Erwerbs-Obstbau (2023) 65:1479–1487
https://doi.org/10.1007/s10341-023-00887-8

ORIGINAL ARTICLE / ORIGINALBEITRAG

Fatty Acid Characterization of "Gulcan 2 × Lauranne" and "Guara × Nurlu" F1 Hybrid Almond Population

Kader Ercik[1] · Songul Comlekcioglu[2] · Nesibe Ebru Kafkas[2] · Sezai Ercisli[3] · Halil Ibrahim Sagbas[3]

Received: 22 January 2023 / Accepted: 20 March 2023 / Published online: 19 April 2023
© The Author(s), under exclusive licence to Der/die Autor(en), exklusiv lizenziert an Springer-Verlag GmbH Deutschland, ein Teil von Springer Nature 2023

Abstract

Almond (*Amygdalus communis* L.) is a type of hard-shell fruit species that is very important for human health due to its nutritional content. This importance is mainly due to its various oils, vitamins, and minerals. Almonds, which contain high amounts of monounsaturated fatty acids, are among the olive oil-like foods recommended for decreasing bad cholesterol and protecting against heart disease. In this study, a total of 166 F1 almond genotypes consisting of 77 F1 obtained from the hybridization of 'Gulcan 2' and 'Lauranne' almond varieties ('Gulcan 2' × 'Lauranne') and 89 F1 obtained from the crosses of 'Guara' and 'Nurlu' almond varieties and their parents ('Guara' × 'Nurlu') were investigated for biochemical characterization. Fatty acids were determined using gas chromatography/flame ionization detector (GC/FID) techniques for the 166 F1 hybrid genotypes. The mean and standard deviation values were calculated for the statistical analyses. For the 'Gulcan 2' × 'Lauranne' F1 population, oleic acid content ranged between 65.793 and 81.146%; linoleic acid content ranged between 9.532 and 22.041%; palmitic acid content ranged between 4.546 and 7.182%; stearic acid content ranged between 0.855 and 4.048%; and arachidic acid content ranged between 0.911 and 5.028%. For the 'Guara' × 'Nurlu' F1 population, oleic acid content ranged between 66.532 and 81.370%; linoleic acid content ranged between 10.516 and 22.310%; palmitic acid content ranged between 5.449 and 7.249%; stearic acid content ranged between 1.070 and 5.557%; and arachidic acid content ranged between 0.000 and 6.836%.

Keywords *Amygdalus communis* L · Fatty acids · Gas chromatography · Breeding · Monounsaturated fatty acid

Introduction

Horticultural crops perform a vital role in the economy of countries that have high horticultural products by generating employment, providing raw material to various food processing industries, and higher farm profitability due to higher production and export earnings from foreign exchange. Most horticultural plants have attractive and promising functional characteristics and a comparatively high value per hectare. These plants also increase quality of life and contribute to the beauty, sustainability, and rehabilitation of our environment and the human condition (Ercisli et al. 2005; Erturk et al. 2012; Ikinci et al. 2014; Nadeem et al. 2018; Abanoz and Okcu 2022; Ari et al. 2022; Taskesenlioglu et al. 2022).

The almond (*Amygdalus communis* L.) originated in Central and Western Asia and spread throughout China, India, Iran, Syria, and the Mediterranean countries (Imani et al., 2021).

The dwarf almond (*Amygdalus nana* L.) species can be naturally found in Anatolia and shows high genetic varia-

✉ Kader Ercik
kader.ercik@tarimorman.gov.tr

Songul Comlekcioglu
songulcomlekcioglu@gmail.com

Nesibe Ebru Kafkas
ebruyasakafkas@gmail.com

✉ Sezai Ercisli
sercisli@gmail.com

Halil Ibrahim Sagbas
hibrahimsagbas@gmail.com

[1] Alata Horticultural Research Institute, Alparslan Turkes Bulvari, 492, 33740 Erdemli, Mersin, Türkiye

[2] Department of Horticulture, Faculty of Agriculture, Cukurova University, 01380 Adana, Türkiye

[3] Department of Horticulture, Faculty of Agriculture, Ataturk University, 25240 Erzurum, Türkiye

