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Full Length Article

Variation of Some Physical and Chemical Quality Traits of the Grains in Different Parts of the Oat Panicle

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Abstract

Besides high grain yield, some quality attributes are also desired in oat (*Avena sativa* L.) grains. The present study was conducted to investigate some physical and chemical characteristics of oat grains located at top, middle and bottom sections of the panicle. A total of twenty five different oat varieties commonly grown in various parts of the world were experimented in randomized blocks design with three replications in for two growing seasons in Samsun, Turkey. Panicles were divided into three groups as of top, middle and bottom. Some physical (thousand-grain weight, grain length and width, groat percentage) and chemical (ash ratio, protein ratio, starch ratio, fat ratio and fatty acids) characteristics of grains in different panicle groups were determined. Significant differences were observed in all quality parameters based on the position of grains within the panicle. Cultivars and cultivar × panicle interactions had significant effects on quality parameters. While higher thousand-grain weight, grain length and width, groat percentage, starch ratio, fat ratio, stearic and oleic acid contents were observed in top grains, higher ash ratio, palmitic and linoleic acid contents were observed in bottom grains.

Keywords: Panicle group; Oat; Physical and Chemical traits; Variety

Introduction

While oat has been used only for animal feeding until recent years in several parts of the world, today it is gaining an increasing popularity in human feeding (Tang *et al*., 2014). Oat is used in human nutrition commonly as oatmeal or oat bran in breakfasts. It is also used in biscuits, baby formulas, soups, sauces, tomato pastes, breads and in several other food stuffs in mixtures with the other cereals (Özcan *et al*., 2006). Purpose to use of oat groats is commonly dominated with their physical characteristics and chemical compositions (Peterson *et al*., 2005). Hectoliter weight, grain weight, groat percentage, flour yield, fat and β-glucan concentration are the most significant physical and chemical quality attributes of oat (Doehlert *et al*., 2001; Peterson *et al*., 2005). Oat is quite rich in digestible fibers, proteins, unsaturated fatty acids, vitamins, minerals and phytochemicals (Flander *et al.,* 2007). Oat grains contain about 12.4–24.4% protein, 3.0–12.0% fat and 1.8–7.5% β-glucan. Oat grains with high fiber content and quality attributes reduce cholesterol and blood glucose levels, thus it is considered as significant food stuff in human nutrition. Oat has quite high protein values, protein digestibility levels and net protein use ratios (Sarı and Ünay, 2013). Oat grains also contain various antioxidants, phenolics and avenanthramids, therefore have a special place in human nutrition (Dokuyucu *et al*., 2003). Oat has a quite well-balanced fatty acid composition and mostly composed of oleic (C18:1) and linoleic (C18:2) unsaturated fatty acids.

Improved grain quality provides significant contributions to producers and food processors (Doehlert and McMullen, 2000). Oat grains have been searched for years because of specific chemical composition, nutritional and physiological characteristics of the grains. Previous researchers working on wheat and paddy indicated that grain physical characteristics and chemical composition might vary based on the position of grain within spike or panicle (Boz *et al*., 2012; Su *et al*., 2014). The studies on physical and chemical characteristics of grains located at different sections of oat panicle are quite limited. A research on physical characteristics and chemical compositions of grains at different positions may contribute to have high quality grains. Therefore, the present study was conducted with twenty five oat varieties to investigate some physical characteristics and chemical composition of the grains located at different sections of the panicle.

Materials and Methods

Plant Materials and Field Experiments

In this study, a total of twenty five different oat (*Avena*

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sativa L.) varieties commonly grown in various parts of the world were used (Table 1). The field experiments were carried out an experimental field at the Department of Field Crops, Faculty of Agriculture, Ondokuz Mayıs University (41°21´ N, 36°15´ E, and 195 m a.s.l.) in 2014–2015 and 2015–2016 growing seasons in Samsun province of Turkey. The varieties were grown in randomized block design with three replications. The sowing rates were 450 seed m^2 for experiment conditions. Sowing dates were 8th November 2014 and 12th November 2015, respectively. The seeds were planted using an experimental drill in 1.2 m × 6 m plots consisting of six rows with 20 cm row space. Fertilizers were applied as 60 kg ha^{-1} N and 60 kg ha^{-1} P_2O_5 at planting. In addition, top-dressing was applied as 60 kg ha^{-1} N at tillering stage. Herbicide was used for weed control. Some climatic data and soil characteristics of the experimental areas are given in Table 2 and 3.

Grain Sampling and Analysis

Plants were harvested at ripening period and 200 panicles were sampled from each replication and divided into 3 equal portions. The panicles of each variety were divided among three spikelet groups as top spikelet, middle spikelet and bottom spikelet. Panicle lengths and number of grain per panicle of each variety are provided in Table 1. The panicle sections (spikelet) were threshed with a single plant thresher separately. Threshed grains were cleaned, placed into air-tight plastic containers and stored at ±4°C in a cold storage until the analyses. Thousand-grain weight, grain length and grain width were determined with MARVIN seed analyzer (GTA Sensorik, Neubrandenburg, Germany). Groat percentage was determined by husking 50 grains from each replication manually. Oat samples for chemical analysis were ground through a 1 mm screen in a Wiley mill and stored for later analyses. The results are expressed on a dry weight basis. The chemical compositions of all grain samples were determined following AOAC (2006). Ash ratio was determined through ashing samples at 580°C for 8 h. Crude protein (N × 6.25) was obtained by the Kjeldahl method. Ether extract was detected by Soxhlet extraction with diethyl ether. The starch content was determined according to Ewers Polarimetric Method. Fatty acid composition was determined using a modified fatty acid methyl ester method as described by Marquard (1987). The methyl esters of the fatty acids (0.5 mL) were analysed in a Shimadzu GC 2010 equipped with a flame ionizing detector, a fused silica capillary column (MN FFAP, 60 m x/0.32 mm i.d.; film thickness, 0.25 µm). It was operated under the following conditions: oven temperature programme, 120^0C for 1 min raised to 240^0C at a rate of 6^0C/min and then kept at 240^0C for 15 min); injector and detector temperatures, 250 and 260^0C, respectively; carrier gas, helium at flow rate of 40 mL/min; and split ratio, 1/20 mL/min. The contents of palmitic acid (C16:0), stearic acid (C18:0), oleic acid (C18:1), linoleic acid (C18:2) and linolenic acid (C18:3) were determined by computing integrator.

