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Fatty Acid Profiles for Almond (*Prunus amygdalus* Batsch) Genotypes with Different Kernel Taste and Formation

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ABSTRACT: This study was conducted to determine fatty acid profiles in relation to kernel taste (sweet and bitter) and kernel formation (single and double kernel) in native almond genotypes (*Prunus amygdalus* Batsch) from Tunceli and Balıkesir. The bitter and sweet kernelled almond genotypes from Tunceli averagely contained 52.8% and 54.0% fat, 6.27% and 6.2% palmitic acid, 0.57% and 0.62% palmitoleic acid, 1.63% and 1.43% stearic acid, 72.47% and 74.06% oleic acid, and 18.69% and 17.23% linoleic acid, respectively, and they had statistically insignificant means for fatty acid profiles. The double and single kernels of genotypes from Balıkesir averagely contained 54.4% and 55.7% fat, 6.1 % and 6.43% palmitic acid, 0.40% and 0.44% palmitoleic acid, 1.99% and 1.96% stearic acid, 69.84% and 72.39% oleic acid, and 21.25% and 17.89% linoleic acid, respectively. Oil composition of almond genotypes was not influenced by kernel taste statistically. In addition, single and double kernels of same genotypes had also insignificant means in fatty acid profiles.

Keywords: Almond, kernel, fatty acid, taste, double kernel

Farklı İç Tadı ve Oluşumuna Sahip Badem (*Prunus amygdalus* Batsch) Genotiplerinde Yağ Asitlerinin Belirlenmesi

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ÖZET: Bu çalışma, Tunceli ve Balıkesir'den alınan badem genotiplerinde iç badem tadı (tatlı ve acı) ve iç badem sayısı oluşumuyla (tek ve çift iç) ilgili olarak, yağ asidi içeriklerini belirlemek amacıyla yürütülmüştür. Ortalama olarak sırasıyla % 52.8 ve % 54.0 yağ, % 6.27 ve % 6.23 palmitik asit, % 0.57 ve % 0.62 palmitoleik asit, % 1.63 ve % 1.43 stearik asit, % 72.47 ve % 74.06 oleik asit, % 18.69 ve % 17.23 linoleik asit içeren Tunceli yöresinin acı ve tatlı içli badem genotiplerinde, yağ asidi profilleri bakımından istatistiki önemsiz farklar bulunmuştur. Balıkesir yöresi badem genotiplerinde, aynı genotiplerin çift ve tek iç meyveleri sırasıyla ortalama % 54.4 ve % 55.7 yağ, % 6.12 ve % 6.43 palmitik asit, % 0.40 ve % 0.44 palmitoleik asit, % 1.99 ve % 1.96 stearik asit, % 69.84 ve % 72.39 oleik asit, % 21.25 ve % 17.89 linoleik asit içermişlerdir. İncelenen genotiplerin yağ profilleri iç tadından istatistiksel olarak etkilenmemiştir. Bunun yanında, aynı genotiplerin tek ve çift içleri arasında yağ profilleri yönünden istatistiki önemsiz farklar belirlenmiştir.

Anahtar kelimeler: Badem, iç badem, yağ asidi, tat, çift iç

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INTRODUCTION

Almond (*Prunus amygdalus* Batsch) belongs to the *Rosaceae* family. Due to its high value for human nourishment and health, together with increasing production in the world, almond is considered one of the leading nut crops worldwide. Almond kernel contains high level of unsaturated fatty acids, mainly monounsaturated fatty acids (MUFA) that play a significant role for human nutrition, diet and healthfulness (McManus et al., 2001; Cherif et al., 2004; Jaceldo-Siegl et al., 2004; Jambazian et al., 2005). In recent years almond kernels preferred by the consumers (Chen et al., 2006) have been used to fight against some important diseases such as heart disease, rheumatoid arthritis, autoimmune disease and cancer today (Spiller et al., 1992; Abbey et al., 1994; Spiller et al., 1998; Davis and Iwahashi, 2001; Jenkins et al., 2002). The chemical composition of almond kernel is a significant characteristic determined for industrial purposes (Socias I Company et al., 2008).

In Turkey, the existence of a large number of almond trees from seedlings under various ecological conditions provides a valuable source for varietal selections (Ercişli, 2004). Almond genetic resources should also be identified based on their nutritional values (Aşkın et al., 2007). The kernel's chemicaI identification would be a selection criterion in almond quality evaluation for varietal characterization (Sathe et al., 2008).

