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Full Length Research Paper

Determination of fatty acid compositions of some important almond (*Prunus amygdalus* L.) varieties selected from Tokat province and Eagean region of Turkey

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This study was conducted to determine the fatty acid composition of Picantili, Ferraduel, Drake and Nonpareil commercial almond species (*Prunus amygdalus* L.) cultivated in Tokat province under dry conditions; of genotype ST-11 and YD-2 selected from Tokat region; and of 101-13, 300-1, 17-4 sweet almond species, selected from the Aegean region. The percentage and composition of the fatty acids of the samples were determined by gas chromatography. The amounts of oleic acid, linoleic acid, palmitic acid and stearic acid, respectively, were found to be higher than the other fatty acids in all genotypes. These fatty acids were similar in amounts and little change was observed between the genotypes. These values were determined to range from 57.46 to 68.65%, 11.77 to 25.15%, 5.06 to 7.26% and 1.26 to 2.41%, respectively. However, genotype 17-4 included more docosaheaenoic acid (DHA), pentadecanoic and nervonic acids than the other genotypes. According to these results, it can be suggested that the fatty acid composition of genotypes were not changed very significantly although there are some differences between samples as percentage. Genotype 17-4 is more heavily affected by dry climatic conditions than other genotypes.

Key words: Fatty acids, almond, gas chromatography.

INTRODUCTION

Almond is an important commercial and medicinal fruit, which originated from Anatolia, Turkey (Dokuzoguz and Gulcan, 1973; Kuden, 1997; Mısırlı and Gulcan, 2000; Balta et al., 2001; Ercisli, 2004). Due to its protein, fat, mineral matter, fibre and vitamin E content, almond is a nutritious and delicious fruit. Moisture content, fat content, protein content and ash content of almond species such as Carmel, Te-as and Nonpareil vary within the range 3.05 to 4.33%, 43.37 to 47.50%, 20.68 to 23.30% and 5.35 to 7.45%, respectively (Ahrens et al., 2005). The nutritional value as well as industrial and medical importance of almond fat has been demonstrated by various large scale literature studies (Spiller et al., 1992; Davis and Iwahasi, 2001). Fruits rich in oleic, linoleic and linolenic fatty acids have become increasingly important due their positive effects on cardiovascular diseases and lowering cholesterol. In addition to its protein, vitamin and mineral matters content, almond contains high amounts of unsaturated fat, which makes it of significant research interest (Kafkas et al., 1995; Zacheo et al., 2000; Gradziel et al., 2001; Ahrens et al., 2005). It is quite important that almond helps to lower

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Abbreviations: DHA, Docosaheaenoic acid; **LDL,** low density lipoprotein; **HDL,** high density lipoprotein; **GC,** gas chromatography; **EPA,** eicosapentaenoic acid; **FID,** flame ionized detector.

high cholesterol and low density lipoprotein (LDL) cholesterol and to increase high density lipoprotein (HDL) cholesterol levels, due to its high unsaturated fat (oleic and linoleic acids) content. The fatty acid composition of oil plants is not fixed; fatty acid synthesis may vary according to genetic, ecological, morphological, physiological and cultural factors (Baydar, 2000). For instance, temperature increase was reported to result in a decrease in the activity of the enzymes (such as oleoyl-PC desaturase and linoleoyl-PC desaturase) that catalyze the synthesis of linoleic and linolenic acids from oleic acid (Braun and Somerville, 1997). As a result, high temperatures had negative effects on linoleic and linolenic acid synthesis and positive effects on oleic acid synthesis in plants (Weiss, 1983; Stryer, 1986; Röbbelen et al., 1989). Statistically significant differences were found between the fatty acid distributions of the ecological regions in different longitudes (Lajara et al., 1990; Seiler, 1983; Knowles, 1972).