tion. *Amygdalus nana* is a typical plant of the dry regions in Turkey (Celik et al. 2019). *Amygdalus*, a genus of almonds grown commercially all around the world, belongs to the Rosaceae family and is a species of the *Prunus* genus (Martinez-Gomez et al. 2007). Almond fruit holds great importance worldwide due to its high nutritional value and beneficial effects on human health (Amarowicz et al. 2005). Almond (*Amygdalus communis*, L.) is a rich food source containing phytochemicals such as vitamin E, monounsaturated fatty acids, polyunsaturated fatty acids, arginine, and potassium, which are associated with the treatment of diseases related to the heart and obesity (Anonymous 2007). One of the widely cultivated nut crops of the Mediterranean area is almond. World almond production was 4,140,043 tons, and the United States was the leading producing country (2,370,021), followed by Spain (416,950 tons). Turkey came fifth, having produced 159,187 tons of almond (FAO 2020). Fatty acids are generally classified as saturated, monounsaturated, or polyunsaturated, and properties of fats depend on fatty acid composition. Some common saturated fatty acids in foods include palmitic, stearic, and myristic acids. One of the common monounsaturated fatty acids is oleic acid, and the most common polyunsaturated fatty acid is linoleic acid (Semma 2002). The most commonly found unsaturated fats are oleic and linoleic fatty acids, which have the ability to lower cholesterol in the blood (Kodad et al. 2004). Almond also contains polyphenols, which are good for health and are known to be protective agents against cancer and cardiovascular disease (Yang et al. 2009). Almond also contains high amounts of tocopherol and phenol (Kornsteiner et al. 2006). Almonds contain essential fatty acids that cannot be synthesized in the body and which people and animals must take from outside in order to survive. With the exception of two acids, linoleic acid (LA) (omega-6 fatty acid) and alpha-linolenic acid (ALA) (omega-3 fatty acid), the human body is capable of producing almost all the fatty acids it needs. These two fatty acids need to be included in a diet and are termed "essential fatty acids". Both of these fatty acids are needed for body growth and tissue repair and can also be used to make other fatty acids (e.g., arachidonic acid [AA] is formed from LA) (Akbulut 2018). Lipids make up 50–60% of the adult human brain, and 35% of these lipids consist of polyunsaturated fatty acids (PUFA). Fatty acids are necessary in the human diet for normal brain development and to protect brain function. Essential fatty acids and their derivatives form structural parts of the brain tissue and are necessary for biological processes. For the formation of myelin, which is a crucial process in the development of the human brain, the synthesis of essential fatty acids is highly important. PUFAs play a structurally and functionally active role in the motor development of the nervous system as well as in cognitive, emotional, and behavioral development. The two PUFAs, α-linolenic acid (ALA, 18:3 n-3) and linoleic acid (LA, 18:2 n-6), are essential for body functioning especially in infancy and old age. Oleic acid, which is a monounsaturated fatty acid (MUFA), participates in the formation of the myelin sheath and provides a protective effect against age-related changes in cognitive function. Conjured linoleic acid (CLA) has positive effects on neurological disorders (Karadag and Basalan 2014). Targets of almond breeding vary from country to country. An almond breeding program aims to obtain almond varieties showing characteristics that include: strong development of tree, short juvenile stage, late flowering habit, self-compatibility, abundant and stable yields every year, uniform fruit at harvest, easy harvesting, non-shedding with the effect of wind, easy husk removal, lack of double and twin almonds, high kernel percentage, and high quality of almonds having high unsaturated fatty acid content. In addition, new varieties should be resistant to abiotic stress factors, various diseases, and pests. Due to the beneficial oil contents, almond has been studied for its oil content in many breeding studies. The effect of almonds as part of a low saturated fat, low cholesterol, high-fiber diet was studied in 26 adults (13 men, 13 women). The baseline diet was modified in a similar way for all subjects by limiting meat, fatty fish, high-fat milk products, eggs, and saturated fat. Grains, beans, vegetables, fruit, and low-fat milk products formed the basis of the diet. During the almond diet period, raw almonds (100 mg/day) were supplied as 34 g/day of monounsaturated fatty acid (MUFA), 12 g/day of polyunsaturated fatty acid, and 6 g/day of saturated fatty acid. Almond oil was the only oil allowed for food preparation. There was a rapid and sustained reduction in low-density lipoprotein cholesterol without changes in high-density lipoprotein cholesterol. This was reflected in a total plasma cholesterol decrease from (means ± SEM) 235 ± 5.0 at baseline to 215 ± 5.0 at 3 weeks, and to 214 ± 5.0 mg/dl at 9 weeks (p less than 0.001). When the consumption of nuts high in MUFA content increases the fat content of the diet, a reduction rather than an elevation in plasma cholesterol needs to be expected, possibly due to the MUFA content of these nuts (Spiller et al. 1992). The nutritional properties of Indian almonds (*Prunus amygdalus*) were examined by Agunbidae and Olanlokun (2006), with the authors reporting that almonds contain 97.70% dry matter, 11.52 ± 0.10% crude protein, 6.76 ± 0.72% ash, 5.09 ± 0.84% crude fiber, 21.76 ± 1.20% fat, and 54.87 ± 2.80% carbohydrate. It was found that the composition of dry matter included 0.25% phytin, 0.07% fittin phosphorus, 0.04% cyanide, and 1.82% tannin. Mineral content is 0.19% phosphorus, 0.17% potassium, 0.25% magnesium, 245.65 ppm sodium, 845.45 ppm calcium, 92.12 ppm zinc, 70.62 ppm iron, and 9.21 ppm copper. The work showed that Indian almonds

contained a significant amount of fat, protein, fiber, and minerals. Samples of eight almond (*Prunus dulcis* L.) cultivars from 12 different Californian counties were collected during crop years 2004–2005 and 2005–2006 and extracted with petroleum ether. The extracts were subjected to gas chromatography mass spectrometry (GC-MS) analyses to determine the fatty acid composition of soluble lipids. Results indicated that palmitic (C16:0), oleic (C18:1), linoleic (C18:2), and α-linolenic (C18:3) acid accounted for 5.07–6.78%, 57.54–73.94%, 19.32–35.18%, and 0.04–0.10%, respectively, of the total lipids. Oleic and linoleic acid were inversely correlated (r = –0.99, $P = 0.05$) and together accounted for 91.16–94.29% of total soluble lipids. Statistically, fatty acid composition was significantly affected by cultivar and location (Sathe et al. 2008). In another study, Li et al. (2011) reported that almond consumption plays an important role against obesity, hyperlipidemia, hypertension, and hyperglycemia. The same authors hypothesized that 12-week clinical trials would show that almond consumption improves glycemic control and reduces the risk of type 2 diabetes and cardiovascular disease in 20 Chinese patients (nine males, 11 females, 58 years; body mass index, 26 kg/m^2). Daily consumption of 60 g almond increased fiber, magnesium, polyunsaturated fatty acid, monounsaturated fatty acid, and vitamin E nutrient intake. As a result of the study, it has been reported that dietary almond could be beneficial to control obesity, glycemic index, and fat profile, thereby significantly reducing the risk of cardiovascular disease in type 2 diabetes mellitus. Afghanistan is the fourth largest producer of almonds worldwide, producing 78 domestic and six imported varieties. However, to date, no comprehensive data are available on the nutritional profile of indigenous varieties. Therefore, tocopherol content and fatty acid composition of 20 selected almond varieties of Afghanistan were analyzed. Variability ranges for the studied nutrients were similar to other countries that grow almond, with 47.8–66.1% total almonds (fresh weight basis), 62.54–81.57% total lipids, and 139.1–355.0 µg/g α-tocopherol. The highest total fat contents were recorded in 'Belabai' and 'Sattarbai', the highest oleic acid content was recorded in 'Khairodini', while the highest α-tocopherol contents were recorded in 'Khairodini-161', 'Samangan', and 'Belabai' ($p < 0.05$). Considering an average of 300 µg α-tocopherol in Afghan almonds, daily consumption of 50 g of almonds was sufficient to meet α-tocopherol needs (15 mg/day). In addition, nutrient-rich varieties can be used in almond breeding programs focused on improving almond oil composition and nutrient content (Zamany et al. 2017).

