The Oil Yield, Mineral Content, and Fatty Acid Compositions of Some Rye (*Secale cereale*) Grains

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ABSTRACT: *The oil contents of rye grain seeds ranged from 0.70% (type 25) to 3.92 % (type 1). Palmitic acid contents of oils changed between 10.82% (type 26) and 22.43% (type 10). In addition, while oleic acid contents of oil samples vary between 20.61% (type 17) and 37.86% (type 3), linoleic acid contents of oils changed between 18.91% (type 3) to 54.0% (type 13). Also, linolenic acid contents of oil samples were found between 2.43% (type 1) and 8.34% (type 26). Total saturated fatty acid contents of oil samples changed between 15.57% (typ 26) and 34.38% (type 1). K contents of rye grains were found between 3810.31 mg/kg (type 2) and 6148.28 mg/kg (type 17). While P contents of grains vary between 1806.43 mg/kg (5) and 3710.25 mg/kg (18), Mg contents of samples ranged from 962.87 mg/kg (type 5) to 1602.33 mg/kg (type 12). The highest Ca content was determined in 14 samples (1447.96 mg/kg). The crude protein contents of rye grains ranged from 10.08% (type 1) to 15.25% (type 3). As a result, rye grain is rich in minerals and essential fatty acids for human health.*

KEYWORDS: *Rye; Oil; Protein; Mineral; Fatty acids; ICP-AES; GC.*

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INTRODUCTION

Rye (*Secale cereale*) is an important cereal crop in the cooler parts of northern and central Europe. Cereals are the fruits of cultivated grasses, members of the Gramineae family [1,2]. Although a great number of cereal grains exist, eight are considered to be principal cereal crops (wheat, corn, barley, rye, oat, rice, sorghum, and millet [3]. Cereal grains contribute significant quantities of energy, protein, and selected micronutrients to the animal and human diet. The chemical composition and bioavailability of nutrients varies between species and varieties of grains and may be affected by forms of processing as feed and food, and also cereals and their products are sources of minerals and fatty acids for human food and animal feed [2]. Rye is a good raw material for human healthy and tasty foods [4]. Generally, wheat germ contains about 11.0% crude oil, and oil is composed of linoleic, oleic, palmitic, stearic, and α-linoleic acids [5]. Also, rye is grown primarily in Eastern, Central, and Northern Europe. Rye is used to make crispbread and normal bread. Its flour is high in gliadin but low glutenin [6]. Although cereal grains have many structural similarities, they do differ in the relative proportion of their principal components and subsequently in the chemical composition of whole-grain flours. The objective of the current study was to determine the significance of the differences in the fatty acid compositions, mineral and protein contents among several rye types growing in Konya (Sarayönü) in Turkey.

EXPERIMENTAL SECTION

Material

Rye grains were provided from Sarayönü High Vocational College plant seed herbarium, Selçuk University, Konya in Turkey. In this study, 22 types rye seeds were used. This investigation was carried out on air-dried seeds in technical ripeness. Seeds were transported to the laboratory. They were cleaned in an air screen cleaner to remove all foreign matter such as dust, dirt and chaff, and immature and broken seeds.

Oil extraction

The oil content was determined according to the method ISO 659:1998 [7]. About 2 g of the rye grains were ground in a ball mill and extracted with petroleum ether in a Twisselmann apparatus for 6 h. The solvent was removed by a rotary evaporator at 40 °C and 25 Torr. The oil was dried by a stream of nitrogen and stored at – 20 °C until used.

Determination of Fatty acids

Fatty acid compositions for rye seed oil were determined using a modified fatty acid methyl ester method as described by *Hışıl* [8]. The oil was extracted three times for 2 g air-dried seed samples by homogenization with petroleum ether. The oil samples (50-100 mg) was converted to its Fatty Acid Methyl Esters (FAME). The methyl esters of the fatty acids (1 µL) were analyzed in gas chromatography (HP 6890) equipped with a Flame Ionising Detector (FID), a fused silica capillary column (60 m x 0.25 mm i.d.; film thickness 0.20 micrometer). It was operated under the following conditions: oven temperature program. 175 ºC for 7 min. Raised to 250 ºC at a rate 5 ºC/min and then kept at 250 ºC for 15 min); injector and detector temperatures, 250 and 250 ºC; respectively, carrier gas. nitrogen at a flow rate of 1.51 mL/min; split ratio. 1/50 µL/min.

