrations were observed in Sahmelik2 (0.02 ppm), Sahmelik3 (0.02 ppm) and Sahmelik1 (0.03 ppm) landraces (Table 1).

TABLE 1
Copper (Cu), Iron (Fe), Manganese (Mn), Selenium (Se), Zinc (Zn), Concentrations of emmer wheat landraces *

	Cu (ppm)	Fe (ppm)	Mn (ppm)	Se (ppm)	Zn (ppm)
Form					
Spelt	3.56 a	7.06 a	35.66 a	0.035 a	5.35 a
Bare	2.95 b	4.60 b	29.71 b	0.014 b	3.09 b
Average	3.26	5.83	32.69	0.025	4.22
Landraces					
Ebce 1	3.58 b	7.77 a	36.48 b	0.086 a	0.63 de
Ebce 2	3.29 d	6.11 c	34.81 c	0.044 b	0.24 e
Kiziloren	3.40 bcd	6.81 b	36.10 b	0.015 f	1.55 d
Sahmelik 1	2.55 f	5.12 d	26.30 e	0.026 d	0.02 e
Sahmelik 2	3.31 cd	6.93 b	30.58 d	0.034 c	0.03 e
Sahmelik 3	2.79 e	7.03 b	27.22 e	0.018 e	0.03 e
Gumusoren	3.57 b	5.80 c	34.89 c	0.010 g	10.74 a
Yenice	4.01 a	4.25 e	38.59 a	0.005 h	11.73 a
Aysepinari1	3.48 cb	3.75 f	31.24 d	0.002 ı	7.95 c
Aysepinari 2	2.63 fe	4.78 d	30.66 d	0.008 g	9.28 b
Soruce of Variation			F Values		
Form (F)	257.92**	831.24**	822.17***	1225.39**	83.68**
Landrace (L)	60.16**	96.85**	156.74**	740.29**	165.70**
F X L	2.26**	27.12**	18.65**	117.15*	10.80**
CV (%)	4.53	5.66	2.46	9.21	22.66

[1] The difference between means with the same letter is not significant (P<0.01).
* The difference between means with different letters is significant at p<0.01 level.

TABLE 2
Arsenic (As), Cadmium (Cd), Cobalt (Co), Chrome (Cr), Nickel (Ni) and Lead (Pb) concentrations of emmer wheat landraces*

	As (ppm)	Cd (ppm)	Co (ppm)	Cr (ppm)	Ni (ppm)	Pb (ppm)
Form						
Spelt	0.036 a	0.0502 a	0.074 a	2.11 a	1.124 a	0.113 a
Bare	0.019 b	0.0261 b	0.055 b	0.17 b	0.448 b	0.017 b
Average	0.027	0.0382	0.065	1.14	0.786	0.065
Landraces						
Ebce 1	0.032 a	0.0595 a	0.093 a	0.69 fe	0.663 d	0.276 a
Ebce 2	0.026 ab	0.0470 bc	0.052 e	0.57 fg	0.557 e	0.121b
Kiziloren	0.028 ab	0.0325 de	0.075 c	0.95 d	0.677 d	0.052 c
Sahmelik 1	0.019 c	0.0255 f	0.035 g	0.80 e	0.407 f	0.025 e
Sahmelik 2	0.025 abc	0.0295 ef	0.076 c	0.45 g	1.197 b	0.055 c
Sahmelik 3	0.024 bc	0.0291 ef	0.081 b	1.08 c	0.913 c	0.047 cd
Gumusoren	0.031 ab	0.0437 c	0.080 b	1.43 b	0.560 e	0.037 d
Yenice	0.028 ab	0.0358 d	0.045 f	3.94 a	1.867 a	0.025 e
Aysepinari1	0.029 ab	0.0281 ef	0.063 d	0.31 h	0.300 g	0.002 f
Aysepinari 2	0.030 ab	0.0511 b	0.047 f	1.19 c	0.717 d	0.011 f
	Soruce of Variation			F Values		
Form (F)	173.77**	361.89**	444.84**	4703.56**	2206.56**	1401.64**
Landrace (L)	3.13*	32.77**	175.81**	541.51**	400.94**	476.52**
F X L	4.89**	10.64**	10.14**	567.42**	311.60**	284.71**
CV (%)	18.61	12.86	5.51	9.63	7.09	15.34

[1] The difference between means with the same letter is not significant (P<0.01).
* The difference between means with different letters is significant at p<0.01 level.