The continuous changes in fatty acid distribution during the period from seed development to maturation are called ontogenetic variability (Baydar, 2000). The lipid accumulation dynamic of almond consists of 4 stages: (i) preparation to fruit in June (dry matter accounting for approimately 8%), (ii) no change in fat during June; (iii) fat level reaching 14 to18% of the dry matter in July; and (iv) tripling of the fat content in August. In the first phase of lipid accumulation, the almond includes significant amounts of saturated fat (palmitic acid), essential fatty acids (linoleic acid) and a small amount of oleic acid. The amount of essential fatty acids was recorded to be lower in September than August (Andelko, 1998). In a related study of some almond species, the palmitic, palmitoleic, stearic, oleic, linoleic and linolenic acid values were observed to vary between 5.936 to 7.312%, 0.354 to 0.458%, 2.145 to 3.194%, 58.961 to 70.890%, 17.518 top 29.886% and 0.032 to 0.121%, respectively (Martins et al., 2000). In addition to maturation and harvest time of fruits (Samanci and Ozkaynak, 2003; Flagella et al., 2002; Jones, 1984; Anastası et al., 2000; Gerçel, 2004; Bayrak, 1997), stress factors particularly drought were found to have significant effects on the fatty acid composition of plants and seeds (Naveed et al., 2006; Dwivedi et al., 1996; Flagella et al., 2002). Soil properties may also affect fatty acid compositions (Dubey et al., 2001; Ahmad and Abdin, 2000; Holmes and Bennet, 1979).

MATERIALS AND METHODS

The material of the present study consisted of seeds e-tracted from the commercial almond species *(Prunus amygdalus* L.*)* Picantili, Ferraduel, Drake and Nonpareil, which were cultivated under dry conditions without irrigation; of 101-13, 300-1, 17-4 sweet almond species selected from the Aegean region (Gulcan, 1985); and of genotype ST-11 and YD-2 selected from Tokat region (Gercekcioglu and Gunes, 1999). Fruit samples were obtained from the implementation and research garden at the department of Horticulture, Faculty of Agriculture, Gaziosmanpasa University, Tokat.

Gas chromatography analysis

The fatty acid methyl esters for gas chromatgraphy (GC) analysis were prepared. Samples were analyzed in triplicate. E-tracted samples were methylated in a methyl esters (BF_3CH_3OH) mixture for separation of fatty acids. The fatty acids (in the hydrolyzed and derived methyl ester forms) were obtained with 1 ml of NaOH/Methanol at 90°C for 10 min and then a complete derivation was assured with 1 ml boron fluoride (BF_3) at 90°C for 10 min. The methyl esters were purified with 1 ml of hexane and 1 ml of water. Individual samples were passed through an anhydrous sodium sulphate (Na_2SO_4) column and then evaporated to dryness under a steam of nitrogen and redissolved in 100 µl of isooctane. For analysis, the high performance (HP)- Innowa- chromatography column (30 m - 0.32 mm ID - 0.25 lm film thickness) and helium as the carrier gas were used. Clarified and methylated samples were run on a GC column containing polyethyleneglycol chromatography medium. The identification and quantitation of fatty acids were performed by GC using an Agilent 6890 series GC systemors. Detector was flame ionized detector (FID). The column temperature was held 50°C for 1 min, then with the first temperature gradient of 8°C/min to 220°C for 5 min. The second temperature (finally) gradient was 2°C/min to 250°C and held for 7.75 min. Injector temperature was 250°C. In analysis, GC gas flow rate was 1.3 ml/min and injection volume was 1 µl (Anonymous, 1990).

