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Chemical Composition and Constituent Value of Selected Soybean (*Glycine max* (L.) Merrill) Cultivars Grown in Turkey

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The aim of this study was to determine and to compare the seed chemical characteristics and constituent value of selected soybean (*Glycine max* (L.) Merrill) cultivars which were grown in the experimental areas of the Black-Sea Agricultural Research Institute, Samsun, Turkey. Moisture, crude protein, crude oil and ash contents and fatty acid compositions in the seeds of 20 soybean cultivars were determined. According to the findings of the research, the major fatty acids were linoleic ($C_{18:2}$) and oleic ($C_{18:1}$) acids, whose contents were in the ranges 51.76-56.76 % and 18.84-26.35 %, respectively. All of the cultivars contained linolenic ($C_{18:3}$) acid, with values ranging from 6.01 to 8.32 %. Palmitic ($C_{16:0}$) and stearic ($C_{18:0}$) acids were the main saturated fatty acids, 10.14-12.19 and 3.49-4.67 %, respectively. Small amounts of $C_{14:0}$, $C_{16:1}$, $C_{17:0}$, $C_{17:1}$, $C_{20:0}$, $C_{20:1}$, $C_{22:0}$, $C_{24:0}$ and $C_{24:1}$ were determined (< 1 %). The crude oil contents of the soybean cultivars were varied from 17.28 to 20.71 % of the weight of whole seed. The important chemical component of the cultivars was the crude protein, which ranged from 35.02 to 39.11 %, as whole seed basis. Moisture and total ash contents were in the ranges 6.05-8.62 and 3.62-5.46 %, respectively.

Key Words: Soybean, Constituent value, Crude oil, Crude protein, Fatty acid composition.

INTRODUCTION

Soybean is the seed from the soybean plant (*Glycine max* (L.) Merill), a member of the Leguminosae family[1]. Soybean is a crop of great importance due to the widespread applicability of its products and their economic value in the national and international markets[2]. Soybean is the dominant oilseed produced in the world, due to its high-protein and its valuable edible oil. It contributes over a half of all oilseeds produced worldwide[3].

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Soybean is mainly cultivated for its seeds, used commercially as human food and livestock feed and for the extraction of oil. The highest domestic consumption is in Asia, where it has been a basic food for centuries[4]. Worldwide soy food consumption, particularly in the western world, is increasing rapidly because of its health benefits[5]. The most important components of soybean seed are protein (about 40 %) and oil (about 20 %) Generally, the protein content of the seed decrease as the oil content increase[6]. Soybean seed is an excellent source of proteins with nutritionally balanced amino acid profile[7]. Soybean oil is somewhat unique among the edible vegetable oils in its fatty acid composition, having a relatively high linolenic acid. Soybean oil has become a popular vegetable oil for foodstuffs due to its nutritional qualities, abundance, economic value and wide functionality[8].

The objective of this study was to determine and to compare some seed chemical characteristics of selected soybean cultivars grown in Turkey. Another objective was to evaluate constituent value of these cultivars.

EXPERIMENTAL

20 Soybeans (*Glycine max* (L.) Merrill) cultivars (domestic two cultivars, identified as A-3127 and A-3935, respectively and introduced 18 cultivars) were selected for this work. The study was conducted in the experimental areas of the Black-Sea Agricultural Research Institute (in Samsun province which is located on the northern Black Sea coast of Turkey). The soil of the experimental area was clay-loamy with a pH of 7.41 and with 2.31 % organic matter. This soil contained phosphorus (12.4 kg/ha) and potassium (283.5 kg/ha). The experimental area was suitable for soybean cultivation. Temperature, rainfall and relative humidity data during the crop growing period were collected from nearby weather station in location. The total rainfall received was 400.6 mm during seed-growing period (May-October, 2006), while average temperature and relative humidity were 19.7 ºC and 77.8 %, respectively. According to the long-term average in the experimental area during seed-growing period, annual total rainfall, temperature and relative humidity were 299.6 mm, 19.6 ºC and 75.7 %, respectively.