Determination of mineral and protein contents

Rye grains were dried at 70 ºC in a drying cabinet with air-circulation until they reached a constant weight. Later, about 0.5 g dried and ground samples were digested by using 5ml of 65% HNO_3 and 2 ml of 35% H_2O_2 in a closed microwave system (Cem-MARS Xpress). The volumes of the digested flour samples were completed to 20 ml with ultra-deionized water, and mineral contents were determined by ICP AES (Varian-Vista, Australia). Measurements of mineral concentrations were checked using the certified values of related minerals in the reference samples received from the National Institute of Standards and Technology (NIST; Gaithersburg, MD, USA) [9]. The nitrogen combustion method was used for the determination of crude protein. The protein determination was made in Leco combustion analyzer and 6.25 was used as the conversion factor. Crude protein values of seed samples were determined according to the Association of Official Analytical Chemists [10].

Working conditions of ICP-AES

Instrument :ICP-AES (Varian-Vista)

RF Power : 0.7-1.5 kw (1.2-1.3 kw for Axial)
Plasma gas flow rate (Ar) : 10.5-15 L/min. (radial) 15 " (Axial)
Auxilary gas flow rate (Ar) :1.5 "
Viewing height : 5-12 mm
Copy and reading time :1-5 s (max.60 s)
Copy time : 3 s (max. 100 s)

Statistical analyses

All analyses were carried out three times and the results are mean±standard deviation (MSTAT C) of independent rye samples [11].

RESULTS AND DISCUSSION

The oil contents of rye grains changed between 0.70% (type 25) and 3.92 % (type 1) (Table 1). The fatty acid compositions of rye grain oils are illustrated in Table 1. Palmitic, stearic, oleic, and linoleic acids were determined as the main fatty acids of oil samples. While palmitic acid contents of grain oils change between 10.82% (type 26) and 22.43% (type 10), stearic contents of oil samples ranged from 1.25% (type 14) to 7.74% (type 10). In addition, oleic acid contents of oil samples vary between 20.61% (typ 17) and 37.86% (type 3), linoleic acid contents of oils changed between 18.91% (type 3) to 54.0% (type 13). Also, linolenic acid contents of oil samples were found between 2.43% (type 1) and 8.34% (type 26). Total saturated fatty acid contents of oil samples changed between 15.57% (typ 26) and 34.38% (type 1). Polyunsaturated fatty acid contents of oils were found higher compared to monounsaturated fatty acids (except for type 1 and 3). The highest palmitoleic acid contents (4.68% 4.39%, 2.01, 5.28, and 2.06) were found in type 1, 3, 10, 25, and 26 sample oils, respectively. In other samples, palmitoleic acid was found <0.7%. In another study, total unsaturated fatty acids of *Triticum durum* and *Triticum aestivum* were determined as 77.34% and 75.31%, respectively [12]. In the previous study, the main fatty acid of several cereal oils was linoleic acid for durum wheat (52.16 %), for common wheat (55.20%), for barley (55.20%), for rye (55.01%), for triticale (59.26%). The climatic factor, genotype, and analytical conditions can be affective on oil content and fatty acid compositions [12]. So, polyunsaturated fatty acids of secale oils were in agreement with previous findings [12-15]. Generally, the dominant fatty acid for cereal oil was linoleic acid (52.16%) for durum wheat, (59.10%) for common wheat, (55.20%) for barley, (55.01%) for rye, (59.26%) for triticale (Kan, 2015). These differences among fatty acid concentrations can be probably due to environmental, genotype, growing conditions, and rye types [12].

