DETERMINATION OF THE NUTRITIONAL PROPERTIES OF TURKISH LOCAL SESAME SEED (*Sesamum indicum L.*) VARIETIES, COLLECTED FROM DIFFERENT LOCATIONS OF TURKEY AND CULTIVATED IN THE SAME ECOLOGICAL CONDITIONS

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Abstract

Seven local sesame seed varieties were selected and cultivated under the same ecological conditions in Konya. Oil and protein content and volatile composition of them were determined after harvest. The effect of Konya ecological condition on sesame seeds properties was determined. As a result, oil ratio of Diyarbakir variety (54.71%) increased, Mersin Mut variety (50.67%) is constant and the rest of them decreased. Protein content of all varieties decreased. Oleic acid ratio increased and linoleic acid ratio decreased in these varieties. The average ratios of the most abundant volatile compounds were identified as 23.6% delta-3-carene, 17.6% 1-hexanol, 8.6% 1,3-dichloro benzene, 10.4% N-methyl-1,3-dithioisoindoline, 6.1% benzoic acid, 29.6% methoxy-phenyl oxime according to results of the analysis of volatile aromatic compounds of sesame seeds. In conclusion, Diyarbakir Cungus and Mersin Mut varieties are the best varieties planted in Konya ecological conditions from these seven varieties with their high oil content.

Key words: *Sesame (Sesamum indicum L.), oil, protein, fatty acids, volatile compounds*

1. INTRODUCTION

Sesame (*Sesamum indicum L.*) is one of the most ancient oily seeds cultivated by human. Sesame has been grown for centuries due to its high content of excellent quality oil (42-60%), protein (22-25%) and desirable high amount of volatile aromatic compound. Sesame is cultivated in some Asian countries such as India, China, Afghanistan, Pakistan, Bangladesh, Indonesia and Sri Lanka. Sesame oil is consumed as cooking oil (77.6%) and bakery purpose (20.1%) in these countries. Sesame seeds have been widely used in the production of paste (tahini), halvah (sweetened tahini) and also used in the traditional bagel (simit) in Turkey. Turkish sesame varieties have oil content with varying between 35.1-63.9% (Baydar and Turgut, 1999).

Sesame is also used in the pharmaceutical and cosmetic industries. Sesame oil differs from all other seed oils because of its characteristic taste and resistance to oxidative deterioration due to the presence of the endogenous antioxidants lignins in combination with tocopherols (Konsoula and Liakopoulou-Kyriakides, 2010). Several studies have demonstrated that lignans in the sesame that consist of sesamin, sesaminol, sesamol, sesamolinol or sesamolin are responsible for various physiological activities including antioxidative (Shahidi et al., 1997, Xu et al., 2012), anticarcinogenic (Hata et al., 2010), serum lipid-lowering (Jannat et al., 2010) activities.

Although sesame seeds have higher oil contents than most other oilseeds and sesame oil has good flavor and oxidation stability, sesame seed have never been a major oil source in all over the world. There are several limiting factors of sesame cultivation. The low yield (40-50 kg/da) of sesame seeds is the main factor of them. The labor intensive harvesting procedure is the other limiting factor. Although sesame seed has a short cultivation time (90-120 days), low soil selectivity, low water and mineral need, resistant to high temperature; it is less preferred for cultivation by the farmers (Baydar and Turgut, 1999). When sesame capsules reached maturity, they fragile and open easily, scatter the seeds on the ground. The collection of the scattered seeds is very difficult (Hwang, 2005). This is the reason of low cultivation of sesame seed in the world compared with the other oily seeds.

Sesame naturally has asynchronous growth habit. It is difficult to harvest asynchronous genotypes. Because, when the upper part of the sesame plant reached the maturity, the flower of the lower part of

the sesame plant just blooms. If the harvest delays for the immature sesame capsule, the ripe capsules may pour (Day, 2000). This causes the sesame seed loss in harvest. This is another reason of low cultivation of sesame seed in the world compared with the other oily seeds.

A lot of sesame varieties and ecotypes which have been grown for hundreds of years are distributed in various ecological regions of Turkey (Baydar *et* al., 1999). All Turkish sesame varieties belong to indeterminant types of sesame seed.