Seeding was made on May 25, 2006. The experiment was carried out using split-split plots in a randomized complete block design with three replicates. In sowing, the row width was 70 cm. Intrarow spacing was stabilized at 5 cm by thinning. Plots were 5 m long and consisted of four rows. Based on soil analysis and local recommendations, the treatment area was fertilized with 5 kg nitrogen per decare. Recommended practices were used for weed and insect control. Weed control was obtained by mechanical rotary tillage in the interrow and by manual weeding in the row. All plots were irrigated three times during seed-growing period and mechanical-harvested at maturity in late September or early October, 2006. The seeds

from two-central rows of each plot were used for analyses. The seeds were cleaned manually to remove all foreign material and broken seeds. Total crude protein, total crude oil and total ash contents of the seed samples were expressed as percentage by weight of whole seed.

Moisture content: The seed samples were analyzed for their moisture contents according to the International Union of Pure and Applied Chemistry (IUPAC)[9] methods no. 1.122.

Crude protein content: The seed samples were analyzed for crude protein contents based on nitrogen analysis utilizing the Kjeldahl system according to the Association of Official Analytical Chemists International (AOAC)[10]. The crude protein was calculated using a nitrogen conversion factor of 6.25.

Total ash content: Ash content was determined according to the International Organization for Standardization (ISO)[11] method 749. The dried seed samples were ignited and incinerated in the muffle furnace. The temperature was gradually raised to 550 °C and the dried seed samples were ashed until constant mass was achieved.

Lipid extraction: The seed samples were dried before lipid extraction. Lipid extraction from the dry seeds was carried out by hexane extraction under the operating conditions specified in IUPAC[9] methods no. 1.121.

Preparation of FAME: FAMEs were prepared according to American Oil Chemists' Society Official (AOCS)[12] Method Ce 2-66. The FAMEs were obtained from the soybean oils after alkaline hydrolysis, followed by methylating in methanol with 12.5 % BF_3 catalyst. The final concentration of the FAMEs was *ca.* 7 mg/mL in heptane. FAMEs standards (99 % purity) were purchased from Nu-Chek-Prep Inc. (Elysian, MN).

Analyses of the FAMEs by capillary gal liquid chromatography (GLC) were carried out on a Hewlett-Packard 6890 chromatograph, equipped with a flame-ionization detector (FID) on a split injector. A fused-silica capillary column (Chrompack, Middleburg, The Netherlands) was used for the FAMEs analysis; CP™-Sil 88, 100 m × 0.25 mm i.d., 0.2 µm film. GLC operating conditions were: a temperature program of 130 ºC for 5 min, rising was at a rate of 2 ºC/min to 177 ºC. The injector temperature, 225 ºC; detector temperature, 250 ºC; carrier gas, 1 mL/min helium.

RESULTS AND DISCUSSION

Some chemical characteristics of selected soybean cultivars grown in Turkey were presented in Table-1. The important chemical component of the soybean cultivars was crude protein, between the values of 35.02 % (Nameha) and 39.11 % (HP-203), as whole seed basis. In other words, all of the soybean cultivars had crude protein contents above 35 %. There were differences among soybean cultivars, regarding to crude protein in

the seeds. On a dry weight basis, soybeans typically contain 40.3 % oil[3]. A variation ranging from 35 to 44 % in protein of soybean seed were also documented. This variation in protein contents in soybeans is due to the locality where the beans are grown and cultivar of the bean[4]. However, some strains have as high as 50 %[13]. In recent years, soybean breeding programs have been emphasizing the increase of protein content and quality[14]. When the protein content is increased, there is a significant decrease in the nonprotein constituents such as oil, sugar and pentosans. Therefore, strains with higher protein have lower oil contents[15].

The other important chemical component of the soybean cultivars was crude oil, between the values of 17.28 % (Athow) and 20.71 % (Nameha), as whole seed basis (Table-1). When the cultivars were considered, they differed with regard to crude oil. The oil content in soybeans ranges from 18 to 20 %[8]. On a dry weight basis, soybeans typically contain 21.0 % oil. Lower oil concentration in response to higher per cent protein may be expected in soybeans due to a negative genetic correlation between these constituents.