The macro and microelement contents of different rye grains are given in Table 2. K was found as the highest macro element and followed by P, S, Mg, and Ca decreasing in orders. Also, Fe was found as the highest microelement among microelements. K contents of rye grains were found between 3810.31 mg/kg (type 2) and 6148.28 mg/kg (type 17). While P contents of grains change between 1806.43 mg/kg (type 5) and 3710.25 mg/kg (type 18), Mg contents of samples ranged from 962.87 mg/kg (type 5) to 1602.33 mg/kg (type 12). The highest Ca content was determined in 14 samples (1447.96 mg/kg). (S contents of samples ranged from 1212.06 mg/kg (type 5) to 1691.38 mg/kg (type 15). Generally, the macro element contents of five rye samples were found partly low compared to the results of other samples. In addition, while Fe contents of rye grain samples are found between 63.62 mg/kg (type 10) and 128.56 mg/kg (type 4), Zn contents of grain samples varied between 21.22 mg/kg (type 7) and 51.57 mg/kg (18). Also, Mn contents of samples changed between 20.13 mg/kg (type 5) and 42.10 mg/kg (type 12). Also, Cu contents of rye samples ranged from 8.73 mg/kg (type 10) to 13.34 mg/kg (type 3). Mo contents of grains were found between 0.34 mg/kg (type7) and 1.77 mg/kg (type 20). According to *Grela* [16], wheat flour contained 3.34 g/kg P, 0.55 g/kg Ca, 1.16 g/kg Mg, 4.63 g/kg K, 0.14 mg/kg Fe, 35.60 mg/kg Mn, 25.80 mg/kg Zn, 4.50 mg7kg Cu and 0.29 mg/kg Mo. The results indicate that the rye grain is rich in K, P and Mg, and some microelements, especially Fe, Zn, and Mn. In the previous study, rye (*S. cereale* cv. aslım 95) contained 5567 ppm K, 3512 ppm K, 820 ppm Ca, 1908 ppm Mg, 30 ppm Fe, 28 ppm Zn and 2 ppm Cu [2]. Generally, microelement contents of rye samples were decreased as Fe>Zn>Mn>Cu>B and >Mo. Especially, decreasing of these elements is important for human nutrition [17]. *Ragaee et al.* [18] reported that hand wheat and soft wheat contained 3498 and 977.6 mg/kg P, 826.2 and 1225 mg/kg K, 301.2 and 306.5 mg/kg Mg, 159.5 and 202.2 mg/kg Ca, 30.8 and 7.6 mg/kg Zn, 13.2 and

Table 1: Oil contents and saturated and unsaturated fatty acid profile of rye type seeds (%)