The aim of this study was to characterize some of the chemical properties and fatty acid compositions of almond F1 populations obtained from 'Gulcan 2' × 'Lauranne' and 'Guara' × 'Nurlu' crosses.

Materials and Methods

Study Area and Plant Material

This research was carried out at the Gaziantep Pistachio Research Institute, which is located in south-southeastern Anatolia, Turkey, in 2015 and 2016. Summers are warm and dry, while winters are cold and rainy. Precipitation follows the Mediterranean winter rain regime. A total of 61% of the lands of Gaziantep and its districts are slightly or heavily textured soils. Soils composed of small particles such as clay have high water-holding capacity as well as low permeability and aeration capacity. Soil cultivation is difficult due to its sticky properties. Fatty acid profiles of late-flowering almond genotypes obtained from 'Gulcan 2' × 'Lauranne' and 'Guara' × 'Nurlu' crosses were examined. In this study, nuts of 77 F1 almond genotypes obtained from the hybridization of 'Gulcan 2' and 'Lauranne' almond varieties, 89 F1 almond genotypes obtained from the crosses of 'Guara' and 'Nurlu' almond varieties, and four parents of the crosses were used as experimental material. The population obtained by crossing (seedlings) and no rootstock was used.

Total Fat and Fatty Acids Analysis

In almond fruits, fat extraction and fatty acid analyses were performed according to Blight and Dyer (1959). Fatty acid methyl esters were analyzed according to the method described by Ichihara et al. (1996), modified using borontrifluoride/methanol (AOAC 1990). Total lipid and fatty acids analysis was performed with three replicates and at least 10 fruits per replica for each genotype and their parents. Fatty acid analysis was performed on a GC Clarous 500 instrument (Perkin-Elmer, Shelton, CT, USA) using a flame ionization detector and acid silicide salt tube SGE (SGE Analytical Science, Ringwood, NJ, USA) (30 m 0.32 mm ID 0.25 lm BP20 0.25 UM, USA). The injector and detector temperatures were first set to 220 °C and then to 280 °C, respectively. In the meantime, the oven temperature was kept at 140 °C for 5 min and then increased by 4 °C every 1 min to 200 °C and from 200 °C to 220 °C every 1 min. The sample size was checked at 1 ml and the carrier gas at 16 ps. The reagent was used in a 1:100 ratio. A mixture of methyl esters of 37 fatty acids (Sigma-Aldrich Chemicals 189-19), including trans fatty acids, starting from butyric acid (C 4:0) to nervonic acid (C 24:1), was used as standard in the diagnosis of fatty acids. Methyl esters were identified by comparison of the mixture based on their arrival times, and the results are given in percent (%).

Statistical Analysis

In the obtained data, the mean and standard deviation values were calculated for the statistical analysis of measured criteria. According to the results of this evaluation, histogram graphs of the genotypes in both populations are given. Evaluations were made by considering the averages of the 2-year data.

Results and Discussion

Fat and Fatty Acids Composition

The distribution of oleic acid content of the 'Gulcan 2' × 'Lauranne' F1 population is given as a percentage in Fig. 1. Oleic acid content of the population varied between 65.793 and 81.146%. As shown in Fig. 1, oleic acid content of 30 genotypes in the 'Gulcan 2' × 'Lauranne' F1 population was determined to be between 71.793 and 74.793%. It was observed that seven genotypes were placed at the lowest distribution and one genotype placed at the highest distribution.

The histogram of the average oleic acid values of the F1 population of 'Guara' × 'Nurlu' is given in Fig. 2. In terms of this feature, the population is divided into six different groups. It was determined that there were two genotypes in the group with the highest distribution (79.032–81.532%) and 13 genotypes in the group with the lowest distribution (66.532–69.032%).

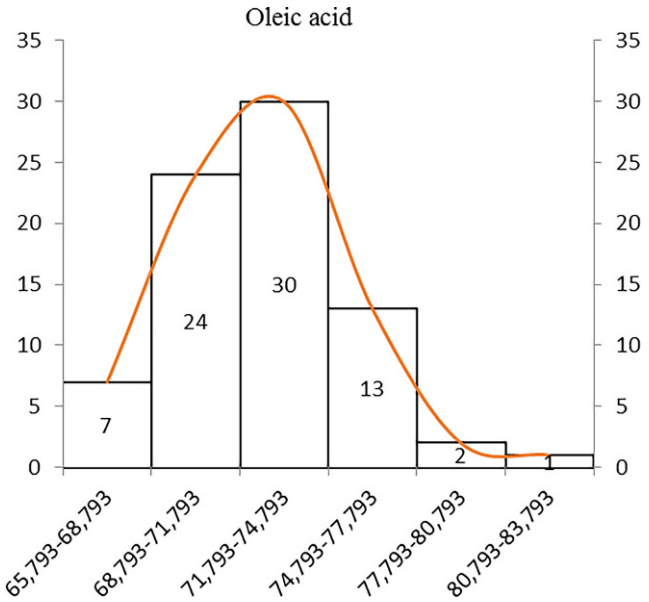


Fig. 1 . Distribution of average oleic acid content of the 'Gulcan 2' × 'Lauranne' F1 population (2015–2016) (%). (*X-axis* Oleic acid value ranges; *Y-axis* Population distribution number)