As for the ash, total ash contents varied with the soybean cultivars. The average total ash content of the soybean cultivars was found to be 4.9 %, as whole seed basis (Table-1). The minimum and maximum values, based on this parameter, ranged between 3.62 % (28-Kenwood) and 5.46 % (Athow). The average total ash content found in this study was similar to those reported by Salunkhe[4] and Perkins[16] for soybean cultivars. Minerals are absorbed by plants during the growing season[8]. The ash content of seeds depended, not only on the variety, but also on the growing conditions such as soil and geographical condition[4]. The moisture content of the soybean cultivars ranged between 6.05 % (HP-203) and 8.62 % (Savoy). Moisture contents declined during seed development. The moisture contents of the seeds were also lower than other reported soybean varieties[17].

The major fatty acids of the soybean cultivars showed a great deal of diversity (Table-1). The linoleic ($C_{18:2}$) acid was the dominant fatty acid (51.76-56.76 %) in all cultivars. The cultivars including linoleic ($C_{18:2}$) acid at more than 55.0 % were 'A-3127' and '28-Kenwood'. The oleic ($C_{18:1}$) acid was the second most abundant fatty acid in the samples and its range was among 18.84 and 26.35 %. The cultivars including oleic ($C_{18:1}$) acid at more than 25.0 % were 'Bicentenniol', 'Olympus' and 'Sprite-87'. The linolenic ($C_{18:3}$) acid as unsaturated fatty acid followed this. The cultivars containing linolenic ($C_{18:3}$) acid, with values ranging from 6.01 (Ataem-7) to 8.32 % (A-3127). The palmitic ($C_{16:0}$) and stearic ($C_{18:0}$) acids were the main saturated fatty acids. The palmitic ($C_{16:0}$) acid contents in the samples studied were between 10.14 % (Sprite-87) and 12.19 % (28-Kenwood). The lowest stearic ($C_{18:0}$) acid content was observed in the Bicentenniol (3.49 %) and the highest stearic ($C_{18:0}$) acid content was determined in the