Table 1: The names, codes and origin of oat varieties used in this study

Genotype code	Genotype	Origin*	Hull*	PL (cm)		GN	
				2014-2015	2015-2016	2014-2015	2015-2016
G1	Blaze	US	W	19.6	20.8	95.4	131.3
G2	Neklan	CZ	Y	22.0	21.6	166.0	185.0
G3	Expander	AT	Y	18.9	20.1	138.0	199.4
G4	Auteuil	FR	B	24.5	23.5	154.2	144.8
G5	Charlton	NZ	Y	20.7	18.9	69.2	99.8
G6	Revisor	DE	W	21.4	20.4	175.3	170.7
G7	Milton	US	Y	17.2	15.0	101.2	97.6
G8	Bajka	PL	Y	23.1	20.6	171.2	149.7
G9	Puhti	FI	W	22.6	24.8	166.1	210.1
G10	Viker	EE	W	23.6	29.8	98.0	132.8
G11	Capa	UY	W	25.4	24.6	117.2	155.0
G12	Aberglen	GB	W	24.1	26.1	146.9	181.2
G13	OT 286	CA	W	20.0	19.7	125.3	137.5
G14	Barra	SE	W	21.4	21.3	103.2	118.7
G15	Irtysh 13	RU	W	21.3	25.0	106.0	106.0
G16	Mara	LV	W	16.5	21.5	57.2	84.7
G17	Ogle	US	Y	16.3	21.1	125.6	172.5
G18	Bakonyalja	HU	W	17.5	21.8	96.4	181.3
G19	Matra	NL	W	20.4	20.4	94.4	147.3
G20	Akiyutaka	JP	W	20.8	24.1	99.0	102.9
G21	Alo	EE	W	20.2	22.7	107.6	211.9
G22	Faikbey	TR	Y	21.8	17.2	58.1	55.6
G23	Yeşilköy-330	TR	Y	21.3	21.4	61.5	55.6
G24	Yeşilköy-1779	TR	Y	22.6	18.7	85.1	87.4
G25	Checota	US	W	18.1	17.2	96.5	59.3

*: Country of origin abbreviated by the ISO 3166 country codes, PL: Panicle length, GN: Grain number per panicle
**Hull colour: W, white; Y, yellow; B, black

Data Analysis

Data was subjected to an analysis of variance utilizing a randomized complete block design arranged as factorial. Statistical analysis was performed using statistics software version SPSS 11.0. The data were submitted for variance analysis and the means were tested by least significant difference.

Results

Combined-years variance analysis revealed that differences in all traits of varieties, panicle groups and years were found to be significant (Table 4 and 5). Year × variety, year × panicle group, variety × panicle group and year × variety × panicle group interactions were also found to be significant with regard to all traits (Table 4 and 5).

According to combined variance analysis, there were significant differences in thousand-grain weights of the varieties, panicle groups and years. Thousand-grain weight of oat varieties varied between 27.1–36.7 g. While the varieties Auteuil, Yeşilköy-330 and Checota had the greatest thousand-grain weight, the varieties Expander, Charlton, Bajka, Bakonyalja and Alo had the lowest thousand-grain weight. In general, the greatest thousand-grain weight was obtained from the top grains that were respectively followed by middle and bottom grains.

The values were respectively measured as 33.7 g, 31.4 g and 29.0 g (Table 4). However, in some varieties bottom grains had higher thousand-grain weights than middle grains. Such a case then resulted in significant variety × panicle group interactions, and the highest thousand-grain weight was obtained from top panicle group of Auteuil variety with 42.1 g. In general, thousand-grain weight decreased from the top to the bottom of the panicle (Fig. 1).

Table 3: Physical and chemical characteristics of experiment soils sampled from 0-30 cm topsoil

Soil characters	2014-2015	2015-2016
Soil texture	Clay	Clay
Organic matter (%)	2.85	2.97
Phosphorus content (kg/ha)	25.4	35.0
Potassium content (kg/ha)	740.0	470.0
Amount of lime (%)	0.26 (Non-limy)	0.32 (Non-limy)
Salinity (%)	0.12 (Non-salty)	0.07 (Non-salty)
pH	6.88	6.30
Nitrogen content (%)	0.20	0.18
Calcium content (%)	0.68	0.60
Magnesium content (%)	0.11	0.11

Thousand-grain weights were higher in the second year than in the first year and values were respectively measured as 29.4 and 33.3 g (Table 4).