The formation of double kernel is an undesired fruit characteristic for almond breeding efforts (Grasselly, 1994; Socias I Company et al., 2007; Socias I Company et al., 2008), and it can be influenced by genetic and environmental factors (Socias I Company et al., 2007; Çelik and Balta, 2011). Many almond varieties do not produce double kernels, whereas some varieties have double kernels at lower or higher percentages. Double kernel in almond is a vital defect in kernel industry for peeling, splitting and salting (Grasselly, 1994). Additionally, kernel bitterness is another undesired characteristic for commercial almond varieties, due to the cyanoglucoside amygdalin (Dicenta et al., 2007).

Although many studies on fatty acid profiles of almond kernels have been reported (Soler et al., 1989; Ağar et al., 1997; Aşkın et al., 2007; Kodad and Socias I Company, 2008; Sathe et al., 2008; Beyhan et al., 2011; Çelik and Balta, 2011), knowledge of fatty acid profiles on the basis of kernel taste and kernel formation is scarce. The objective of this paper was to determine and compare kernel fatty acid profiles for different kernel taste and kernel formation in native almond genotypes collected from the eastern and western regions of Turkey.

MATERIALS AND METHODS

Plant materials and sampling

The material of this study consisted of kernels of native almond (*Prunus Amygdalus* Batsch) genotypes from Tunceli province with 39°32' E longitude and 39°07' N (East Anatolia Region with cold climate conditions, Eastern Turkey) and Balıkesir province with 27°53' E longitude and 39°39' N latitude (Aegean Region with hot climate conditions, western Turkey). For the comparison fatty acid profiles of sweet and bitter kernelled almonds, the 18 genotypes from Tunceli district were evaluated. Seven genotypes from Balıkesir district were studied to compare fatty acid profiles of single and double kernelled almonds. Thus, 25 different genotypes were provided for the present study. The fruits of almond genotypes were harvested, their shells were removed from kernels, and kernels were dried in a vacuum oven at 60 °C for three days. The values of kernel weight were determined for each genotype using three replications and 20 fruit samples were used for each replication.

Determination of fatty acid profiles by GC

The fatty acid profiles (ether-extractable) from the kernel samples of fruits belonging to almond genotypes were analysed according to standard procedure (AOAC, 1990). In order to prepare the fatty acid methyl esters (FAME), kernel oil of 0.4 g was dissolved in 4 mL of isooctane and methylated in 0.2 mL 2 M methanolic KOH. The FAMEs were analysed by an Agilent 6890 series gas-chromatography equipped with flame-ionization detector and a 60-m capillary column (ID= 0.25 mm) coated with 0.25 mm of 50% - cyanopropyl-methylpolysiloxane (J&W Scientific, in Folsom, CA, USA). Helium was used as a carrier gas at a flow rate

of 1.5 mL min^{-1} and a split ratio of 1:10. The temperatures of injector and detector were 250 °C and 260 °C, respectively. The temperature of oven was at 120 ºC for a hold of 5 min, and it it was increased to 240 °C at a rate of 15 °C min^{-1} and hold at the final temparture for 20 min. FAMEs were identified by comparison of their retention times and equivalent chain lengths in terms of standard FAMEs (Supelco. 47885-U). FAMEs of the samples were quantified according to their percentage areas (AOAC, 1990). All the kernel samples were analyzed in triplicate.

Statistical analysis

In the present study, descriptive statistics for each characteristic measurable were expressed as mean. A randomized block design with three replications for each genotype and formation was used. The statistical package program Minitab release 10.2 for Windows was used for the analysis of variance (ANOVA). The means were compared by t-test, and significant differences were found.