TABLE-1
FATTY ACID COMPOSITIONS AND SOME CHEMICAL CHARACTERISTICS OF THE SOYBEAN SEED CULTIVARS GROWN IN TURKEY

Fatty acids[a]	Soybean cultivars[b]																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
14:0	0.07	0.08	0.07	0.07	0.10	0.08	0.07	0.09	0.09	0.08	0.07	0.08	0.09	0.06	0.07	0.08	0.08	0.08	0.08	0.06
16:0	11.55	10.53	10.96	11.37	12.05	11.35	10.77	12.09	11.54	11.05	11.25	12.19	11.41	11.02	11.60	10.99	10.83	11.11	11.59	10.14
16:1	0.06	0.03	0.07	0.09	0.29	0.09	0.09	0.07	0.05	0.10	0.08	0.07	0.05	0.08	0.08	0.10	0.08	0.32	0.08	0.09
17:0	0.11	0.08	0.08	0.09	0.09	0.09	0.09	0.10	0.09	0.09	0.10	0.10	0.10	0.09	0.10	0.09	0.09	0.08	0.09	0.08
17:1	0.04	0.04	0.05	0.04	0.04	0.05	0.04	0.04	0.03	0.05	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.05
18:0	4.55	3.81	3.49	4.27	4.08	3.68	4.50	4.51	4.25	3.87	3.79	4.09	4.67	3.89	4.08	4.34	4.26	4.12	4.21	3.75
18:1	22.38	22.31	26.35	23.90	21.71	24.38	23.57	22.75	21.11	22.53	18.84	20.45	22.25	25.96	21.04	24.26	21.90	23.10	23.29	25.37
18:2	53.39	54.65	51.76	53.32	54.08	52.86	53.10	52.63	54.63	54.37	56.76	55.18	54.11	52.04	54.82	53.12	54.60	54.05	53.07	53.48
18:3	6.99	7.39	6.29	6.03	6.63	6.71	6.91	6.80	7.03	7.17	8.32	6.95	6.30	6.03	7.38	6.08	7.25	6.01	6.64	6.19
20:0	0.32	0.31	0.27	0.31	0.31	0.28	0.32	0.35	0.39	0.27	0.27	0.29	0.35	0.29	0.31	0.32	0.31	0.33	0.33	0.26
20:1	0.17	0.23	0.21	0.17	0.21	0.16	0.16	0.18	0.22	0.16	0.15	0.16	0.21	0.19	0.16	0.22	0.16	0.25	0.18	0.17
22:0	0.30	0.38	0.29	0.29	0.33	0.27	0.31	0.33	0.40	0.26	0.29	0.26	0.33	0.31	0.32	0.32	0.30	0.35	0.30	0.27
24:0	-[c]	0.11	-	-	-	-	-	-	0.12	-	-	-	-	-	-	-	-	0.10	-	-
24:1	0.07	0.05	0.11	0.05	0.08	-	0.07	0.06	0.05	-	0.04	0.14	0.09	-	-	0.05	0.10	0.06	0.10	0.09
Total SFA	16.90	15.30	15.16	16.40	16.96	15.75	16.06	17.47	16.88	15.62	15.77	17.01	16.95	15.66	16.48	16.14	15.87	16.17	16.60	14.56
Total MUFA	22.72	22.66	26.79	24.25	22.33	24.68	23.93	23.10	21.46	22.84	19.15	20.86	22.64	26.27	21.32	24.66	22.28	23.77	23.69	25.77
Total PUFA	60.38	62.04	58.05	59.35	60.71	59.57	60.01	59.43	61.66	61.54	65.08	62.13	60.41	58.07	62.20	59.20	61.85	60.06	59.71	59.67
Moisture (%)	7.48	8.62	7.65	6.58	7.01	7.68	7.73	7.41	7.99	6.65	7.22	7.08	7.19	7.04	6.19	6.05	7.70	6.53	6.91	6.54
Crude oil (%)	20.71	19.79	19.58	19.95	20.18	18.54	19.16	18.80	17.39	18.25	18.48	19.42	18.39	17.70	17.98	18.54	17.28	17.77	18.49	18.35
Crude protein (%)	35.02	37.83	37.08	36.45	37.62	38.80	36.09	36.43	38.29	36.95	37.79	35.37	37.83	36.72	35.88	39.11	36.27	37.60	36.14	36.84
Ash (%)	5.29	4.98	5.13	5.17	4.93	4.40	5.36	4.88	4.00	4.32	5.11	3.62	4.75	4.30	5.13	5.25	5.46	5.27	5.44	5.16

[a]Values are expressed as a weight percentage of total FAMEs. Fatty acids are designated by number of carbon atoms; number of double bonds. MUFA, monounsaturated FA; PUFA, polyunsaturated FA; SFA, saturated FA.
[b](1) Nameha, (2) Savoy, (3) Bicentenniol, (4) Iraquois, (5) Holt, (6) NE-3399, (7) General, (8) MN-1801, (9) Apollo, (10) Macon, (11) A-3127, (12) 28-Kenwood, (13) Lambert, (14) Olympus, (15) A-3935, (16) HP-203, (17) Athow, (18) Ataem-7, (19) NE-3292, (20) Sprite-87.
[c]Not detected or trace amounts (< 0.01%).

Lambert (4.67 %). Small amounts of $C_{14:0}$, $C_{16:1}$, $C_{17:0}$, $C_{17:1}$, $C_{20:0}$, $C_{20:1}$, $C_{22:0}$ and $C_{24:1}$ were determined (< 1 %) in all soybean seeds. However, only three soybean cultivar contained the $C_{24:0}$ acid, ranged between 0.10 and 0.12 % (Savoy, Apollo and Ataem-7). As may be seen from the values given (Table-1), the majority of the unsaturated fatty acid was the polyunsaturated fatty acid in all the samples. The highest total polyunsaturated fatty acid (65.08 %) and the lower total monounsaturated fatty acid (19.15 %) contents were determined in the cultivar, identified as A-3127. Conversely, the lower total polyunsaturated fatty acid and the highest total monounsaturated fatty acid contents were founded in the cultivar, identified as Bicentenniol, 58.05 and 26.79 %, respectively. Much information is available in the scientific literature, dealing with the fatty acid compositions of soybean seeds. O'Brien[8] informed fatty acid composition of soybean oil comprises 49.8-57.1 % of $C_{18:2}$, 17.7-26.1 % of $C_{18:1}$, 5.5-9.5 % of $C_{18:3}$, 8.0-13.3 % of $C_{16:0}$ and 2.4-5.4 % of $C_{18:0}$ acids. Also, small amounts of $C_{14:0}$ (0.1 %), $C_{16:1}$ (0.1 %), $C_{17:0}$ (0.1 %), $C_{20:0}$ (0.3 %), $C_{20:1}$ (<0 .3 %), $C_{22:0}$ (0.3 %) and $C_{24:0}$ (< 0.4 %) were given by the author[8]. Orthoefer[18] presented average fatty acid composition of oils from soybean seeds were $C_{16:0}$ acid, 11.0 %; $C_{18:0}$ acid, 4.0 %; $C_{18:1}$ acid, 23.4 %; $C_{18:2}$ acid, 53.2 % and $C_{18:3}$ acid 7.8 %. The physical and chemical characteristics of soybean seeds are markedly influenced by genetic, climatic factors during growing season, maturity and location and vary considerably within variety[2,19].