The histogram of the average linoleic acid values of the F1 population of 'Gulcan 2' × 'Lauranne' is given in Fig. 3. It was determined that there were five genotypes in the group with the highest distribution (21.032–23.332%) and one genotype in the group with the lowest distribution (9.532–11.832%). Linoleic acid content of the majority of

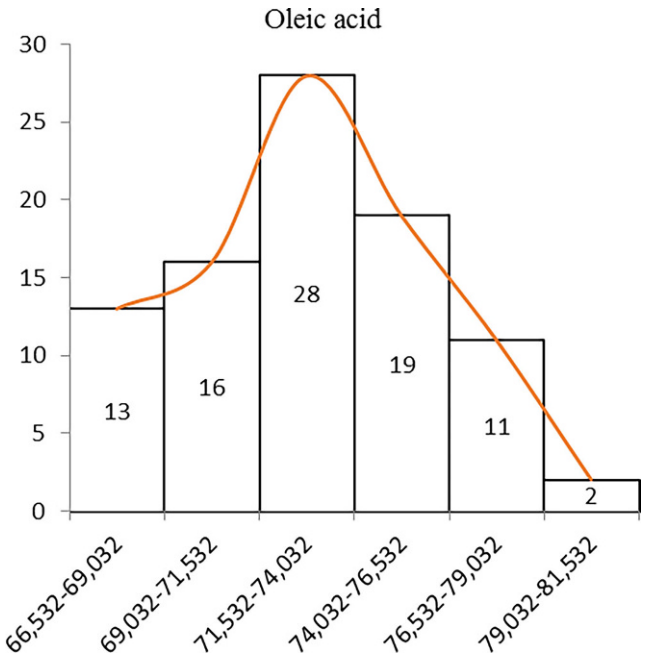


Fig. 2 Distribution of average oleic acid content of the 'Guara' × 'Nurlu' 'F1 population (2015–2016) (%). (*X-axis* Oleic acid value ranges; *Y-axis* Population distribution number)

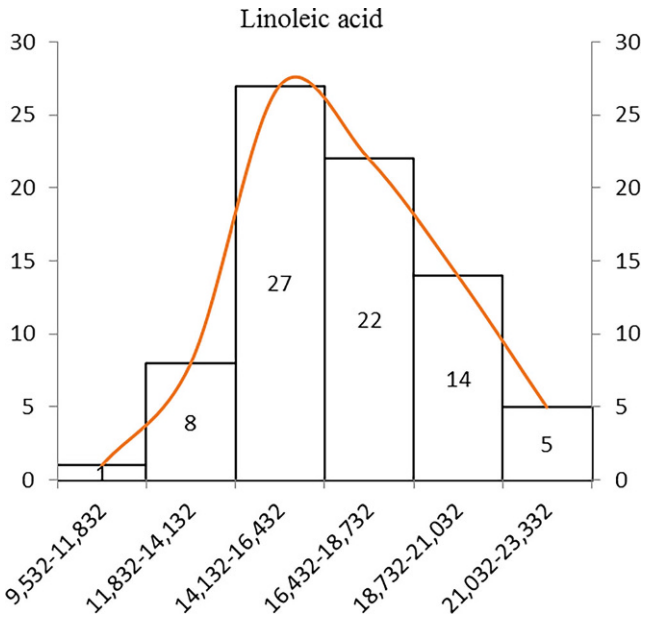


Fig. 3 Distribution of average linoleic acid content of the 'Gulcan 2' × 'Lauranne' F1 population (2015–2016) (%). (*X-axis* Linoleic acid value ranges; *Y-axis* Population distribution number)

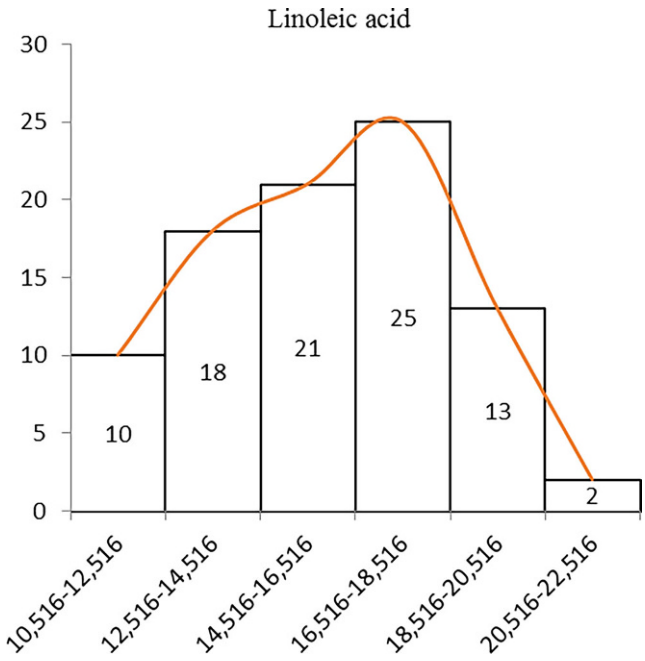


Fig. 4 Distribution of average linoleic acid content of the 'Guara' × 'Nurlu' F1 population (2015–2016) (%). (*X-axis* Linoleic acid value ranges; *Y-axis* Population distribution number)

genotypes (a total of 49 genotypes) was found to be between 14.132 and 16.432%.

Figure 4 gives the distribution of linoleic acid content of the 'Guara' × 'Nurlu' F1 population. Linoleic acid content of most of the genotypes was between 16.516% and 18.516%. Only two genotypes were included in the highest (27.26–29.26%) group in terms of linoleic acid content.

The average palmitic acid content distribution of the 'Gulcan 2' × 'Lauranne' F1 population is given in Fig. 5. Most of the genotypes were placed at between 5.746% and 6.346%. The highest distribution was determined in 44 genotypes. There was only one genotype with the lowest palmitic acid content (4.546–5.146%); at the same time, one genotype was found to have the highest range, which was between 7.546 and 8.146%.