RESULTS AND DISCUSSION

Table 1 presents the comperative values of kernel weight, kernel moisture, fat content and fatty acid compositions (g per 100 g of dry weight) in bitter and sweet almond genotypes belonging to the same growing region (Tunceli, eastern Turkey). The bitter genotypes having 0.89-1.43 g kernel weight and 1.0-2.2% kernel moisture contained 43.0-68.3% fat, 5.21-7.53% palmitic acid, 0.45-0.66% palmitoleic acid, 1.18-2.09% stearic acid, 70.54-74.90% oleic acid, 17.03-20.94% linoleic acid, 90.22-92.22% UFA (unsaturated fatty acids), 7.76-9.71% SFA (saturated fatty acids) and 9.2-11.8 UFA/SFA ratio. In sweet genotypes, the range was from 0.91 g to 1.44 g for kernel weight and from 0.6% to 2.0% for kernel moisture. They contained 45.9-58.7% fat, 5.75-7.10% palmitic acid, 0.48-0.85% palmitoleic acid, 1.14-1.95% stearic acid, 68.63-78.88% oleic acid, 13.66-22.0% linoleic acid, 90.63-92.57% UFA, 7.42-9.35% SFA and 9.6-12.4 UFA/SFA ratio. In addition, the bitter and sweet almond genotypes averagely had 1.18-1.17 g kernel weight, 1.45-1.28% kernel moisture, 52.8-54.0% fat content, 6.27-6.23% palmitic acid, 0.57-0.62% palmitoleic acid, 1.63-1.43% stearic acid, 72.42-74.06% oleic acid, 18.69-17.23% linoleic acid, 0.08-0.08% linolenic acid, 0.38-0.42% myristic acid, 91.21-91.32% UFA, 8.71-8.63% SFA and 10.4-10.5 UFA/SFA ratio, respectively. The contents of fat and fatty acids in bitter and sweet genotypes were statistically insignificant means (Table 1).

Table 2 depicts the comperative values of kernel moisture, fat content and fatty acid compositions (g per 100 g of dry weight) in double and single kernels of the same genotypes (Balikesir, Western Turkey). The double kernels of seven almond genotypes contained 44.9-58.6% fat, 5.26-6.69% palmitic acid, 0.33-0.45% palmitoleic acid, 1.61-2.40% stearic acid, 65.33-74.73% oleic acid, 17.36-25.17% linoleic acid, 90.50-92.1% UFA, 7.61-9.48% SFA and 9.5-12.1 UFA/SFA ratio. Oil profiles of single kernels of the same genotypes were 49.5-61.6% fat, 5.63-7.22% palmitic acid, 0.36-0.55% palmitoleic acid, 1.21-4.01% stearic acid, 68.42-75.12% oleic acid, 14.82-21.10% linoleic acid, 87.85-91.97% UFA, 7.99-11.59% SFA and 7.6-11.5 UFA/SFA ratio. The double and single kernels of the same averagely had 1.71-1.17% kernel moisture, 54.4-55.7% fat content, 6.12-6.43% palmitic acid, 0.40-0.44% palmitoleic acid, 1.99-1.96% stearic acid, 69.84-72.39% oleic acid, 21.25-17.89% linoleic acid, 0.11-0.08% linolenic acid, 0.44-0.64% myristic acid, 91.18-90.32% UFA, 8.77-9.19 % SFA and 10.4-9.9 UFA/SFA ratio, respectively. With respect to fat contents and fatty acid composition of the double and single kernels of the same genotypes, insignificant differences were found statistically (Table 2).

This paper compared kernel fatty acid profiles of almond genotypes based on kernel taste and kernel formation. The comparisons were performed on native almond genotypes from Tunceli district (East Anatolia Region, Eastern Turkey) and Balikesir district (Aegean Region, Western Turkey). Some promising almond genotypes from western and eastern Turkey had kernel weight over 1.0 g. It was reported that large kernel was a desired varietal characteristic for almond breeding efforts (Kester et al., 1991; Grasselly, 1994).

The fat content ranging from 48.1% to 63.5% for the single kernelled sweet genotypes was more than 50% in the most of genotypes (Table 1-2). Different fat content values for many almond varieties and geno-

Table 1. Values of kernel weight, kernel moisture, fat content and fatty acid compositions (g $100g^{-1}$ dry weight) in bitter and sweet kernelled almond genotypes from eastern Tur