Combined variance analysis revealed that differences in length and width values of the varieties, panicle groups and years were significant different (Table 4). Grain length of the varieties varied between 8.6 mm (Puhti variety) and 13.5 mm (Faikbey variety). Considering the grain lengths of panicle groups, it was observed that grain lengths of top and middle panicle groups were placed in the same statistical group and the values were measured respectively as 10.8 and 10.6 mm. Bottom grains had smaller grain lengths (10.3 mm) (Table 4). Varieties exhibited different trends in grain lengths in different panicle groups, therefore variety ×panicle group interactions were found to be significant, and the highest grain length was measured from middle group of Faikbey variety with 14.5 mm. Generally, the grain lengths in the top and middle of the panicle were higher, while the grain length in the bottom of Milton, Puhti and Bakonyalja varieties were longer (Fig. 2). Grain widths of oat varieties varied between 2.39 mm (Viker variety) and 2.84 mm (Yeşilköy-330 variety). Average width of the grains in top and middle sections was respectively measured as 2.67 mm and 2.65 mm and they were placed in the same statistical group. Grain widths in bottom grains were lower and average value was 2.53 (Table 4). Grain weights of panicle groups varied with varieties. The highest grain width was measured from top group of Yeşilköy-330 variety with 2.95 mm. The widths of grain of in the top and middle portions were higher than that in the bottom portions, except

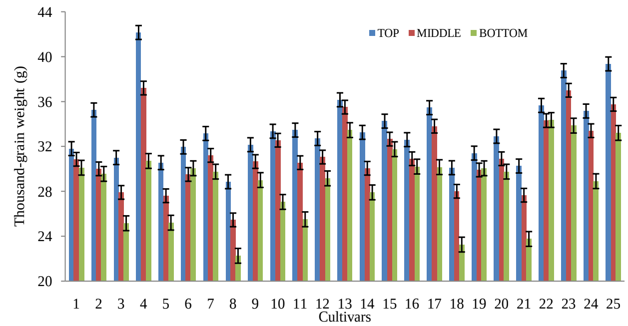

Fig. 1: Cultivar × spikelet group interaction for thousand-grain weight

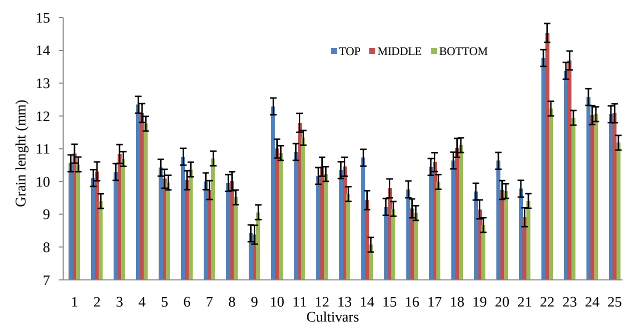

Fig. 2: Cultivar × spikelet group interaction for grain length

in Revisor, Milton, Mara, Bakonyalja and Matra varieties (Fig. 3). Grain width of the first and the second year was respectively measured as 2.68 and 2.56 mm.

Combined variance analysis revealed that the effect

Table 2: Some climatic values of the study area

		Months								Total/Mean
		November	December	January	February	March	April	May	June	
	2014-2015	93.7	79.3	129.3	84.5	70.5	95.7	30.4	54.4	637.8
Rainfall (mm)	2015-2016	28.6	100	88.1	30.9	109.6	49.9	188.2	63.1	658.4
	30-year average	82.1	76.4	57.2	52.9	55.8	58.4	51.9	46.6	481.3
	2014-2015	67.0	64.6	60.3	63.4	73.9	67.9	73.9	68.5	67.4
Relative Humidity (%)	2015-2016	56.5	62.5	59.8	60.3	67.9	70.4	71.5	69.1	64.8
	30-year average	70.6	66.7	67.9	70.2	75.9	79.5	75.7	76.5	72.9
	2014-2015	11.8	11.4	7.6	8.7	8.7	10.9	16.2	21.4	12.1
Temperature (ºC)	2015-2016	14.3	8.4	7.5	11.3	10.2	13.8	16.9	22.5	13.1
	30-year average	11.9	9.0	7.0	6.7	8.0	11.2	15.3	20.2	11.2

Table 4: The mean TGW, GL, GW, GP, AC, PC and SC values for Cultivar and Spikelet Groups combined years