Ecological accordance of the sesame seed is very important for the agriculture of this seed. For this reason ecological accordance of the sesame seed cultivated in Turkey was evaluated by investigation of harvest yield and oil composition in this study. Konya has the large cultivation area of sesame seed. But there is no study related with the ecological accordance of the selected sesame seeds in Konya province.

2. MATERIALS AND METHODS

2.1. Materials

One hundred raw local sesame seed varieties were provided from whole region of Turkey and determined oil and protein contents before cultivation. Seven high oil content of one hundred local sesame seed were selected and cultivated under the same ecological conditions in Konya. The selected cultivars are: Aydın İncirliova, Bartın Ulus, Urfa Siverek, Konya Akören, Mersin Mut, Diyarbakır Çüngüş, Konya Çumra.

2.2. Meteorological conditions of the cultivation

Sesame seeds cultivated on 20 May 2011 and harvested at the end of the August by maturation of the sesame capsules. The climatic conditions (rains, min and max temperature) of Konya were obtained from General Directorate of Meteorology and showed in Table 1.

Table 1. Rains, min and max temperature of Konya during cultivation period

	Rains			Max Temperature			Min Temperature		
	Average	2010	2011	Average	2010	2011	Average	2010	2011
January	35.6	43.6	52.9	18.0	18.0	8.0	-22.1	-12.8	-6.3
February	28.1	33.3	40.1	20.8	20.8	15.1	-19.0	-12.7	-9.9
March	31.9	12.1	44.2	28.2	26.9	22.9	-14.6	-6.0	-8.7
April	40.0	67.4	48.0	31.5	24.9	24.0	-9.7	0.4	-2.1
May	32.2	12.4	52.5	33.8	32.1	25.8	-0.8	4.8	
June	21.1	47.9	39.5	35.2	33.5	32.2	3.9	9.7	2.0
July	6.0	0.0	0.0	39.9	36.4	36.7	7.6	13.0	9.5
August	4.0	0.0	1.0	39.2	39.2	36.4	8.6	12.5	11.4
September	13.2	1.6	3.8	36.1	36.1	31.1	1.4	1.4	11.2
October	27.3	62.6		31.8	30.5		5.0	5.0	6.3
November	33.8	4.2		24.0	24.0		-18.2	-18.2	
December	46.1	106.8		22.9	22.9		-21.8	-21.8	

2.3. Methods

2.3.1. Determination of oil content

The oil content was measured by the soxhelet method according to AOAC (1990). Briefly, 5±0.05 g of ground sesame seeds were placed into a cellulose paper and extracted using n-hexane (boiling point: 65-70°C) in a soxhelet extractor for 6 hours. Hexane was removed by evaporator (Buchi) and sesame seed oils were waited in oven (Heraus, FT 420, Turkey) at 103 °C for removal of residual hexane. After cooling to room temperature in desiccators, the extracted oil was weighted and the result was calculated as a percentage.

2.3.2. Determination of protein content

0.2±0.02 g sesame seeds weighed in aluminum capsule and placed in the device (Leco FP-528 Protein/Nitrogen Analyzer). Crude protein contents were determined by multiplying the nitrogen percentage with 6.25 constant.

2.3.3. Determination of fatty acid composition

Fatty acid composition was determined according to AOAC (1990) method by gas chromatography after derivatization to fatty acid methyl esters. Briefly, the sesame oil samples were extracted with n-hexane from sesame seeds by soxhelet extractor and obtained oil was stored at 4◦C until analysis. Approximately 100 mg oil was weighed and saponified with 100 µL 2 N KOH. Three mL hexane was added to the mixture, vigorously shaken with a vortex for 1 min, and then centrifuged at 5000 rpm for 5 min. The fatty acid compositions were analyzed by a GC (Agilent 6890, U.S.A.) fitted with a FID and a 100 m×0.25 mm ID HP-88 column. The injector temperature was 250 ◦C. The oven temperature was held at 103 ◦C for 1 min, then increased from 103 ◦C to 170 ◦C at 6.5 ◦C/min, from 170 ◦C to 215 ◦C for 12 min at 2.75 ◦C/min, and held at 230 ◦C for 5 min. The carrier gas was helium with a flow rate of 2 mL/min; the split rate was 1/50. Fatty acid composition was identified by the comparison of retention times to known standards. The results were expressed as g fatty acid/100 g total fatty acids (%).