Almond genotypes	Kernel taste	Kernel weight (g)	Kernel moisture (%)	Fat content (%)	Palmitic acid C16:0	Palmitoleic acid C16:1	Stearic acid C18:0	Oleic acid C18:1	Linoleic acid C18:2	Linolenic acid C18:3	Myristic acid C14:0	UFA (%)	SFA (%)	UFA/ SFA
T-010	B	1.50	1.0	57.0	6.19	0.62	1.18	74.90	17.03	-	-	91.93	7.99	11.5
T-011	B	1.15	1.6	68.3	6.71	0.66	1.87	72.41	18.34	-	-	90.75	9.24	9.8
T-021	B	0.89	1.4	50.5	7.53	0.64	1.27	71.18	18.96	0.08	0.27	90.22	9.71	9.2
T-030	B	1.11	1.4	46.4	5.78	0.45	1.59	74.44	17.37	0.09	0.27	91.90	8.09	11.3
T-032	B	1.17	1.4	51.3	6.08	0.54	1.89	70.54	20.94	-	-	91.48	8.51	10.7
T-043	B	1.01	2.2	52.8	5.21	0.45	1.64	71.75	20.37	0.10	0.46	92.22	7.76	11.8
T-097	B	1.15	1.2	52.8	6.19	0.63	2.09	71.54	18.98	0.08	0.47	90.60	9.38	9.6
T-118	B	1.43	1.4	43.0	6.50	0.57	1.52	73.03	17.59	-	0.43	90.62	9.02	10.0
T-014	S	0.97	1.8	45.9	5.75	0.54	1.13	78.88	13.69	-	-	92.57	7.42	12.4
T-031	S	1.03	1.4	56.1	5.78	0.48	1.61	75.20	16.43	-	0.42	91.63	8.29	11.0
T-037	S	1.28	1.0	54.7	6.14	0.58	1.29	73.41	18.21	-	0.35	91.62	8.36	10.9
T-059	S	1.04	1.0	55.0	6.69	0.85	1.36	74.14	16.45	-	0.44	90.59	9.34	9.6
T-062	S	0.91	1.6	50.0	7.10	0.73	1.34	72.12	18.61	-	-	90.73	9.17	9.8
T-066	S	1.00	0.6	56.7	6.50	0.57	1.51	73.60	17.19	0.08	0.51	90.87	9.09	9.9
T-125	S	1.30	0.6	58.7	6.95	0.61	1.35	68.63	22.00	-	0.44	90.63	9.35	9.6
T-129	S	1.35	1.4	57.0	6.02	0.71	1.14	73.64	17.88	-	0.58	91.52	8.45	10.8
T-136	S	1.44	2.0	51.0	6.04	0.64	1.66	77.37	13.66	0.09	0.40	91.12	8.74	10.4
T-137	S	1.38	1.4	54.9	5.38	0.50	1.95	73.65	18.18	0.07	0.25	91.90	8.08	11.3
Mean of BG		1.18	1.45	52.8	6.27	0.57	1.63	72.47	18.69	0.08	0.38	91.21	8.71	10.4
Mean of SG		1.17	1.28	54.0	6.23	0.62	1.43	74.06	17.23	0.08	0.42	91.32	8.63	10.5
Significance		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

B: Bitter, S: Sweet, BG: Bitter kernelled genotypes, SG: Sweet kernelled genotypes, UFA: Unsaturated fatty acids, SFA: Saturated fatty acids, ns: non-significant.

Table 2. In the native almond genotypes from western Turkey, values of kernel moisture, fat content and fatty acid composition (g $100g^{-1}$ dry weight) in double and single kernels belonging to the same genotypes.

Almond genotypes	Kernel formation	Kernel moisture (%)	Fat content (%)	Palmitic acid C16:0	Palmitoleic acid C16:1	Stearic acid C18:0	Oleic acid C18:1	Linoleic acid C18:2	Linolenic acid C18:3	Myristic acid C14:0	UFA (%)	SFA (%)	UFA/ SFA
B-06	DK	1.2	44.9	6.26	0.44	1.76	71.82	19.70	-	-	91.52	8.46	10.8
B-08	DK	2.8	58.3	6.35	0.45	2.12	65.33	25.17	0.11	0.44	90.61	9.36	9.6
B-09	DK	0.8	55.8	6.48	0.44	2.01	68.40	22.56	0.09	-	91.05	8.93	10.1
B-21	DK	1.2	55.2	5.67	0.33	1.61	74.73	17.36	0.10	-	92.19	7.61	12.1
B-22	DK	1.0	58.6	5.26	0.36	2.06	74.16	17.47	0.10	0.56	91.73	8.24	11.3
B-29	DK	2.4	56.6	6.69	0.37	1.98	65.64	24.76	0.10	0.44	90.50	9.48	9.5
B-35	DK	2.6	52.0	6.16	0.39	2.40	68.80	21.72	0.17	0.33	90.69	9.28	9.7
B-06	SK	1.2	49.5	6.69	0.54	1.21	68.99	18.86		0.51	87.85	8.95	9.8
B-08	SK	1.2	53.8	7.22	0.36	4.01	73.57	14.82	-	-	88.39	11.59	7.6
B-09	SK	1.4	57.5	6.12	0.44	2.05	74.70	16.67	-	-	91.37	8.61	10.6
B-21	SK	1.0	61.6	6.06	0.55	1.38	75.12	16.75	0.10	-	91.97	7.99	11.5
B-22	SK	1.4	58.5	5.63	0.37	1.71	74.73	17.01	-	0.52	91.74	8.23	11.1
B-29	SK	1.0	57.9	7.13	0.39	1.86	68.42	21.10	0.09	0.91	89.61	10.29	8.7
B-35	SK	1.0	51.3	6.15	0.40	1.47	71.24	20.02	0.07	0.64	91.33	8.66	10.5
Mean of DK		1.71	54.4	6.12	0.40	1.99	69.84	21.25	0.11	0.44	91.18	8.77	10.4
Mean of SK		1.17	55.7	6.43	0.44	1.96	72.39	17.89	0.08	0.64	90.32	9.19	9.9
Significance		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