The average palmitic acid content of the F1 genotypes obtained from 'Guara' × 'Nurlu' is given in Fig. 6. It was determined that the highest distribution ranged between 6.349 and 6.649%, consisting of 24 genotypes. It was found that there were a total of four genotypes with the lowest palmitic acid content placed in the lowest range and a total of three genotypes placed in the highest range.

The average stearic acid content distribution of the 'Gulcan 2' × 'Lauranne' F1 population is given in Fig. 7. Most of the genotypes ranged between 2.055% and 2.655%. The highest number of genotypes was recorded as 41 in the 2.055–2.655%. It was determined that there were two genotypes in the group with the lowest distribution (0.855–1.455%) and one genotype in the group with the highest distribution (3.855–4.455%).

Figure 8 gives the distribution of stearic acid content of the 'Guara' × 'Nurlu' F1 population. Stearic acid content of most of the genotypes was between 2.47% and 3.17%. The highest number of genotypes was 47 in the 2.47–3.17%

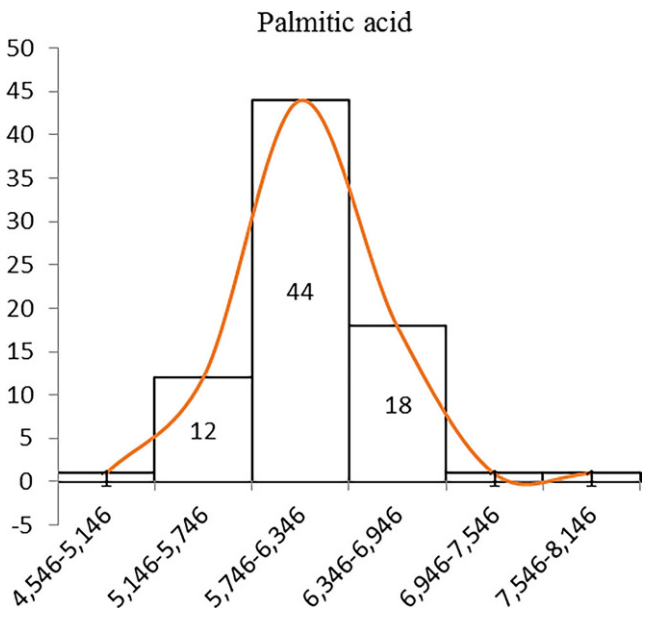


Fig. 5 Distribution of average palmitic acid content of the 'Gulcan 2' × 'Lauranne' F1 population (2015–2016) (%). (*X-axis* Palmitic acid value ranges; *Y-axis* Population distribution number)

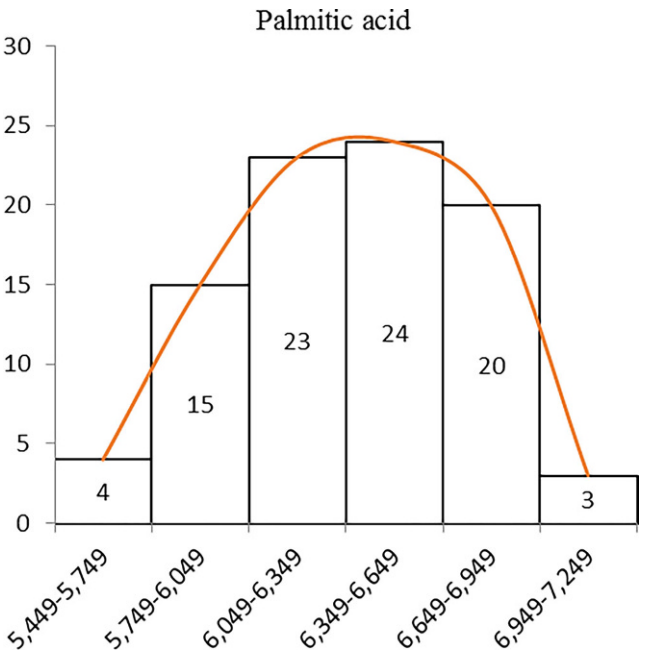


Fig. 6 Distribution of average palmitic acid content of the 'Guara' × 'Nurlu' F1 population (2015–2016), (%). (*X-axis* Palmitic acid value ranges; *Y-axis* Population distribution number)

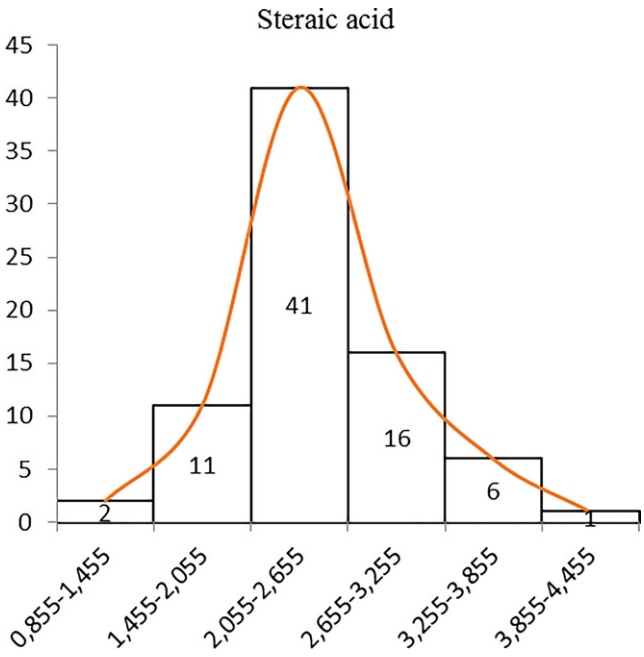


Fig. 7 Distribution of average stearic acid content of the 'Gulcan 2' × 'Lauranne' F1 population (2015–2016) (%). (*X-axis*: Stearic acid value ranges; *Y-axis*: Population distribution number)

group. Only one genotype was included in the highest group (5.27–5.97%).