2.3.4. Determination of volatile content

Analysis of volatile aromatic compounds was determined according to the method of Krist et al. (2006) by GC-MS (Agilent 7890A GC System, Agilent, Avondale, U.S.A.) using a mass spectrometry detector (Agilent Technologies, Agilent, Avondale, U.S.A.) and HP-5MS column (60 m x 0.250 mm i.d.; film thickness 0.25 µm). GC-MS vials were kept at 300°C in the furnace to remove volatile compounds. The vials were cooled to room temperature in desiccator. Briefly, 2.5 g of ground sample was put into vial and sealed with PTFE-faced silicone septum (Supelco, Bellefonte, PA, USA). The vial was kept in a thermo-block (RCT basic, IKA, Germany) for 20 min at 50°C and SPME fiber (75 mm, carboxen/poly-dimethylsiloxane) (Supelco, Bellefonte, PA, USA) was injected to the headspace while maintaining the sample at 50°C for 20 min to absorb all volatile compounds. Then fiber injected to the injection port of GC-MS for 20 min at 50°C in the splitless mode. GC-MS conditions were set as following: The oven temperature was held at 50°C for 10 min, then heated to 95 °C at 3 °C/min, from 95 to 210 °C at 10°C /min, and held 210°C for 10 min. The carrier gas was helium with a flow rate of 0.5 mL/min. The voltage of the electron ionization detector was 70 eV. The compounds were identified by comparison with spectra from the libraries Flavor 2, HPCH 1607, and WILEY 7n. Trials were carried out in duplicate. The results were expressed as percentage of total volatile compounds.

2.3.5. Statistical analysis

Data were statistically analyzed by one-way analysis of variance (ANOVA) using the SAS statistical software. Significant differences between means were determined by Tukey's Multiple Comparison Test procedure at the 5% significance level ($p<0.05$).

3. RESULTS AND DISCUSSION

3.1. Oil content

The oil content of the sesame seeds before and after the cultivation in Konya province were shown in Table 2. There are significant differences (P <0.05) between before and after cultivation in Konya province sesame seeds oil content except Mersin-Mut samples. While an increase was observed in Diyarbakır Çüngüş, a reduction was observed in the other seed samples. While the highest oil content was observed in Diyarbakır Çüngüş, the lowest one was determined as Konya Akören. According to these results cultivation of Mersin Mut and Diyarbakır Çüngüş seeds is suitable for agricultural area of Konya province.

Table 2. Oil content of the sesame seeds before and after the cultivation

Sesame seed	Before cultivation	After cultivation
Aydın İncirliova	59,00±0,83a	54,41±0.14b
Bartın Ulus	57,73±1,56a	50,48±0,20b
Urfa Siverek	59,81±0,22a	51,84±0,04b
Konya Akören	54,60±0,11a	49,21±2,14b
Mersin Mut	51,60±0,89a	50,67±0,28a
Diyarbakır Çüngüş	53,57±0,38a	54,71±0,33b
Konya Çumra	54,03±0,13a	51,71±0,05b

Different letters within same line indicate significant differences at the level P <0.05

Similar differences in oil content have been obtained by changing of the cultivation year or area in previous studies. Baydar et al. (1999) cultivated the same sesame seeds in two different years, 2000 and 2002, and he found significant differences in oil content. The oil content of the same sesame seeds cultivated in 2000 and 2002 are varied between 49.9-56.4% and 43.2-48.3, respectively. Were et al (2006) cultivated the same variety consecutive three years and they observed differences in oil content of the seeds. They pointed out that these differences may be caused by differences of climatic condition in each year such as rainfall, sunny day and average temperature of the cultivation periods. As shown in Table 2, rainfall and average temperature of the Konya province are different. That's why differences of oil content of the local sesame seeds may be caused by these climatic differences in Konya.

3.2. Protein Content

The protein content of the sesame seeds before and after the cultivation in Konya province were shown in Table 3. There are significant differences (P <0.05) between before and after cultivation in Konya province sesame seeds protein content. While the highest protein content was observed in Konya Akören with the amount of 26.17%, the lowest content was determined as Diyarbakır Çüngüş. The complementary relation was observed between oil and protein content of the seeds. In general, there is a negative relation between the oil and protein content of sesame seed (Baydar et al., 1999). We observed this negative relation in our study. Sesame seed proteins contain important amino acids such as valine, methionine and tryptophane (Cano-Media et al., 2011).