		TGW	GL	GW	GP	AC	PC	SC
Cultivars(C)		**	**	**	**	**	**	**
	1	30.9 ef	10.6 hi	2.63 a-g	71.3 e	2.440 l	13.21 f	45.43 pq
	2	31.6 de	9.9 kl	2.59 a-g	69.9 g	2.177 t	13.42 e	52.93 c
	3	28.0 h	10.6 hi	2.49 d-g	67.9 j	2.456 k	12.51 ijk	46.60 n
	4	36.7 a	12.1 cd	2.71 a-e	66.9 m	2.230 r	13.00 g	46.62 n
	5	28.0 h	10.2 jkl	2.52 c-g	64.6 r	2.641 f	14.49 b	46.98 m
	6	30.5 fg	10.4 ij	2.74 a-d	67.0 m	2.528 g	12.30 lm	44.81 s
	7	31.4 ef	10.1 jkl	2.65 a-f	72.1 d	2.327 n	13.37 e	50.23 g
	8	27.8 h	9.8 l	2.44 fg	65.5 p	2.299 o	11.55 o	50.47 f
	9	30.6 efg	8.6 n	2.78 abc	64.5 r	2.840 a	12.61 i	41.73 v
	10	31.0 ef	11.4 ef	2.39 g	66.0 o	2.771 b	12.62 i	42.41 u
	11	29.8 g	11.3 fg	2.56 bg	68.6 h	2.655 e	13.64 d	45.20 r
	12	31.0 ef	10.3 ijk	2.49 d-g	68.0 ij	2.168 u	12.07 o	49.37 i
	13	35.0 b	10.1 jkl	2.53 cg	73.0 b	2.210 s	12.57 ij	50.99 e
	14	30.4 fg	9.4 m	2.55 bg	67.9 ij	2.289 p	12.46 jk	48.58 j
	15	32.9 c	9.4 m	2.74 a-d	68.1 i	2.478 j	12.79 h	45.47 p
	16	31.2 ef	9.3 m	2.72 a-e	66.7 n	2.860 d	13.79 c	47.25 l
	17	33.1 c	10.3 ijk	2.80 ab	73.6 a	2.263 q	12.81 h	53.12 b
	18	27.1 h	10.9 gh	2.46 efg	66.7 n	2.455 k	11.95 p	47.23 l
	19	30.5 fg	9.2 m	2.74 a-d	67.2 l	2.391 m	12.40 kl	49.70 h
	20	31.2 ef	10.0 jkl	2.52 cg	65.3 q	2.483 i	15.06 a	45.31 qr
	21	27.2 h	9.4 m	2.57 bg	63.4 s	2.760 c	13.19 f	44.09 t
	22	34.8 b	13.5 a	2.70 a-f	66.0 o	2.452 k	12.26 mn	51.86 d
	23	36.5 a	13.0 b	2.84 a	70.8 f	2.099 v	12.42 kl	55.35 a
	24	32.5 cd	12.2 c	2.54 bg	67.5 k	2.516 h	12.17 no	46.05 o
	25	36.1 a	11.7 d	2.67 a-f	72.6 c	2.475 j	12.90 gh	47.40 k
Spikelet Group (SG)		**	**	**	**	**	**	**
	TOP	33.7 a	10.8 a	2.67 a	69.1 a	2.404 c	12.76 b	48.41 a
	MIDDLE	31.4 b	10.6 a	2.65 a	68.1 b	2.446 b	12.78 b	47.75 b
	BOTTOM	29.0 c	10.3 b	2.53 b	67.0 c	2.478 a	13.03 a	47.26 c
Years (Y)		**	**	**	**	**	**	**
	2014-2015	29.4 b	10.3 b	2.56 b	68.6 a	2.514 a	13.59 a	47.95 a
	2015-2016	33.3 a	10.8 a	2.68 a	67.5 b	2.371 b	12.13 b	47.66 b
Y × C		**	**	**	**	**	**	**
Y × SG		**	**	**	**	**	**	**
C × SG		**	**	**	**	**	**	**
Y × C × SG		**	**	**	**	**	**	**

**Significant at P<0.01, TGW: Thousand grain weight (g), GL: Grain length (mm), GW: Grain with (mm), GP: Groatpercantage (%), AC: Ash content (%), PC: Protein content (%), SC: Starch content (%)

of variety, panicle group and year were significant difference on groat percentage. As the average of two years, groat percentages varied between 63.4% (Alo variety) and 73.6% (Ogle variety).

The greatest groat percentage (69.1%) was obtained from top grains which followed by middle (68.1%) and bottom (67.0%) grains (Table 4). Variety × panicle group interactions were also found to be significant; some varieties had higher percentages in middle and bottom grains than the top grains, and the highest groat percentage was obtained from middle group of OT 286 variety with 76.0%, the lowest value was obtained from bottom group of Charlton variety with 59.9%. Differences in groat percentage among grain positions within the panicle were observed. However, most of the varieties had a higher groat percentage in the top of the panicle (Fig. 4). Groat percentage was higher in the first year than the second year and it was measured respectively 68.6 and 67.5%.

Grain ash ratios of the varieties changed between 2.10% (Yeşilköy-330 variety) and 2.84% (Puhti variety). Considering the panicle groups, the lowest ash ratio (2.40%)

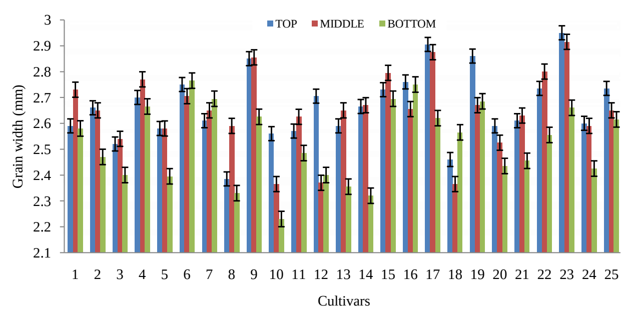

Fig. 3: Cultivar × spikelet group interaction for grain width

was obtained from top grains. The ash ratios of middle and bottom panicle groups were respectively measured as 2.45 and 2.48%. Ash ratios of the first year were higher than of the second year with 2.51 and 2.37%, respectively (Table 4). Variety × panicle group interactions were also found to be significant for ash ratio (Table 4). The highest ash content was obtained from the bottom group of Puhti

Table 5: The mean FC, 16:0, 18:0, 18:1, 18:2 and 18:3 values for Cultivar and Spikelet Groups combined years