As can be seen from Table-2, there were differences between the soybean cultivars for theoretical product yield and constituent value. Theoretically,

TABLE-2
THEORETICAL PRODUCT YIELD AND CONSTITUENT VALUE FOR SOME SOYBEAN CULTIVARS ANALYZED

Statistic	Soybean cultivars[a]									
	2	3	5	6	12	14	15	16	17	19
A	197.9	195.8	201.8	185.4	194.2	177.0	179.8	185.4	172.8	184.9
B	378.3	370.8	376.2	388.0	353.7	367.2	358.8	391.1	362.7	361.4
C	802.1	804.2	798.2	814.6	805.8	823.0	820.2	814.6	827.2	815.1
D	47.2	46.1	47.1	47.6	43.9	44.6	43.8	48.0	43.9	44.3
E	859.8	842.7	855.0	881.8	803.9	834.6	815.5	888.9	824.3	821.4
F	163.1	161.9	166.9	153.3	160.6	146.4	148.7	153.3	142.9	152.9
G	245.9	241.0	244.5	252.2	229.9	238.7	233.2	254.2	235.8	234.9
Total ($)	409.0	402.9	411.4	405.5	390.5	385.1	381.9	407.5	378.7	387.8

A = Crude oil kg/MT soybean; B = Crude protein kg/MT soybean; C = Defat meal kg/MT soybean; D = Crude protein (df meal) (%); E = Crude protein meal[b] (kg 44 %); F = Oil ($)/MT soybean[c]; G = Meal ($ 44 %)/MT soybean[c].

[a](2) Savoy, (3) Bicentenniol, (5) Holt, (6) NE-3399, (12) 28-Kenwood, (14) Olympus, (15) A-3935, (16) HP-203, (17) Athow, (19) NE-3292.

[b] Equivalent weight; [c] Data based on annual average prices from January 2007 to October 2007 (source: worldbank.org[20]). MT = Metric ton.

the cultivar, identified as 'Holt' should yield 201.8 kg oil and the equivalent of 855.0 kg (44 % protein) meal per metric ton soybean and the cultivar, identified as 'Athow' should yield 172.8 kg oil and the equivalent of 824.3 kg (44 % protein) meal per metric ton soybean. The estimated minimum and maximum constituent values of selected soybean cultivars were, based on annual average prices from January 2007 to October 2007[20], ranged between $ 378.7 per metric ton and $ 411.4 per metric ton (Table-2). To increase soybean production in Turkey is a high requirement for meeting domestic demand. Besides, soybean cultivars containing optimum chemical composition should be selected for enhancement of their constituent value. It is reported[21] that increased production and processing costs, greater competition from other oilseed crops and observed world market trends in the constituent value for soybean products have created awareness that fundamental change in soybean composition may be desirable.

The present investigation showed some chemical characteristics of 20 soybean cultivars. Besides, the constituent values of several soybean cultivars were presented. The information provided by this study may be helpful for selection of the soybean cultivars in terms of optimum protein and oil contents in similar climate and soil conditions. The soybean cultivars containing higher levels of protein and partly lower oil content can give considerable economic advantage for industry.

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