Table 3. Protein content of the sesame seeds before and after the cultivation

Sesame seed	Before cultivation	After cultivation
Aydın İncirliova	23.30±0.15[a]	24.38±0.06[b]
Bartın Ulus	24.46±0.63[a]	25.85±0.21[b]
Urfa Siverek	17.19±0.35[a]	24.96±0.37[b]
Konya Akören	20.93±0.15[a]	26.17±0.34[b]
Mersin Mut	22.65±0.14[a]	25.36±0.29[b]
Diyarbakır Çüngüş	20.82±0.18[a]	21.88±0.18[b]
Konya Çumra	22.72±0.21[a]	25.41±0.32[b]

Different letters within same line indicate significant differences at the level P <0.05

3.3. Fatty acid composition

Fatty acid compositions of the sesame seeds before and after the cultivation were shown in Table 4 and 5 respectively. The most abundant fatty acid in the seeds are oleic and linoleic acids. The sum of them is approximately equal to constant value at almost 83%. These two fatty acids are unsaturated fatty acids. Mersin Mut has the highest oleic acid composition (46.87%), and Diyarbakır Çüngüş has the lowest oleic acid composition after the cultivation. Oleic acid composition of sesame seeds increased after the cultivation. The highest increase was observed in Mersin Mut and Urfa Siverek after the cultivation. On the opposite linoleic acid composition decreased after the cultivation. The lowest linoleic acid value was observed in Mersin Mut with amount of 37.30%. Saturated fatty acids were determined as palmitic and stearic acids. While significant decrease (P <0.05) was observed in palmitic acid composition, significant increase (P <0.05) was observed in stearic acid composition after the cultivation.

Table 4. Fatty acid composition of the sesame seed before cultivation

	C16:0	C18:0	C18:1	C18:2	C18:3	C20:0	C20:1
Aydın İncirliova	9,48±0,35	5,46±0,04	39,25±0,08	44,47±0,34	0,59±0,02	0,34±0,02	0,19±0,01
Bartın Ulus	9,53±0,40	5,47±0,01	39,47±0,09	44,22±0,54	0,59±0,02	0,35±0,02	0,18±0,00
Urfa Siverek	9,79±0,00	5,39±0,00	41,76±0,01	42,70±0,01	0,59±0,00	0,34±0,00	0,20±0,01
Konya Akören	9,18±0,01	5,68±0,00	42,49±0,03	41,28±0,02	0,59±0,00	0,41±0,00	0,19±0,00
Mersin Mut	9,14±0,01	5,33±0,00	43,38±0,01	40,92±0,01	0,59±0,00	0,34±0,00	0,19±0,00
Diyarbakır Çüngüş	9,02±0,00	5,86±0,00	40,42±0,00	43,29±0,00	0,59±0,00	0,36±0,00	0,18±0,00
Konya Çumra	9,06±0,01	6,02±0,00	41,78±0,00	41,67±0,00	0,59±0,00	0,41±0,00	0,19±0,00

Different letters within same line indicate significant differences at the level P <0.05

Fatty acid composition of sesame seeds has been investigated by several researchers during cultivation. Baydar et al., (1999) reported that fatty acid composition of the sesame seed may be changed by ecological condition. The change may be also seen between different varieties. The complementary relation between oleic and linoleic acids was observed by Baydar et al., (1999). Sesame seeds have approximately equal amount of oleic and linoleic acid.

Table 5. Fatty acid composition of the sesame seed after cultivation

	C16:0	C18:0	C18:1	C18:2	C18:3	C20:0	C20:1
Aydın İncirliova	8,85±0,01	6,04±0,00	43,39±0,00	40,47±0,01	0,62±0,00	0,34±0,00	0,18±0,00
Bartın Ulus	8,48±0,00	6,32±0,00	45,57±0,00	38,33±0,00	0,66±0,00	0,36±0,00	0,19±0,00
Urfa Siverek	8,62±0,01	6,25±0,01	46,28±0,01	37,56±0,01	0,66±0,00	0,34±0,00	0,19±0,00
Konya Akören	9,17±0,35	6,12±0,05	45,45±0,20	37,89±0,16	0,65±0,01	0,48±0,01	0,19±0,00
Mersin Mut	8,56±0,01	6,07±0,00	46,87±0,03	37,30±0,03	0,62±0,00	0,39±0,00	0,20±0.00
Diyarbakır Çüngüş	8,74±0.00	5,92±0,01	41,39±0,02	42,71±0,03	0,61±0,01	0,44±0,09	0,18±0,00
Konya Çumra	8,97±0,29	6,27±0,03	45,46±0,08	37,99±020	0,62±0,02	0,40±0,02	0,19±0,00