Oil	Secale grains												
	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7	Type 8	Type 9	Type 10	Type 11	Type 12	Type 13
	3.92 ±0.45*	1.29 ±0.27	3.42 ±0.31	1.75 ±0.18	1.49 ±0.33	1.42 ±0.19	1.61 ±0.27	1.72 ±0.18	1.55 ±0.21	3.32 ±0.54	1.04 ±0.17	1.63 ±0.13	1.19 ±0.11
Fatty acids (%)													
C8:0	0.80± 0.03	-**	0.54± 0.07	-	0.44± 0.05	1.00± 0.11	0.81± 0.13	0.62±0. 09	-	0.24±0. 07	0.60±0. 09	-	0.66 ±0.05
C10:0	-	1.02± 0.17	0.15± 0.03	-	0.19± 0.03	-	-	0.18±0. 01	-	0.27±0. 05	0.09±0. 03	0.16±0. 03	0.08 ±0.01
C12:0	0.16± 0.03	0.51± 0.07	0.13± 0.01	0.20± 0.03	-	0.16± 0.03	-	-	1.11±0. 09	-	0.08±0. 03	-	-
C14:0	4.45± 0.17	1.20± 0.09	4.38± 0.27	0.25± 0.03	0.23± 0.05	0.20±0. 03	0.08±0. 03	0.29±0. 07	0.52±0. 07	1.04±0. 13	0.65±0. 09	0.12±0. 03	0.13 ±0.01
C16:0	22.01 ±0.65	15.08 ±0.72	20.69 ±0.86	16.72 ±0.43	18.43 ±0.21	16.44 ±0.27	14.44 ±0.81	19.01 ±0.21	14.44 ±0.67	22.43 ±0.34	16.35 ±0.15	14.55 ±0.78	15.03 ±0.81
C17:0	0.97± 0.09	0.96± 0.07	1.07± 0.05	-	-	-	-	-	-	0.22±0. 03	-	-	-
C18:0	4.84 ±0.11	2.23 ±0.23	5.21 ±0.27	2.81 ±0.13	3.53 ±0.21	2.03 ±0.15	1.57 ±0.18	2.38 ±0.09	3.38 ±0.51	7.74 ±0.67	1.94 ±0.43	1.83 ±0.19	1.29 ±0.15
C20:0	1.15± 0.09	0.57± 0.03	1.24± 0.07	-	-	1.13± 0.11	-	-	-	0.14±0. 01	0.28±0. 03	-	-
C22:0	-	-	-	-	-	-	-	-	-	-	-	-	-
C14:1	1.3± 20.08	0.25± 0.06	1.23± 0.03	-	-	-	-	-	-	0.06±0. 01	0.14±0. 03	-	0.06 ±0.01
C16:1	4.68 ±0.32	0.20 ±0.18	4.39 ±0.26	0.42 ±0.13	0.37 ±0.09	0.26 ±0.03	0.26 ±0.05	0.32 ±0.03	-	2.01 ±0.11	0.72 ±0.09	0.41 ±0.07	0.30 ±0.05
C17:1	0.52±0. 03	0.29± 0.03	0.49± 0.07	-	-	-	-	-	-	0.21±0. 03	-	-	-
C18:1 (*n*-9)	37.60 ±0.45	27.06 ±0.67	37.86 ±0.51	28.28 ±0.65	25.17 ±0.19	25.23 ±0.61	23.01 ±0.49	22.81 ±0.58	24.58 ±0.27	37.47 ±0.65	23.88 ±0.44	27.63 ±0.56	19.59 ±0.38
C20:1	0.80 ±0.07	1.29 ±0.11	1.18 ±0.09	1.63 ±0.07	1.28 ±0.05	-	1.09 ±0.03	0.94 ±0.07	-	1.03 ±0.05	1.17 ±0.08	1.23 ±0.11	1.42 ±
C22:1	-	-	-	-	-	-	-	-	-	-	-	-	-
C18:2 (*n*-6)	19.07 ±0.23	43.21 ±0.35	18.91 ±0.56	42.66 ±0.39	44.15 ±0.27	47.05 ±0.59	52.02 ±0.43	47.42 ±0.41	50.08 ±0.33	23.92 ±0.64	47.99 ±0.37	47.53 ±0.45	54.00 ±0.34
C18:3 (*n*-3)	2.43 ±0.35	6.12 ±0.67	2.53 ±0.54	7.02 ±0.28	6.20 ±0.31	6.50 ±0.56	6.72 ±0.47	6.02 ±0.13	5.89 ±0.23	3.21 ±0.17	6.11 ±0.35	6.54 ±0.58	7.43 ±0.47
TOTAL	100.00	99.99	100.00	99.99	99.99	100.00	100.00	99.99	100.00	99.99	100.00	100.00	99.99
∑SFA	34.38	21.57	33.41	19.98	22.82	20.96	16.90	22.48	19.45	32.08	19.99	16.66	17.19
∑MUFA	44.12	29.09	45.15	30.33	26.82	25.49	24.36	24.07	24.58	40.78	25.91	29.27	21.37
∑PUFA	21.50	49.33	21.44	49.68	50.35	53.55	58.74	53.44	55.97	27.13	54.10	54.07	61.43
∑UFA	65.62	78.42	66.59	80.01	77.17	79.04	83.10	77.51	80.55	67.91	80.01	83.34	82.80
∑*Trans*	-	-	-	-	-	-	-	-	-	-	-	-	-
P/S	0.63	2.29	0.64	2.49	2.21	2.55	3.48	2.38	2.88	0.85	2.71	3.25	3.57
*n*6/*n*3	7.85	7.06	7.47	6.08	7.12	7.24	7.74	7.88	8.50	7.45	7.85	7.27	7.27