The average arachidic acid content of the 'Gulcan 2' × 'Lauranne' F1 population is given in Fig. 9. It was determined that the highest numbers of genotypes was 27 ranged between 2.311–3.011%. According to this distribution, 19 genotypes had the lowest arachidic acid content (0.911–1.611%) and four genotypes had the highest content (4.411–5.111%).

The average arachidic acid content distribution of the 'Guara' × 'Nurlu' F1 population is given in Fig. 10. The genotypes had different ranges of arachidic acid, and the group that had the highest number of genotypes (40) ranged between 1.200% and 2.400%. It was determined that there were 10 genotypes in the group of lowest distribution (0.000–1.200%) and one genotype in the group of highest distribution (6.000–7.200%).

The average fatty acid composition of the 'Gulcan 2' × 'Lauranne' F1 population was as follows: The genotypes that had higher oleic acid content were 1 (81.146), 134 (79.805), 39 (78.365), 115 (77.295), 138 (76.917), 191 (76.888), 2 (76.541), 196 (76.302), 13 (75.998), 27 (75.732), and 195 (75.683). The genotypes that had higher linoleic acid content were 199 (22.014), 180 (21.878), 150 (21.864), 179 (21.147), 104 (21.037), 21 (20.806), and 176 (20.740). The genotypes that had higher palmitic acid content were 28 (7.648), 102 (7.182), 176 (6.935), 180 (6.851), 187 (6.731), 179 (6.704), 100 (6.698), and 150 (6.685). The genotypes that had higher stearic acid content were 182 (4.048), 140 (3.807), 186 (3.656), 175 (3.616), 29 (3.533), 57 (3.412), and 26 (3.289). The genotypes that had higher arachidic acid content were 103 (5.028), 165 (4.834), 125 (4.594), 177 (4.558), 29 (4.136), 175 (3.971), and 197 (3.885).

When the average fatty acid composition of the 'Guara' × 'Nurlu' F1 hybrid population was examined, the genotypes

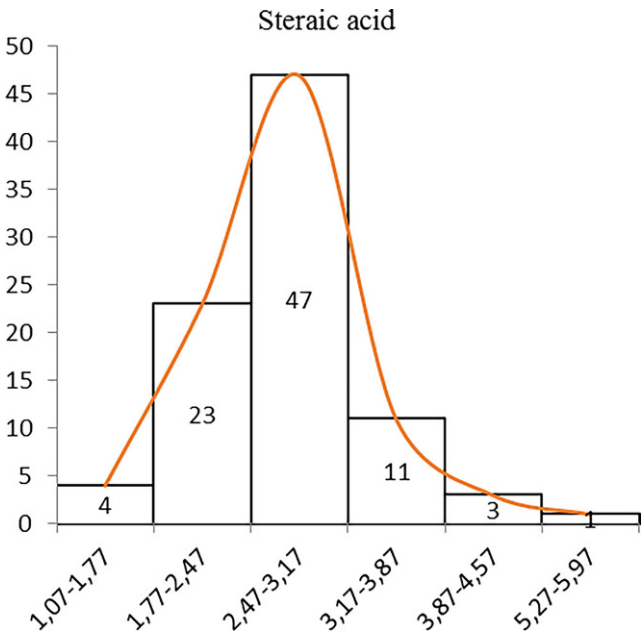


Fig. 8 Distribution of average stearic acid content of the 'Guara' × 'Nurlu' F1 population (2015–2016) (%). (*X-axis* Stearic acid value ranges; *Y-axis* Population distribution number)

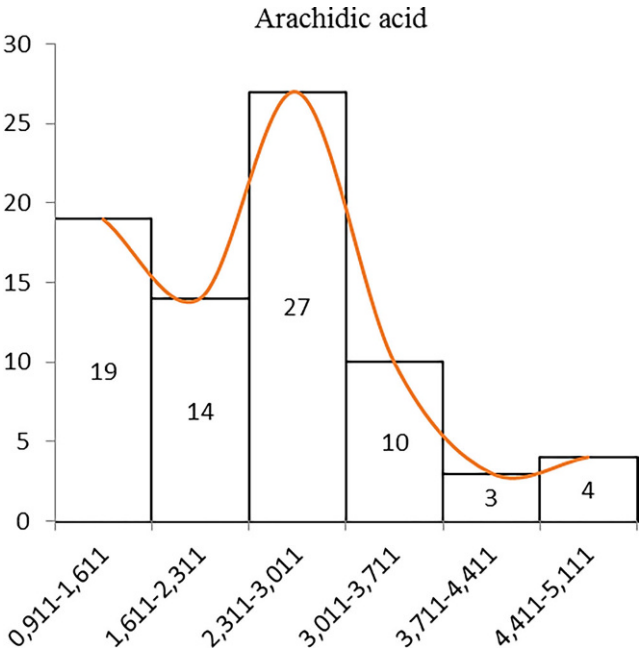


Fig. 9 Distribution of average arachidic acid content of the 'Gulcan 2' × 'Lauranne' F1 population (2015–2016) (%). (*X-axis* Arachidic acid value ranges; *Y-axis* Population distribution number)