RESULTS AND DISCUSSION

The analysis of the fatty acid compositions of the study samples is shown in Table 1. As can be seen in Table 1, none of the study samples contained the fatty acids Cis-10 pentadecenoic acid (C15:1), linolenic acid (C18:3n6), erucic acid (C22:1n,9), arachidonic acid (C20:4n6), docosadienoic acid (C22:2) or eicosapentaenoic acid (EPA) (C20:5,n3). The undecanoic acid (C11:0) content of genotype 101-13 was found to be 0.13 and 1.02% in genotype 17-4. Myristoleic acid (C14:1), a monounsaturated fatty acid, was found only in Ferraduel species at 0.06%; Heneicosanoic acid (C21:0) was present in Ferraduel species at 0.09%; eicosatrienoic acid (C20:3n3) in genotype ST-11 (selected from the central district of Tokat) at 0.11% and lignoceric (C24:0) fatty acid in YD-2 genotype at 0.02%. Lauric acid (C12:0) was found in genotype ST-11 at 0.05% rate and in genotype 17-4 at 0.35%, while eicosadienoic acid (C20:2) was found in genotype ST-11 at 0.32% and in genotype 300-1 at 0.02%. The minimum amount of oleic acid, an important unsaturated fatty acid, was found in genotype 300-1 at 57.46% and the maximum amount in genotype YD-2 at 68.65%. The oleic acid content of 17-4, Picantili, ST-11, 101-13, 300-1, Drake, Nonpareil and Ferraduel species and genotypes was found to be 63.71, 62.15, 62.23, 61.76, 57.46, 59.84, 64.76 and 67.9%, respect-tively. Linolenic acid (C18.3n3) is a polyunsaturated fatty acid of the Omega-3 family, which plays an important role in the prevention of heart diseases and in cell development; it cannot be synthesized by the body and

Table 1. The fatty acid composition in some important almond varieties.

Fatty acid	Variety								
	Picantili	ST -11	101-13	Ferraduel	300-1	Drake	Nonpareil	17-4	YD-2
Undecanoic acid (C11:0)	0	0	0.13	0	0	0	0	0.2	0
Lauric acid (C12:0)	0	0.05	0	0	0	0	0	0.35	0
Tridecanoic acid	0	0.05	0	0	0	0.02	0	0.23	0
Myristic acid (C14:0)	0.15	0.22	0.09	0.44	0.18	0.09	0.11	0.59	0.15
Myristoleic acid (C14:1)	0	0	0	0.06	0	0	0	0	0
Pentadecanoic acid (C15:0)	0.02	0	0.02	0	0.02	0.02	0.02	0.27	0
Palmitic acid (C16.0)	6.33	5.54	6.63	6.17	7.26	7.04	6.09	5.06	5.25
Palmitoleic acid (C16:1)	0.58	0.49	0.62	0.87	0.82	0.56	0.48	0.51	0.55
Heptadecanoic Acid (C17:0)	0.06	0.07	0.05	0.1	0.06	0.07	0.07	0	0.06
Cis-10 Heptadecanoic acid (C17:1)	0.08	0.07	0.09	0.11	0.07	0.08	0.08	0	0.09
Stearic acid (C18.0)	2.41	2.22	2.1	2.26	1.98	2.25	2.02	1.26	1.84
Elaidic acid (C18:1n9t)	0	0	0.02	0.34	0	0.02	0	0	0
Oleic acid (C18:1n9c)	62.15	62.23	61.76	67.9	57.46	59.84	64.76	63.71	68.65
Linolelaidic acid (C18:2n6t)	0.44	0.4	0.47	0.4	0.38	0.45	0.42	0	0.41
Linoleic acid (C18:2n6c)	22.75	17.14	22.64	11.77	25.15	23.52	22.08	22.2	16.67
Arachidic acid (C20:0)	0.11	0.08	0.1	0.12	0.08	0.08	0.07	0	0.09
Eicosenoic acid (C20:1)	0.04	0	0.02	0.1	0.05	0.03	0.06	0	0.03
Linolenic acid (C18.3n3)	0.06	0.08	0.06	0.1	0.05	0.07	0.06	0	0.08
Heneicosanoic acid (C21:0)	0	0	0	0.09	0	0	0	0	0
Eicosadienoic acid (C20:2)	0	0.32	0	0	0.02	0	0	0	0
Behenic acid (C22:0)	0	0	0.03	0	0.02	0.03	0.02	0	0.02
Eicosatrienoic acid (C20:3n6)	0	0.32	0.11	0.44	0.21	0.14	0.15	0.72	0.19
Eicosatrienoic acid (C20:3n3)	0	0.11	0	0	0	0	0	0	0
Tricosanoic (C23:0)	0	0.11	0.05	0.17	0.05	0.04	0.04	0.63	0.04
Nervonic (C24:1)	0.29	0.46	0.17	0.73	0.29	0.2	0.23	0.89	0.28
DHA (C22:6n3)	0.22	0	0.12	0.27	0.04	0.12	0.09	0.81	0.13