Table 1: Oil contents and saturated and unsaturated fatty acid profile of rye type seeds (%). (continued…)

Grain samples									
Types	Type 14	Type 15	Type 16	Type 17	Type 18	Type 19	Type 20	Type 21	Type 22
Oil	1.23±0.28	1.45±0.17	1.30±0.11	1.64±0.13	1.94±0.32	1.51±0.9	2.42±0.19	1.49±0.21	1.82±0.13
		Fatty acids (%)							
C8:0	0.68±0.03	0.62±0.07	0.64±0.01	0.62±0.09	0.17±0.03	0.08±0.01	0.09±0.01	0.05±0.01	0.11±0.03
C10:0	0.03±0.01	0.07±0.01	-	0.46±0.03	0.06±0.01	0.34±0.05	0.05±0.01	0.17±0.03	-
C12:0	-	-	-	-	-	-	0.35±0.03	0.06±0.01	-
C14:0	0.16±0.03	0.17±0.01	0.29±0.07	0.29±0.05	0.11±0.03	0.26±0.07	0.25±0.03	0.27±0.05	0.18±0.03
C16:0	14.01±0.17	15.09±0.21	14.87±0.19	13.72±0.54	13.98±0.38	14.75±0.27	13.30±0.51	17.95±0.68	14.46±0.34
C17:0	-	-	-	-	-	-	-	-	-
C18:0	1.25±0.18	2.06±0.09	1.55±0.07	2.25±0.03	1.71±0.05	2.04±0.13	1.94±0.11	1.84±0.23	1.73±0.09
C20:0	-	0.55±0.03	-	0.33±0.07	-	0.26±0.01	0.21±0.03	0.23±0.05	-
C22:0	-	-	-	-	-	-	-	-	-
C14:1	0.06±0.01	0.08±0.01	-	0.06±0.01	0.08±0.03	0.07±0.01	0.05±0.01	0.07±0.01	0.09±0.01
C16:1	0.37±0.03	0.33±0.07	0.41±0.09	0.28±0.03	0.36±0.05	0.35±0.03	0.33±0.07	0.32±0.05	0.56±0.09
C17:1	-	-	-	-	-	-	-	-	-
C18:1 (*n*-9)	23.65±0.46	23.63±0.51	22.92±0.38	20.61±0.27	22.08±0.43	20.88±0.51	24.20±0.37	24.29±0.33	21.70±0.19
C20:1	1.39±0.11	1.30±0.09	1.33±0.07	1.28±0.13	1.43±0.09	1.20±0.07	1.30±0.11	1.45±0.09	1.42±0.05
C22:1	-	-	-	-	-	-	-	-	-
C18:2 (*n*-6)	51.76±0.58	49.48±0.71	49.67±0.49	52.83±1.07	52.57±0.48	52.76±0.51	51.79±0.64	46.75±0.38	52.60±0.23
C18:3 (*n*-3)	6.64±0.17	6.61±0.13	8.32±0.21	7.27±0.19	7.45±0.44	7.01±0.51	6.14±0.27	6.54±0.18	7.15±0.24
TOTAL	100.00	99.99	100.00	100.00	100.00	100.00	100.00	99.99	100.00
∑SFA	16.13	18.56	17.35	17.67	16.03	17.73	16.19	20.57	16.48
∑MUFA	25.47	25.34	24.66	22.23	23.95	22.50	25.88	26.13	23.77
∑PUFA	58.40	56.09	57.99	60.10	60.02	59.77	57.93	53.29	59.75
∑UFA	83.87	81.43	82.65	82.33	83.97	82.27	83.81	79.42	83.52
∑*Trans*	-	-	-	-	-	-	-	-	-
P/S	3.62	3.02	3.34	3.40	3.74	3.37	3.58	2.59	3.63
*n*6/*n*3	7.80	7.49	5.97	7.26	7.06	7.53	8.43	7.15	7.36

**mean±standard deviation; **nonidentified;SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; UFA, unsaturated fatty acids; nd, non-detected*

Table 2: Mineral contents of rye grains (mg/kg).