DK: Double kernel, SK: Single kernel, UFA: Unsaturated fatty acids, SFA: Saturated fatty acids, ns: non-significant.

types were recorded as 50–64% by Soler et al. (1989), 47–56% by Aslantas (1993), 52–56% by Barbera et al. (1994), 52-57% by Agar et al. (1997), 30–51% by Martins et al. (2000), 25-60 % by Aşkın et al. (2007), 48-67% by Kodad and Socias I Company (2008) and 48.1-63.5% by Çelik and Balta (2011). Although fat contents of genotypes generally agreed with those reported in the related references, the statistical differences in fat content were not found based on kernel taste and kernel formation in almond genotypes. Therefore, kernel fat was not affected by sweet and bitter kernels, and also single and double kernels.

Sathe et al. (2008) determined that fatty acid composition of almond kernel was significantly influenced by variety and county. In addition, Barbera et al. (1994) reported 5.88–6.19% palmitic acid, 0.88–0.93% palmitoleic acid, 1.85–2.09 % stearic acid, 72.17–71.83% oleic acid, and 19.19–18.91% linoleic acid for Ferragnes and Tuono almond kernels. Martins et al. (2000) reported that almond varieties had 58.96–69.68% oleic acid, 17.52–29.89 % linoleic acid, 5.94–7.31% palmitic acid and 2.15–3.13% stearic acid. Gradziel et al. (2000) recorded that the 13 almond varieties contained 5.0–6.4 % palmitic acid, 64.7–76.0% oleic acid and 16.3–26.9% linoleic acid contents. Aşkın et al. (2007) determined that almond genotypes contained 50.41–81.20% oleic acid, 6.21–37.13% linoleic acid, 5.46–15.78% palmitic acid, 0.36–2.52% palmitoleic acid, and 0.80–3.83% stearic acid. Sathe et al. (2008) determined 57.54–73.94% oleic acid, 19.32–35.18% linoleic acid, 5.07–6.78% palmitic acid, and 0.20-1.66% stearic acid contents for eight almond varieties from 12 different California counties. Kodad and Socias I Company (2008) recorded contents of oleic acid from 63% to 78%, linoleic acid from 12% to 27 %, palmitic acid from 5% to 7%, stearic acid from 1.2% to 2.5%, palmitoleic acid from %0.3 to %0.8 for eight varieties and 47 self-compatible almond genotypes.

In this study, a significant variation was observed in fat and fatty acids among genotypes, which was in agreement with some authors (Aşkın et al., 2007, Kodad and Socias I Company, 2008). In this work, some genotypes contained higher fat and major fatty acids compared to the commercial varieties. The presence of almond selections with higher oil and fatty acid contents in comparison with the commercial varieties not only represents a very promising base to obtain new almond varieties with oil of higher quality, but also satisfies the industrial and consumer sectors (Kodad and Socias I Company, 2008). Almond genotypes with higher oil and major fatty acids than the commercial varieties could contribute to future nutritional breeding efforts as promising genetic resources with oil of higher quality. On the other hand, although the contents of fat and fatty acids were not affected by sweet, bitter, single and double kernelled genotypes statistically, further studies should be evaluated in detail using more genetic materials.

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