		FC	16:0	18:0	18:1	18:2	18:3
Cultivars (C)		**	**	**	**	**	**
	1	6.02 de	17.6 ij	1.54 efg	43.3 b	34.3 jk	1.49 ghi
	2	4.14 o	18.0 e-h	1.59 cde	35.9 l	39.6 a	1.80 a
	3	4.66 mn	18.5 d	1.62 b-e	37.3 k	37.8 d	1.39 kl
	4	4.99 j	17.1 k	1.43 g	39.7 h	37.3 e	1.74 ab
	5	5.30 hi	18.8 b	1.56 d-g	37.3 k	38.3 c	1.62 de
	6	4.14 o	18.5 d	1.57 def	38.2 j	37.4 e	1.40 kl
	7	6.41 b	17.7 hi	1.62 b-e	39.8 h	36.7 f	1.72 bc
	8	4.87 jk	18.0 efg	1.53 efg	37.3 k	37.8 d	1.65 d
	9	5.00 j	17.8 f-i	1.45 fg	38.6 j	37.3 e	1.56 ef
	10	6.42 b	18.6 cd	1.52 efg	42.0 cd	34.2 k	1.37 l
	11	5.36 h	18.5 d	1.56 d-g	39.0 i	36.6 f	1.54 fg
	12	4.68 lm	18.1 ef	1.62 b-e	37.5 k	38.6 b	1.48 hij
	13	5.93 ef	17.4 j	1.61 b-e	41.3 ef	36.1 g	1.67 cd
	14	4.54 n	19.0 b	1.65 b-e	36.2 l	39.3 a	1.30 m
	15	5.56 g	18.1 e	1.54 efg	39.7 h	36.6 f	1.53 fgh
	16	6.06 d	18.5 d	1.54 efg	40.9 fg	35.5 h	1.64 d
	17	5.39 h	17.8 ghi	1.69 bcd	39.6 h	37.1 e	1.64 d
	18	4.74 lm	18.5 d	1.65 b-e	38.2 j	37.3 e	1.42 jkl
	19	4.78 kl	18.8 bc	1.73 b	37.6 k	37.8 d	1.39 kl
	20	5.22 i	19.3 a	1.63 b-e	37.6 k	38.0 cd	1.44 ijk
	21	6.24 c	18.5 d	1.58 cde	41.6 de	34.6 j	1.50f-i
	22	6.28 c	18.5 d	1.71 bc	39.5 h	36.4 f	1.54 fg
	23	6.87 a	18.1 e	1.89 a	42.3 c	35.0 i	1.18 n
	24	5.86 f	18.4 d	1.54 efg	40.8 g	35.4 h	1.29 m
	25	6.96 a	17.8 f-i	1.61 b-e	45.3 a	32.6 l	1.44 ijk
Spikelet Group (SG)		**	**	*	**	**	*
	TOP	5.54 a	18.1 c	1.62 a	40.1 a	36.4 c	1.49 b
	MIDDLE	5.42 b	18.2 b	1.59 b	39.4 b	36.7 b	1.52 a
	BOTTOM	5.41 b	18.4 a	1.59 b	38.9 c	37.1 a	1.51 a
Years (Y)		**	**	**	**	**	**
	2014-2015	5.57 a	19.3 a	1.67 a	37.9 b	37.4 a	1.39 b
	2015-2016	5.35 b	17.1 b	1.53 b	41.0 a	36.0 b	1.63 a
Y × C		**	**	**	**	**	**
Y × SG		**	**	**	**	**	**
C × SG		**	**	**	**	**	**
Y × C × SG		**	**	**	**	**	**

FC; Fat content (%), 16:0; Palmitic (%), 18:0; Stearic (%), 18:1; Oleic (%), 18:2; Linoleic (%), 18:3; Linolenic (%)

variety with 3.122%, while the lowest was obtained from the top group of Yeşilköy-330 variety with 1.942%. Most of the varieties had higher ash content in the bottom of the panicle (Fig. 5).

Protein ratio, is among the primary attribute designating the purpose of use in cereals, was significantly different between varieties, panicle groups and years. In combined years, the mean protein ratio was the greatest in Akiyutaka variety (15.06%) and the lowest was in Bajka variety (11.55%). The varieties respectively Akiyutaka (15.06%), Charlton (14.49%), Mara (13.79%), Capa (13.64%), Neklan (13.42%), Milton (13.37%), Blaze (13.21%), Alo (13.19%), Auteuil (13.00%) and Checota (12.90%) had protein ratio greater than the general average (12.86%) (Table 4). Considering the protein ratios of the panicle groups, the greatest value (13.03%) was obtained from the bottom grains, and followed by middle grains (12.78%) and top grains (12.76%). Average grain protein ratio was 13.59% in the first year and 12.13% in the second year (Table 4). With regard to protein contents, varieties × panicle group interactions were also found to be significant. Protein ratio was higher in the middle group of Blaze (13.74%), Neklan (13.59%), Miltton (13.63%), Puhti (12.63%), Faikbey (12.67%) and Checota (13.52%) varieties, but higher in the top group of Auteuil (13.18%), Viker (13.03%), Bakonyalja (12.01%), Alo (13.39%), Yeşilköy-330 (12.83%) and Yeşilköy-1779 (12.67%) varieties. In other varieties, protein ratio was higher in the bottom group (Fig. 6).