Types		P	K	Ca	Mg	S	Fe	Zn	Mn	B	Cu	Mo
Type 1	Mean SD	2855.59 5.73*	4526.66 8.00	313.90 2.00	1292.78 2.86	1433.92 3.70	79.07 0.93	29.35 1.51	31.27 2.25	10.28 0.36	10.94 0.92	0.59 0.03
Type 2	Mean SD	2347.71 6.67	3810.31 5.45	249.13 8.07	1076.46 5.44	1272.98 6.66	69.26 1.26	24.33 0.73	28.18 1.51	7.82 0.38	10.74 0.61	0.35 0.03
Type 3	Mean SD	3242.02 3.63	4130.14 5.57	336.77 5.72	1353.95 6.55	1470.24 3.42	107.58 3.28	37.50 1.67	37.57 0.99	7.78 0.41	13.34 0.34	1.05 0.05
Type 4	Mean SD	2287.33 6.70	3892.35 5.02	526.73 7.84	1102.83 4.62	1609.46 5.59	128.56 3.69	26.90 1.87	28.19 1.61	7.43 0.39	11.24 0.55	0.52 0.04
Type 5	Mean SD	1806.43 5.07	3888.09 6.47	261.43 3.43	962.87 5.41	1212.06 4.75	72.07 2.62	22.17 1.74	20.13 1.09	7.39 0.44	9.20 0.31	0.39 0.03
Type 6	Mean SD	2808.88 6.28	5024.91 5.25	288.82 5.75	1122.58 4.15	1395.44 3.67	77.95 2.92	24.92 1.45	27.55 1.09	7.36 0.26	11.04 0.21	0.36 0.02
Type 7	Mean SD	3066.53 6.03	5006.06 3.24	358.34 6.21	1206.17 4.15	1318.71 2.73	68.34 2.32	21.22 2.15	28.67 1.23	6.35 0.22	10.31 0.33	0.34 0.03
Type 8	Mean SD	2877.16 6.65	4584.84 7.15	378.41 6.27	1124.42 7.23	1503.69 2.69	67.31 3.14	25.29 1.18	24.20 0.91	5.07 0.41	9.45 0.47	0.59 0.03
Type 9	Mean SD	2635.79 5.86	4741.25 5.56	310.43 4.11	1150.95 3.33	1453.70 1.96	65.42 2.31	22.55 1.87	24.56 1.42	5.16 0.35	9.66 0.55	0.42 0.04
Type 10	Mean SD	3202.61 6.85	5812.34 5.78	536.62 3.07	1377.16 5.51	1377.46 6.28	63.62 1.43	27.12 1.43	26.02 1.63	5.51 0.43	8.73 0.51	0.047 0.02
Type 11	Mean SD	3468.40 5.28	5206.91 4.40	483.01 4.66	1521.54 5.38	1673.19 4.50	82.05 3.67	36.21 1.72	38.21 1.18	6.41 0.46	12.20 0.27	0.41 0.03
Type 12	Mean SD	3215.76 6.69	4886.18 7.14	451.74 3.43	1602.33 5.46	1707.78 6.37	75.21 3.74	31.67 1.41	42.10 1.16	7.50 0.39	12.49 0.47	0.64 0.03
Type 13	Mean SD	2909.78 6.17	5718.78 3.90	645.70 7.96	1164.63 3.79	1283.69 3.59	68.21 3.98	29.36 2.10	31.13 1.22	5.51 0.39	10.60 0.45	0.42 0.04
Type 14	Mean SD	3290.84 3.85	4876.28 3.91	1447.96 5.98	1442.21 4.82	1419.65 6.29	63.26 3.63	44.12 1.57	32.45 1.15	4.11 0.66	9.75 0.39	0.65 0.04
Type 15	Mean SD	3556.21 6.88	4646.79 3.21	343.58 4.81	1458.21 3.21	1691.38 3.01	77.43 3.05	42.93 1.42	27.84 0.79	5.47 0.28	11.77 0.49	0.55 0.06
Type 16	Mean SD	3347.66 5.88	4661.60 6.67	400.01 3.48	1371.70 3.46	1429.54 5.58	83.97 3.55	40.42 2.35	29.32 0.87	5.57 0.28	12.35 0.33	1.01 0.05
Type 17	Mean SD	3472.24 3.36	6148.28 6.00	405.17 4.65	1195.72 3.93	1460.83 6.97	83.54 2.11	39.23 1.10	30.45 0.85	5.41 0.37	10.64 0.54	0.79 0.05
Type 18	Mean SD	3710.25 4.20	5848.88 5.68	482.81 3.06	1373.67 6.78	1545.59 6.37	69.05 1.66	51.57 1.37	28.40 1.15	4.26 0.35	11.13 0.23	0.47 0.04
Type 19	Mean SD	3033.77 3.84	4932.02 6.81	279.00 4.77	1291.42 2.75	1611.59 4.11	71.97 1.75	40.55 1.37	28.87 1.56	5.45 0.33	11.27 0.61	1.29 0.06
Type 20	Mean SD	2986.19 4.52	5673.94 5.26	401.75 3.55	1360.93 6.30	1657.25 2.83	76.53 0.93	39.48 0.91	30.08 1.63	5.06 0.27	11.55 0.63	1.77 0.09
Type 21	Mean SD	3132.71 5.46	5734.21 4.24	286.92 6.59	1332.39 5.92	1488.18 5.09	67.53 0.90	41.95 1.82	24.71 0.98	4.46 0.29	10.20 0.47	1.20 0.04
Type 22	Mean SD	2615.50 6.16	4522.07 3.41	157.22 2.92	1246.75 6.46	1481.69 6.30	66.92 1.54	33.57 1.44	28.54 1.39	4.62 0.54	11.41 1.11	1.46 0.12