must be obtained through a balanced diet. Linolenic acid (C18.3n3) was not found in genotype 17-4, but was found at low levels (0.1%) in Ferraduel species; at 0.08% in genotype YD-2; at 0.07% in genotype ST-11; at 0.06% in Drake species; and at 0.05% in Picantili, 101-13 and Nonpareil species. Eicosapentaenoic acid (EPA) was not found in any of the almond species and genotypes analyzed. Docosaheaenoic acid (DHA) was found in 17-4 species at 0.81% and in 300-1 species at 0.04%. However, DHA was not found in genotype ST-11. While gamma linoleic acid and arachidonic acid were not found in any of the almond samples, eicosatrienoic acid (C20:3n6) was found in all almond species (at 0.11-2.72%) and genotypes, except for Picantili species.

Oleic acid was found at 68.65%, linoleic acid at 25.15%, palmitic acid at 7.26% and stearic acid at 2.41% in the seed samples analyzed in this study. When compared to other species and genotypes, the 17-4 species contained higher amounts of lauric, tridecanoic, myristic, pentadecanoic, 20:3n6 eicosatrienoic, tricosanoic, nervonic and DHA fatty acids. It contained no palmitic, linolelaidic or arachidic acid; compared to In the the fatty acid contents of other almonds, it contained similar amounts of stearic acid, oleic acid and linoleic acid.Picantili, Ferraduel, Drake and Nonpareil species were found to contain no undecanoic, lauric, cis-10 pentadecanoic, linoleic, eicosadienoic, eurosis, eicosatrienoic, arachidonic, docosadienoic, lignoceric acid or EPA; only Drake species was found to contain tridecanoic acid (0.02%) and only Ferraduel species was found to contain myristoleic and heneicosanoic acid (0.09%). Oleic acid was found in Ferraduel species at 67.9% and in Drake species at 59.84%. Among the sweet almond genotypes selected from the central district of Tokat, genotype ST-11 and YD-2 were found to contain palmitic acid at 5.54 to 5.25%; palmitoleic acid at 0.49 to 0.55%; stearic acid at1.84 to 2.22%; oleic acid at 62.23 to 68.65%; and linoleic acid at 16.67 to 17.14%, respectively. The almond species of 101-13, 300-1 and 17-4, which were selected from the Aegean region, were found to contain palmitic acid at 6.63, 7.2, and 5.06%, respectively; palmitoleic acid at 0.62, 0.82, 0.51%; stearic acid at 2.1, 1.98, 1.26%; oleic acid at 61.76, 57.46, 63.71%; and linoleic acid at 22.64, 25.15, 22.2%.

The fatty acid compositions of the study materials were determined by GC. There were some differences as fatty acid contents between almond varieties. These values were found to be high in some materials and considerably low in some others. The findings of the present study comply with those of previous studies in the literature. For instance, oleic acid content was found to be 56.36% and linoleic acid was 24.24% in a previous study on fatty acids in almonds. Palmitic acid, stearic acid, palmitoleic acid and myristic acid were reported to be 6.33, 0.97, 0.59 and 0.04%, respectively (Mehran and Filsoof, 1974). In the present study, oleic acid, linoleic acid, palmitic acid, stearic acid and palmitoleic acid were found to be 68.65, 25.15, 7.26, 2.41 and 2.30%, respectively. Oleic acid content was found to be higher in the present study than those reported by Mehran et al. (1974) in a study by Richter (1980), stearic acid, linoleic acid and oleic acid contents were found to be 10.4, 21.8 and 59.2%, respectively (Richter, 1980). When compared to that study, the present study found lower stearic acid levels and higher levels of oleic and linoleic acid. Soler et al. (1988) recorded palmitic acid (6.5%), stearic acid (1.5%), oleic acid (62.5%) and linoleic acid (29.0%) levels and Fourie and Bossan (1990) reported similar levels of oleic, linoleic, palmitic fatty acid amounts (of almond and pican fruits) to those found in the present study.