Starch ratio was significantly affected by the varieties, panicle groups and years (P<0.01). Starch ratio varied between 41.73% (Puhti) and 55.35% (Yeşilköy-330) among the varieties; Yeşilköy-330, Ogle, Neklan, Faikbey, OT 286, Bajka, Milton, Matra, Aberglen, Barra had greater starch ratio than the general average (47.81%). Considering the starch ratio of the grains based on their position in panicle, the greatest value was obtained from top grains (48.41%) and, it was followed by middle (47.75%) and bottom grains (47.26%) (Table 4). With regard to starch content, variety x panicle group interactions was also found to be significant (Table 4) and, starch content changed with the position of the grain within the panicle. Starch content of the varieties included in the study was the

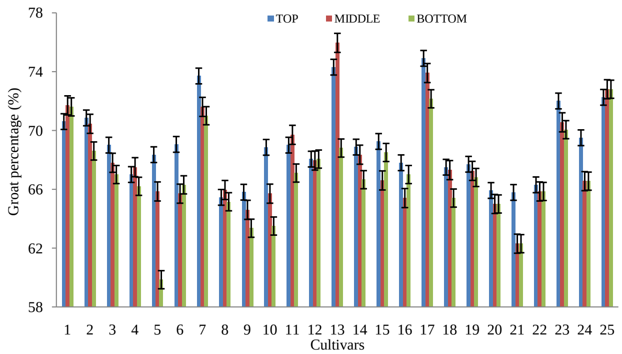

Fig. 4: Cultivar × spikelet group interaction for groat percentage

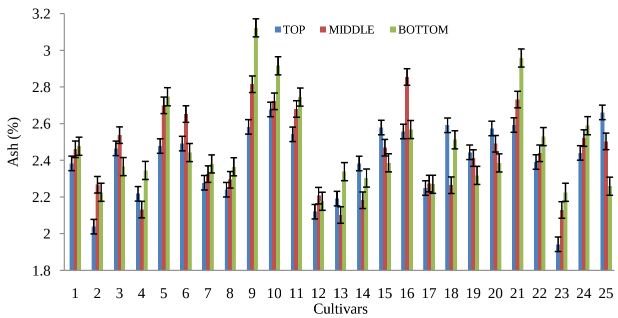

Fig. 5: Cultivar × spikelet group interaction for ash

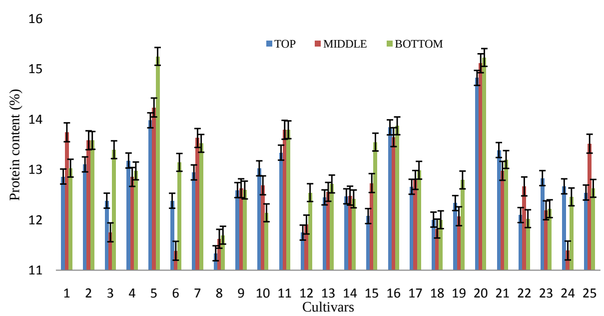

Fig. 6: Cultivar × spikelet group interaction for protein content

highest in the top group in eleven varieties, in the middle group in eight varieties and in the bottom group in six varieties (Fig. 7). Starch ratio was 47.95% in the first year and 47.66% in the second year.

Grain fat contents varied between 4.14% (Revisor) and 6.96% (Checota). The varieties respectively Checota (6.96%), Yeşilköy-330 (6.23%), Viker (6.42%), Milton (6.41%), Faikbey (6.27%), Alo (6.06%), Blaze (6.01%), (5.93%), Yeşilköy-1779 (5.86%) and Irtysh 13 (5.56%) had fat contents greater than the general average (5.46%) (Table 5). Considering the fat ratio of grains with respect to their positions within panicle, top grains exhibited greatest fat ratio (5.54%) than observed in middle (5.42%) and bottom grains (5.41%). The fat ratio was 5.57% in the first year and

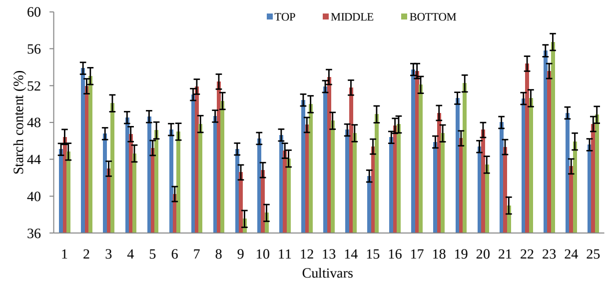

Fig. 7: Cultivar × spikelet group interaction for starch content

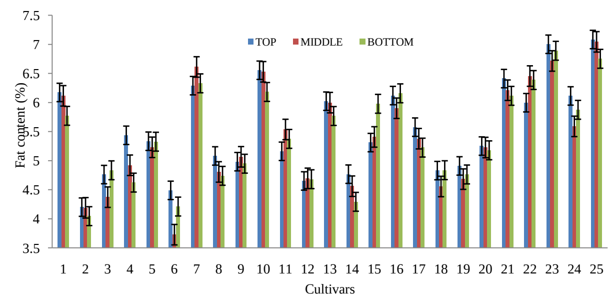

Fig. 8: Cultivar × spikelet group interaction for fat content

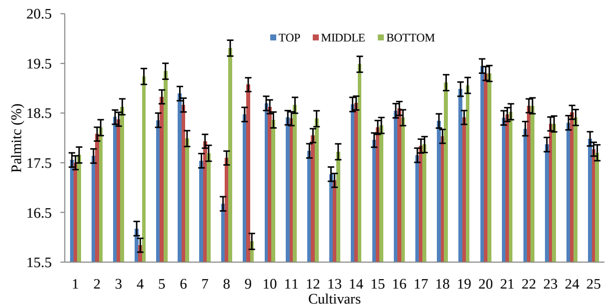

Fig. 9: Cultivar × spikelet group interaction for palmitic acid content

5.35% in the second year. With respect to fat ratios, variety × panicle group interactions were also found to be significant and fat content of varieties varied with the position of grain within panicle.