Different letters within same line indicate significant differences at the level P <0.05

3.4. Volatile composition

Volatile composition of the sesame seeds is shown in Table 6. Different hydrocarbon, alcohol and acid compounds were determined in sesame seeds. The most abundant volatiles are methoxy phenyl oxime and delta-3-caren varied between 17.17-38.0% and 12.8-40.16% in sesame seeds samples, respectively. These compounds were found in all sesame seeds. Montanari et al. (2012) reported that antimicrobial effect of delta-3-caren. Hexanol was found in all sesame seed samples between 13.15-23.42%. It has a fruity flavor and made up by activity of alcohol dehydrogenase enzyme from linoleic acid (Olias et al. 1993; Aparicio and Morales, 1998). Although benzoic acid was found in all samples varied between 0.6-8.36%, its amount less than above three volatile. It is the precursors of the most organic compounds. It is used in food industry because of its antimicrobial effect (Fyfe et al., 1998).

Table 6. Volatile composition of the sesame seeds

Compounds	Aydın Incirliova	Bartın Ulus	Urfa Siverek	Konya Akoren	Mersin Mut	Diyarbakir Cungus	Konya Cumra
Delta-3-karen	13,09	26,4	21,77	12,92	12,8	37,7	24,29
Stiren	5,96	0,45	-	-	-	-	-
1-Hekzanol	13,88	14,78	21,31	23,42	18,9	19,67	15,5
1,3-dikloro benzen	10,09	0,53	10,68	17,94	7,76	5,64	7,55
2-Etil-1-hekzanol	0,17	-	-	-	-	-	-
N-methyl-1,3-Ditioizoindolin	11,22	11,01	10,43	11,73	12,65	8,26	9,24
Benzoik asit	6,84	7,12	7,2	8,36	7,62	4,92	0,6
Linalool	0,23	-	0,42	-	-	-	-
Fluoren-9-ol	0,17	0,35	-	-	-	-	-
Nonanol	0,36	0,28	-	0,68	0,43	6,18	-
Metoksi-feniloksim	38	38,74	27,62	24,97	39,48	17,17	20,97
3-Hidroksimandelik asit	-	-	-	-	0,36	0,22	-
4-Difenilpirazol	-	-	-	-	-	-	13,61
8-Dimetil-1,3,7-nonatrien	-	0,33	-	-	-	-	-
Alfa-terpinen	-	-	-	-	-	0,24	-
2-fenoksi-etanol	-	-	-	-	-	-	8,25

Linalool is an important acyclic monoterpene, but it was found in only two varieties, Aydın İncirliova (0.23%) and Urfa Siverek (0.42%). Stiren is another hydrocarbon that was found in only Aydın İncirliova (5.96%) and Bartın Ulus (0.45%). 2-Ethyl-hexanol was found in only Aydın İncirliova.

Several researchers have studied on heat treated sesame seeds (Schieberle, 1996; Shimoda et al., 1996; Shimoda et al., 1997; Agyemang et al., 2011; Lee and Choe, 2012; Xu-Yan et al., 2012; Zhao et al., 2013). In this research I studied the aromatic compound of the raw samples. Heat treated samples contain large amount of volatiles than the raw sesame seeds (Agyemang et al., 2011). For this reason I determined fewer amounts of volatiles than the mentioned literatures. Reducing sugar and sulphur containing amino acids such as methionine and sistein react together and dicarbonyl compounds were occured. Maillard reactions occur during the heat treatment and hydroxyl ketones, hydrogen sulphite and thiazolines occured (Haiyan et al., 2007). Different aromatic volatile compounds were produced by these compounds. For this reason heat treated samples have large amount of volatiles than raw samples. While Shimoda et al (1996) determined the monoalkyl-pyrazine in less heat treated samples, but they determined di and trialkyl in intense heat treated samples. Thiazolines and pyrazines were not determined in my study, because I did not apply heat to my samples.

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