**mean±standard deviation (SD)*

13.9 mg/kg Fe, 5.2 and 8.1 mg/kg Mn and 1.4 and 1.6 mg/kg Cu, respectively. The crude protein contents of rye grains ranged from 10.08% (type 1) to 15.25% (type 3) (Table 3). Generally, the protein contents of grains were found similar. The protein contents of type 19 and type 22 were found close to the result of type 3 grain. Also, protein contents of whole-grain flours (barley, oat, wheat, buckwheat, and rye) changed between 13.74% (rye) and 17.46% (Oat) [1]. In previous study, hard wheat, soft wheat, barley, millet, rye and sorghum contained 13.5%, 11.0%, 19.4%, 8.8%, 13.3% and 12.1% crude protein [18]. Protein results showed partly differences with literatüre results. These differences can be probably due to several factors such as cereal type, climatic conditions, location, and structure of grains.

CONCLUSIONS

Rye grain is rich in essential fatty acids (oleic and linoleic) and minerals for human health. Palmitic, stearic, oleic and linoleic acids were determined as the main fatty

Table 3: Protein contents of rye grains (%).

Types	Crude Protein*
Type 1	10.08±0.35**
Type 2	12.90±0.70
Type 3	15.25±0.38
Type 4	12.08±0.38
Type 5	10.63±0.32
Type 6	12.62±0.30
Type 7	11.58±0.18
Type 8	11.85±0.24
Type 9	11.88±0.23
Type 10	12.23±0.34
Type 11	12.55±0.12
Type 12	13.16±0.10
Type 13	11.54±0.23
Type 14	11.82±0.10
Type 15	12.58±0.10
Type 16	11.06±0.48
Type 17	12.21±0.13
Type 18	13.47±0.26
Type 19	14.77±0.17
Type 20	13.78±0.26
Type 21	15.33±0.28
Type 22	14.75±0.27

**Nx6.25; **Mean±Standard Deviation (SD)*

acids of oil samples. K was found as the highest macro element, and followed by P, S, Mg and Ca decreasing in orders. Besides, Fe was found as the highest microelement among microelements. Generally, microelement contents of rye samples were decreased as Fe>Zn>Mn>Cu>B and >Mo. Decreasing of these elements is important for human nutrition. Considering the protein contents, rye flour significantly differs from other flour samples according to literature values.

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