Fat ratio was higher in the middle group of Milton (6.61%), Puhti (5.07%), Capa (5.54%), Aberglen (4.70%), and Faikbey (6.45%) varieties, but higher in the bottom group of Expander (4.83%), Irtysh 13 (5.98%), Mara (6.16%) and Bakonyalja (4.84%) varieties. In other varieties, fat ratio was higher in the top group (Fig. 8).

Fatty acid composition significantly varied with the varieties, panicle groups and years (Table 5). Palmitic acid content of the varieties varied between 17.1% (Auteuil) and 19.3% (Akiyutaka), stearic acid content varied between 1.43% (Auteuil) and 1.89% (Yeşilköy-330), oleic acid contents varied between 35.9% (Neklan) and 45.3% (Checota), linoleic acid contents varied between 32.6% (Checota) and 39.6% (Neklan) and linolenic acid contents

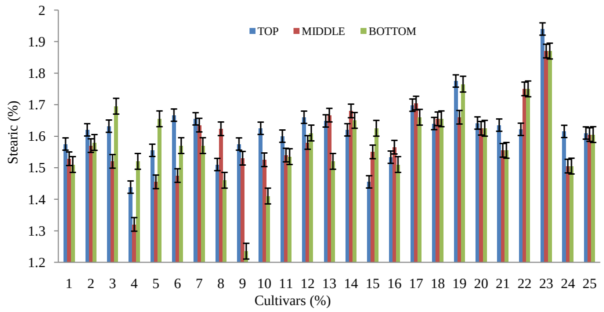

Fig. 10: Cultivar × spikelet group interaction for stearic acid content

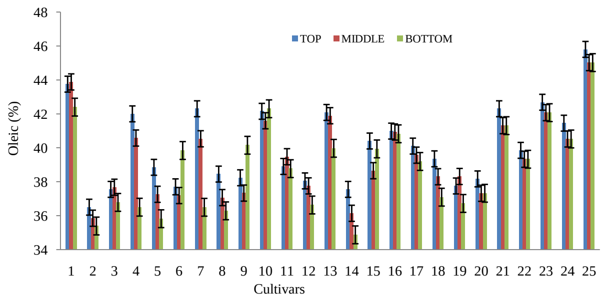

Fig. 11: Cultivar × spikelet group interaction for oleic acid content

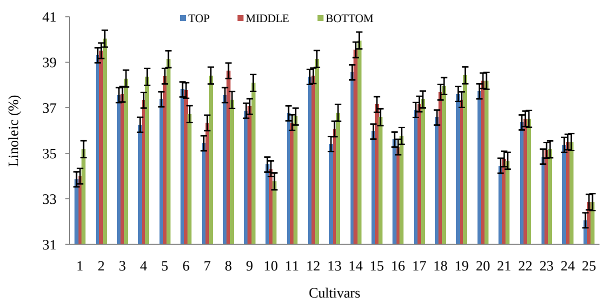

Fig. 12: Cultivar × spikelet group interaction for linoleic acid content

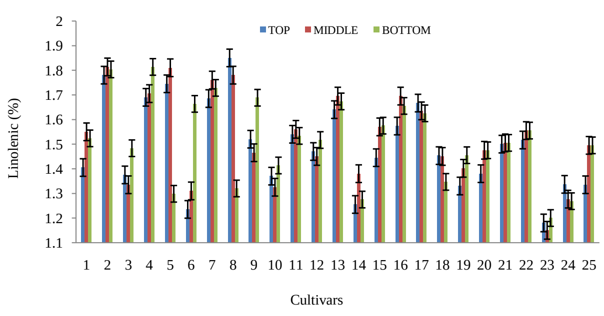

Fig. 13: Cultivar × spikelet group interaction for linolenic acid content

varied between 1.18 (Yeşilköy-330) and 1.80% (Neklan). Considering grain position, the greatest palmitic acid content (18.4%) was observed in bottom grains and they were followed by middle (18.2%) and top grains (18.1%). The greatest stearic acid content (1.62%) was observed in top grains, but stearic acid contents of middle and bottom grains were not significantly different from the top gains. Contrary to palmitic acid content, the greatest oleic acid contents were observed in top grains (40.1%) and they were followed by middle (39.4%) and bottom (38.9%) grains. Linoleic acid content of top, middle and bottom grains was respectively noted as 36.3, 36.7 and 37.1%. The greatest linolenic acid content was observed in middle and bottom grains (1.52 and 1.51%) and the lowest value was determined in top grains (1.49%) (Table 5). Variety × panicle group interaction was also found to be significant for all fatty acids. Fatty acid contents of varieties at different panicle groups are presented in Fig. 9, 10, 11, 12 and 13. The highest palmitic acid content was determined in bottom of Bajka variety with 19.8% while the lowest was found in middle of Auteuil variety with 15.8% (Fig. 9). Stearic and oleic acid content was found the highest in top group (Yeşilköy-330 and Checota, respectively) while the lowest content was found in the bottom group (Puhti and Barra, respectively) (Fig. 10 and 11). The highest linoleic acid content was determined in bottom of Neklan variety with 40.0% while the lowest was found in middle of Checota variety with 32.1% (Fig. 12). Linelenic acid content was found the highest in top group of Bajka variety while the lowest content was found in the middle group of Yeşilköy-330 variety (Fig. 13). While palmitic, stearic and linoleic acid contents were higher in the first year, oleic and linolenic acid contents were higher in the second year (Table 5).