A previous study by Barbera et al. (1994) studied the fatty acid composition of the Ferragnes and Tuono almond species; palmitic acid, palmitoleic acid, stearic acid, oleic acid and linolic acid were found to vary between 5.88 to 6.19%, 0.88 to 0.93%, 1.85 to 2.09%, 72.17 to 71.83% and 19.19 to 18.91%, respectively. The present study recorded higher fatty acid percentages (in Nonpareil, Drake, Ferraduel, Picantili, sT-11, YD-2, 101-13, 300-1, 17-4 species and genotypes) than the study by Barbara et al. (1994) However, both studies produced similar results in terms of stearic acid content. Balta (2002) recorded the levels of two unsaturated fatty acids, oleic acid and linoleic acid, which varied between 50.41 to 81.20% and 6.21 to 37.13%, respectively. In the same species, the levels of three saturated fatty acids, palmitic acid, palmitoleic acid and stearic acid, varied between 5.46 to 15.78%, 0.36 to 2.52% and 0.80 to 3.83%, respectively. In comparison, the present study found that levels of oleic acid and linoleic acid varied between 57.46 to 68.65% and 11.77 to 25.15%, respectively; and palmitic acid, palmitoleic acid and stearic acid contents varied between 5.06 to 7.26%, 0.48 to 0.87% and 1.26 to 2.41%, respectively. Kodad and Socias (2004) recorded oleic acid rates varying between 63-78% and linoleic acid at 2.27%. In comparison, the present study found that oleic acid varied from 57.46 to 68.75% and linoleic acid from 11.77 to 25.15%, except for one genotype. In another study conducted in the Mediterranean region, the fatty acid content of 14 unit var almond genotypes were found to vary between 44.25 to 54.68% and that of 8 promising genotypes was found to be above 50%. In the same study, oleic acid content was found to be 71.59% and linoleic acid content was 19.20% (Yıldırım et al. 2008). The findings of the present study comply with these findings. When compared to the present study, Askın et al. (2007) found higher levels of oleic acid (81.20%) and palmitic acid (15.78%) and lower levels of linoleic acid (33.15%). Riemersma (1986) reported low concentration of linoleic acid in the fatty tissues of Scottish and Finnish populations, which experience high mortality due to coronary heart disease. However, linoleic acid concentration was recorded to be quite high in populations with low risk of coronary heart disease (Logan et al., 1978).

The present study found higher levels of linoleic acid than many other fatty acids present in the almond samples. The nutritional value as well as industrial and medical importance of almond fat has been demonstrated by various large-scale literature studies (Spiller et al., 1992; Davis and Iwahasi, 2001). Therefore, analysis of the presence and amounts of fatty acids in almond fruit is of great importance for health and industrial applications.

The fatty acid composition of oil plants is not fixed; it may vary according to many factors as well as unique characteristics of the species. Therefore, understanding the possible changes that may occur in the fatty acid concentrations of oil plants under specific conditions is important for oil quality (Karaca and Aytac, 2007).

Previous studies have also shown that synthesis of fatty acids may vary according to genetic, ecological, morphological, physiological and cultural factors (Baydar, 2000). This is supported by the findings of the present study.

Conclusion

Almond has beneficial effects on human health since it contains a high level of unsaturated fatty acids. These is oleic, linoleic, palmitic and stearic acids. In this study, the amounts of these fatty acids were found to be higher than the other fatty acids in all genotypes. These fatty acids were similar amounts and little changed between genotypes.

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