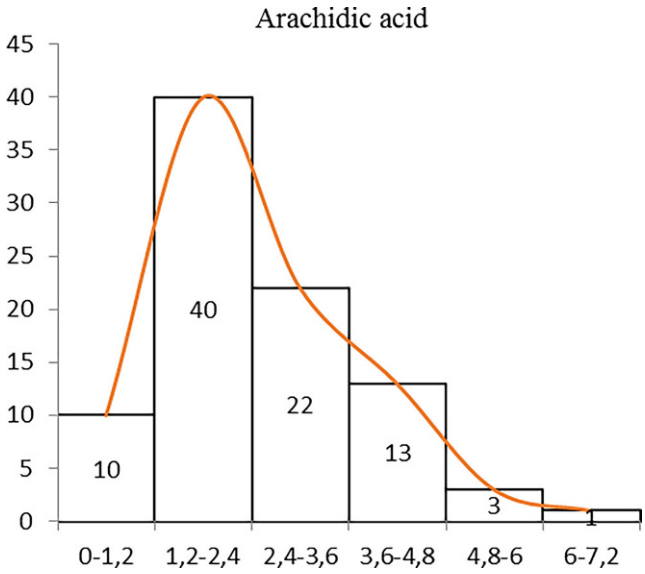


Fig. 10 Distribution of average arachidic acid content of the 'Guara' × 'Nurlu' F1 population (2015–2016) (%). (*X-axis* Arachidic acid value ranges; *Y-axis* Population distribution number)

that had the highest oleic acid content were 218 (81.3709), 301 (79.624), 256 (78.926), 253 (78.633), 254 (78.329), 304 (78.165), 269 (77.406), 358 (76.962), 343 (76.926), 239 (76.821), 360 (76.795), and 320 (76.711). The genotypes that had the highest linoleic acid content were 263 (22.310), 203 (22.093), 352 (20.434), 356 (20.196), 293 (20.152), 327 (20.131), 261 (20.070), 204 (20.036), 201 (19.845), 311 (19.787), 250 (19.725), and 326 (19.607). The genotypes that had the highest palmitic acid content were 290 (7.249), 203 (7.158), 258 (6.960), 352 (6.948), 261 (6.935), 229 (6.932), 204 (6.926), 293 (6.905), 284 (6.884), 260 (6.866), 356 (6.865), and 218 (6.850). The genotypes that had the highest stearic acid content were 201 (5.557), 302 (4.503), 352 (4.011), 351 (3.883), 203 (3.444), 356 (3.407), 243 (3.371), 293 (3.368), 280 (3.344), and 248 (3.340), The genotypes that had the highest arachidic acid content were 280 (6.836), 313 (5.950), 288 (5.600), 273 (5.370), 310 (4.504), 328 (4.455), 324 (4.412), and 285 (4.341).

In almond studies conducted on fatty acid content, Agunbidae and Olanlokun (2006) reported oleic acid fat content to be 65%. Kodad et al. (2004) reported the rate of oleic acid to be 66.8–76.2% and the linoleic acid ratio to be 15.1–24.3% in almond. Kafkas et al. (1995) reported palmitic acid content to be 5.76–7.86% in Pozanti, 5.45–6.59% in Sanliurfa, while stearic acid content was 1.14–3.04% in Pozanti and 1.42–2.45% in Sanliurfa; oleic acid content was 63.01–75% in Pozanti and 70.73–77.78 in Sanliurfa, while linoleic acid content was 15.53–45% in Pozanti and 13.63–20.57% in Sanliurfa. Gulsoy and Balta (2014) reported that the highest and lowest oleic acid content in the almond genotypes was 67.53% (AYD-59) and 77.97% (AYD-151); linoleic acid content was 13.07% (AYD-123) and 22.32% (AYD-59); palmitic acid content was 6.06% (AYD-123) and 7.46% (AYD-137); stearic acid content was 1.29% (AYD-73) and 2.16% (AYD-61); the ratio of palmitoleic acid was 0.13% (AYD-151) and 0.67% (AYD-137), and the ratio of myristic acid was 0.02% (AYD-73) and 0.27% (AYD-61), respectively. The ratio of oleic, linoleic, palmitic, stearic, palmitoleic, and myristic acid for 'Texas' cultivar was 69.15%, 20.47%, 7.37%, 2.13%, 0.19%, and 0.03%, respectively; and for 'Ferragnes' it was 73.54%, 16.46%, 6.58%, 1.94%, 0.42%, and 0.03%, respectively. Yildirim et al. (2016) reported that the highest oleic acid content was 83.35% in 2008 and 72.74% in 2009 for 'Glorieta' cultivar; the highest linoleic acid content was 26.08% in 2008 for 'Picantili' cultivar and 30.01% in 2009 for 'Sonora' cultivar. The same study indicated that 'Yaltinski' had the highest rate of palmitic acid in both years (7.76% in 2008, 10.11% in 2009). Zamany et al. (2017) reported total lipids in almond consisted of 62.54–81.57% oleic acid. Matthaus et al. (2018) found that the oleic acid content of almond oils was between 71.98% (1.11) and 78.68% (5.11). It was concluded that these findings obtained in previous years are similar to the results of the present research in terms of fatty acid profiles in almond. Although there are differences, it can be stated that these differences could be due to variety, ecology, and environmental conditions.

In a study to determine some chemical properties and fatty acid contents of eight local varieties and two standard almond varieties ('Texas' and 'Ferragnes') in the Yenipazar, Bozdogan, and Karacasu districts of Aydin province, Turkey, protein ratio was the lowest at 25.7% for the 'AYD-73' genotype and highest at 32.9% for 'AYD-181'; fat ratio was the lowest in 'AYD-66' at 48.1% and highest in 'AYD-137' at 63.1%. For 'Texas' and 'Ferragnes' varieties, the fat content was 49.8% and 54.7% and the protein content 33.1% and 22.8%, respectively. The ratio of oleic acid of almond genotypes ranged between 67.53% (AYD-59) and 77.97% (AYD-151); linoleic acid content was 13.07% (AYD-123)–22.32% (AYD-59); palmitic acid content was 6.06% (AYD-123)–7.46% (AYD-137); stearic acid content was 1.29% (AYD-73)–2.16% (AYD-61); palmitoleic acid ratio ranged from 0.13% (AYD-151) to 0.67% (AYD-137); and myristic acid ratio ranged from 0.02% (AYD-73) to 0.27% (AYD-61). The ratio of oleic, linoleic, palmitic, stearic, palmitoleic, and myristic acid in 'Texas' was 69.15%, 20.47%, 7.37%, 2.13%, 0.19%, and 0.03%, respectively; and in 'Ferragnes', 73.54%, 16.46%, 6.58%, 1.94%, 0.42%, and 0.03%, respectively. A total of 15 almond cultivars ('Cristomorto', 'Dr Largueta', 'Ferraduel', 'Ferragnes', 'Ferrastar', 'Glorieta', 'Lauranne', 'Masbovera', 'Nonpareil', 'Picantili', 'Sonora', 'Suparnova', 'Texas', 'Tuono', and 'Yaltinski') were used to determine the total