Discussion

Total precipitation and average temperature of experimental years were higher than the long-term averages. On the other hand, relative humidity values of experimental years were lower than long-term averages. Amount of precipitation was measured as 658.4 mm in 2015–2016 growing season and was 20.6 mm higher than 2014-2015 growing season (Table 2). Higher precipitations especially in March, April and May of the second year than the first year probably resulted in higher thousand-grain weights in the second year (Table 2). Larger grains can be husked easier than small grains at the same rotor speeds. Therefore, large and homogeneous grains are more preferred in flour industry (Doehlert *et al*., 2004). It was indicated in previous studies that oat grain quality was mostly dependent on genetic factors and environmental impacts throughout the growing season (Doehlert and McMullen, 2000; Peterson *et al*., 2005; Rhymer *et al*., 2005; Buerstmayr *et al*., 2007; Mut *et al*., 2016). In a study carried out with different oat varieties, thousand-grain weight was reported between 23.6–38.2 g (Buerstmayr *et al*., 2007). In another study, thousand-grain weights of 25 oat varieties were reported between 24.5–41.3 g (Mut *et al*., 2016). The results obtained in the study were similar to those obtained in previous studies.

Mean grain length in second year was higher than was in first year. Higher values in the second year were probably because of more favorable climate conditions (Table 2). In a study that was conducted with different environment and oat varieties was reported that grain length and width had changed according to environment and varieties, and there were no linear relationships between grain size with grain length and width (Doehlert *et al*., 2005). Differences in oat grain sizes are not desired as such differences may result in broken grains during husking. In such cases, grains are initially divided into different size groups and then each group is husked separately (Doehlert *et al*., 2004). Grain morphology and groat percentage are significant factors influencing flour yield. Grain morphology is an extra selection criterion in oat breeding. Millers generally prefer varieties with full, long and thin grains. Although, there are no relationships between grain morphology and chemical composition, selection of varieties with certain grain morphology may influence quality attributes or selection of grains based on certain chemical composition may alter grain morphology (Groh *et al*., 2001). Our study showed that thousand-grain weight in the top of panicle was generally higher, but the chemical content such as fat and protein was not always as high in the top of panicle.

Low hull content is particularly important for the achievement of high milling yield, which is an important criterion for hulled food oat (Cowan and Valentine, 2004). Peltonen-Sainio *et al.* (2004) found that high hull rate limited oat use as an animal feed. In previous studies carried out with different oat varieties and under different growing conditions, groat percentage was reported between 59.5 and 79.0% (Doehlert *et al*., 2004; Peltonen-Sinio *et al*., 2004; Zute *et al*., 2010; Mut *et al*., 2016). In this study, it was found that the groat percentage varied according to the variety and position of the grain. While Brunava and Alsiņa (2015) indicated that small-grain oats had higher groat percentages, Doehlert *et al.* (2004) indicated the reverse, in other words higher groat percentages for large-grains. In our study, it was determined that oat varieties generally had a higher thousand-grain weight and groat percentage in top group, and these findings were similar to Doehlert *et al.* (2004).

Varieties had different protein contents in different panicle groups. Significant differences in protein ratios of different oat genotypes were also reported in previous studies. Farrell *et al.* (1991) reported protein ratios of full-oat grains as between 10.0–18.0%, Mut *et al.* (2016) reported protein ratios of oat varieties as between 11.1–14.3%. Boz *et al.* (2012) indicated for wheat that the greatest protein ratio obtained from the bottom grains of the spike and were followed by middle and top grains of the spike.

Starch is the primary digestible carbohydrate of plants and it is an important energy source in human and animal nutrition. In previous studies, starch ratios of 15 Argentinean oat varieties were reported as between 33.6–41.5% (Martinez *et al*., 2010); starch ratios of British oat varieties were reported as between 40.0–58.0% (Givens *et al*., 2000); starch ratios of oat varieties with different origins in Turkey were reported as between 34.85–47.72 (Mut *et al*., 2016). Potential use of oat in functional foods usually designated by diet fiber, protein content and fat composition of the grains (Demirbaş, 2005). As compared to other cool-season cereals, oat usually have higher fat ratio (Youngs, 1986). In a study carried out with world collection including 4000 oat genotypes, fat content was reported between 3.1–11.6% (Martinez *et al*., 2010). Oat has quite high nutritional values, because of fatty acid composition of the fat (Zhou *et al*., 1999; Martinez *et al*., 2010). Since grain fat ratio is controlled genetically, breeders usually prefer low-fat ratio genotypes for oats to be used in human nutrition (Zhou *et al*., 1999).

Fatty acid profile of oat is quite remarkable for both human and animal nutrition. Oleic and linoleic acid contents designate fat quality and final use of the products (Özcan *et al*., 2006). High oleic and linoleic acid contents were also reported by Zhou *et al.* (1999). Martinez *et al.* (2010) reported that the fatty acids palmitic, oleic and linoleic acids were 91% of total fatty acids under certain site conditions. Zhou *et al.* (1998) indicated that palmitic, oleic and linoleic acid contents ranged from 15.6 to 17.6%, 37.9 to 47.1% and 31.8 to 38.9%, respectively. The results we obtained from our study were similar to those of these researchers.

Conclusion

Present findings revealed that varieties had differences in quality parameters based on the position of the grains within the panicle. Significant differences were observed in thousand-grain weight, grain length, grain width, groat percentage, ash ratio, protein ratio, starch ratio, fat ratio and fatty acids of the grains located at different sections of the panicle with higher values of these traits in top grains. On the other hand, ash ratio, palmitic and linoleic acid contents were higher in bottom grains.

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