Present zinc values were much lower than the ones reported in previous studies [12, 28, 31, 42]. Since cereals are a major part of the human diet, high content of minerals and especially of Zn and Fe has a potential to contribute substantially to human health [43, 44, 45]. Furthermore, large international breeding programs, such as the CIMMYT spring wheat program, has focused on bio fortification breeding to combine high yield and wide adaptation with high grain Zn content and processing quality [46, 47]. Iron and zinc deficiency are among the most common nutritional disorder [48]. Iron and zinc deficiency influence both the yield and quality. For this reason, micronutrient element studies are focused mainly on these two elements. In wheat, there is a positive correlation between zinc and iron concentrations [49] and a negative correlation between these two elements and yield [49, 50].

Arsenic (As): Arsenic concentrations of bare and spelt wheat grains varied between 0.019 - 0.032 ppm with an average value of 0.027 ppm. The highest arsenic concentration was observed in Yenice landrace with 0.032 ppm; the lowest arsenic concentration was observed in Gumusoren landrace with 0.019 ppm (Table 2).

Foods can be an important source of inorganic As for human intake. In a study conducted in Europe using 26 wheat varieties, it was determined that the average As concentrations of wheat varieties (in ground white flour) were between 69 ± 17 µg kg^{-1}. It has been determined that As concentration was 3.8−4.7 times higher in the case that the obtained flour was milled as whole wheat (grain into bran.) As a result, it was emphasized that using wheat flour by taking bran was important in terms of low As content [51]. In the study conducted by Maltzahn et al [52] on wheat in Brazil, arsenic and cadmium could not be determined in the grain.

Cadmium (Cd): Cadmium concentrations of bare and spelt wheat grains varied between 0.0255 - 0.0595 ppm with an average value of 0.0382 ppm. The highest cadmium concentration was observed in Ebce1 landrace with 0.0595 ppm; the lowest cadmium concentration was observed in Sahmelik2 landrace with 0.0255 ppm (Table 2).

Present findings were much lower than the Cd contents previously obtained from tetraploid (einkorn) wheat [39, 53]. Significantly higher Mn, Fe and Zn contents were reported for local hulled wheat varieties [54]. Moreover, the former genotypes were also the ones with the lowest level of accumulation of the trace toxic elements, in particular Cd. These results are in accordance with the literature data, indicating the superiority of “old” cultivars over the modern wheat cultivars for minerals [32]. Wild genotypes were prominent with higher Mn, Fe and Zn contents and lower Cd levels [32].

Cobalt (Co): Cobalt concentrations of bara and spelt wheat grains varied between 0.035 - 0.093 ppm with an average value of 0.065 ppm. The highest cobalt concentration was observed in Ebce1 landrace with 0.093 ppm and the lowest cobalt concentrations were observed in Sahmelik (0.035 ppm), Yenice

(0.045 ppm) and Aysepinari2 (0.047 ppm) landraces (Table 2). Cobalt contents significantly varied with the emmer landraces. Genetics play a significant role in mineral formation of primitive wheat [21, 28, 31].

Cobalt (Co) is a part of vitamin B12 necessary for human health. Cobalt concentrations of siyez samples were reported as between 11.7 - 24.1 mg kg^{-1} (mean: 16.8 mg kg^{-1}) with the greatest value from Siyez-14 and the lowest value from Siyez-15 [55].

Chrome (Cr): Chrome concentrations of bare and spelt wheat grains varied between 0.31 - 3.94 ppm with an average value of 1.14 ppm. The highest chrome concentrations were observed in Sahmelik (3.94 ppm), Gumusoren (1.43 ppm) and Aysepinari2 (1.19 ppm) landraces; the lowest chrome concentrations were observed in Aysepinari1 (0.31 ppm) and Yenice (0.45 ppm) landraces (Table 2).

Chromium (Cr), especially Cr (III), is an essential mineral for humans and its deficiency may lead to heart disease, impaired metabolism and diabetes. Chromium concentrations of Siyez wheat samples were reported as between 2.8 - 7.2 mg kg^{-1} (mean: 3.6 mg kg^{-1}) with the greatest value from Siyez-4 and the lowest value from Siyez-1 [55].

Nickel (Ni): Nickel concentrations of bare and spelt wheat grains varied between 0.300 - 1.867 ppm with an average value of 0.786 ppm. The highest nickel concentrations were observed in Gumusoren (1.867 ppm), Sahmelik2 (1.197 ppm) and Sahmelik3 (0.913 ppm) landraces; the lowest nickel concentration was observed in Aysepinari1 landrace with 0.300 ppm (Table 2).

Nickel (Ni) plays a significant role in physiological processes as a co-factor in the absorption of iron in the intestines. Nickel concentrations siyez samples were reported as between 11.0 - 13.4 mg kg^{-1} (mean: 12.1 mg kg^{-1}) with the greatest value from Siyez-14 and the lowest value from Siyez-9 [55].

Lead (Pb): Lead concentrations of bare and spelt wheat grains varied between 0.002 - 0.298 ppm with an average value of 0.065 ppm. The highest lead concentrations were observed in Ebce1 (0.298 ppm) and Yenice (0.121 ppm) landraces; the lowest lead concentrations were observed in Ebce2 (0.002 ppm), Sahmelik1 (0.003 ppm) and Sahmelik3 (0.011 ppm) landraces (Table 2).

As it was in present study, Zook et al [29] found significant differences in Pb, Ni, Cd and Cr contents of wheat cultivars. It was reported in Del Coco et al [32] that wild accessions were less influenced by different environmental conditions, thus "old" cultivars were superior to the modern ones in terms of minerals.

CONCLUSIONS

Significant differences were observed in heavy metal contents of different grain forms and landraces (Table 1, Table 2). Average Cu, Fe, Mn, Se, Zn, As, Cd, Co, Cr, Ni and Pb contents of ground samples were respectively identified as 3.26, 5.83, 32.69, 0.025, 4.22, 0.027, 0.0382, 0.065, 1.14, 0.786 and 0.065 ppm. Mineral contents of spelt grains were greater than the mineral content of bare grains since the bran covering the grain is rich in minerals. Climate, soil, crop management and genotype all play significant roles in trace element and macronutrient levels of whole grains. Therefore, the higher trace element and mineral contents of emmer may partially be attributed to smaller size of the T. monococcum seeds.

The greatest Fe, Se, As, Cd, Co and Pb contents were observed in Ebce-1 landrace (7.77, 0.086, 0.032, 0.0595, 0.093 and 0.298 ppm, respectively) and the greatest Cu, Mn, Zn, Cr and Ni contents were observed in Yenice landrace (4.01, 38.59, 11.73, 3.94 and 1.867 ppm, respectively). On the other hand, the lowest Cu, Mn, Zn, As, Cd and Co contents were observed in Sahmelik-1 landrace (2.55, 26.30, 0.02, 0.019, 0.0255 and 0.035 ppm, respectively) and the lowest Fe, Se, Cr, Ni and Pb contents were observed in Aysepinari-1 landrace (3.75, 0.002, 0.31, 0.300 and 0.025 ppm, respectively). It should be noted that in all emmer wheat samples, all mineral element levels were below the EU maximum allowed levels for cereals and cereal products intended for human consumption [56, 57, 58, 59].

According to present findings, Ebce-1 and Yenice landraces were found to be prominent with higher Fe, Se, Cu, Mn and Zn contents. The emmer wheat (Gacer) landraces can play a vital role in human nutrition as a functional food such as bakery, pasta and infant products. On the other hand, Sahmelik-1 and Aysepinari-1 landraces were found to be prominent for lower As, Cd, Co, Cr, Ni and Pb contents. These emmer wheat landraces could be used as parent materials in durum and bread wheat breeding programs.

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