oil content and fatty acid composition. Total oil content of all cultivars except for 'Ferrastar' showed significant variations between the years ($p < 0.05$). The total fat content changed from 50.90% ('Picantili') to 62.01% ('Supernova') in 2008 and from 52.44% ('Lauranne') to 63.18% ('Cristomorto') in 2009. For unsaturated fatty acids, oleic and linoleic acid were determined as highest, while palmitic acid was the highest in terms of saturated fatty acids. The highest amount of oleic acid was obtained from 'Glorieta' almond variety in 2008 (83.35%) and 2009 (72.74%). Linoleic acid content was 26.08% in 'Picantili' in 2008 and 30.01% in 'Yaltinski' in 2009. 'Sonora' had the highest amount of palmitic acid (7.76% in 2008, 10.11% in 2009) in both years. The average unsaturated fatty acid (UFA) and saturated fatty acid (SFA) ratio was 11.73% in 2008 and 7.59% in 2009. Researchers determined palmitic acid, palmitoleic acid, stearic acid, oleic acid, and arachidic acids in almonds (Yildirim et al. 2016).

Conclusions

Almond (*Amygdalus communis* L.) is a type of hard-shelled fruit species that is very important in terms of its positive effects on human health and the nutrients it contains. It is important especially in terms of various oils and rich nutritional content. Almond, which contains high amounts of monounsaturated fatty acids, is similar to olive oil, which is recommended for lowering bad cholesterol and protecting against heart disease. Adequate fatty acid intake is necessary for human health, normal brain development, and the preservation of brain functions. When the 'Gulcan 2' × 'Lauranne' F1 hybrid genotypes were ranked in terms of their content of average fatty acids, the following results were observed for oleic acid, linoleic acid, palmitic acid, stearic acid, and arachidic acid: The oleic acid content of genotypes was between 65.793 and 81.146%; linoleic acid content was between 9.532 and 22.014%; palmitic acid content was between 4.546 and 7.648%; stearic acid contents were between 0.855 and 4.048%; while arachidic acid contents ranged from 0.911% to 6.766%. When looking at the average fatty acid composition of 'Guara' × 'Nurlu' F1 hybrid genotypes, the highest oil contents were in oleic acid (66.532–81.370%). Linoleic acid contents were between 10.516 and 22.310%; palmitic acid contents were between 5.449 and 7.249%; stearic acid contents were between 1.070 and 5.557%. It was observed that arachidic acid contents ranged from 0% to 6.836%. In addition to the effects of fatty acids on cognitive development, their importance in terms of human health has been indicated by various studies, and it is important that the fatty acids that our body needs are adequate and balanced. The need to pay attention to fatty acids intake should not be overlooked. Regarding differences in oil content, some almond genotypes should be prioritized for oil extraction. Breeding programmes focused on the improvement of specific characteristics of almond oils should focus on chemical parameters mainly determined by the genotype.

Conflict of interest K. Ercik, S. Comlekcioglu, N. E. Kafkas, S. Ercisli, and H. I. Sagbas declare that they have no competing interests.

References

Abanoz YY, Okcu Z (2022) Biochemical content of cherry laurel (Prunus laurocerasus L.) fruits with edible coatings based on caseinat, Semperfresh and lecithin. Turk J Agric For 46(6):908–918

Agunbidae SO, Olanlokun JO (2006) Evaluation of some nutritional characteristics of indian almond (Prunus amygdalus). Nut 5(4):316–318

Akbulut G (2018) Omega (n)-3 alpha linolenic and omega (n)-6 linoleic essential fatty acids and health. J Public Health 4(1):68–72

Amarowicz R, Troszynska A, Shadidi F (2005) Antioxidant activity of almond seed exract and its fractions. J Food Lipids 12:344–358

Anonymous (2007) Nuts, almonds, USDA national nutrient database for standard reference, release 20. http://www.nal.usda.gov/fnic/foodcomp/cgi-bin/list_nut_edit.pl. Accessed 27 Aug 2008

AOAC (1990) Official methods of analysis of the AOAC, 15th edn. Association of official analytical chemists, Arlington (Methods 932.06, 925.09, 985.29, 923.03)

Ari E, Mutlu N, Soylu I, Bedir H, Genc I, Deniz IG (2022) Morphological and agronomic characterization of Turkish Vaccaria hispanica (Mill.) Rauschert populations. Turk J Agric For 46(6):933–946

Blight EG, Dyer WJ (1959) A Rapid method of total lipid extraction and purification. Can J Biochem Physiol 37(8):911–917

Celik F, Balta MF, Ercisli S, Gundogdu M, Karakaya O, Yavic A (2019) Tocopherol contents of almond genetic resources from eastern and western Turkey. Erwerbs-Obstbau 61(3):257–262

Ercisli S, Esitken A, Turkkal C, Orhan E (2005) The allelopathic effects of juglone and walnut leaf extracts on yield, growth, chemical and PNE composition of strawberry cv. Fern. Plant Soil Environ 51(6):283–387

Erturk Y, Ercisli S, Cakmakci R (2012) Yield and growth response of strawberry to plant growth-promoting rhizobacteria inoculation. J Plant Nutr 35(6):817–826

FAO (2020) Food and agriculture organization crop statistics. http://www.fao.org/faostat/en/#data/QC. Accessed: 22.10.2021

Gulsoy E, Balta F (2014) Protein, fat and fatty acid composition of selected almond (Prunus amygdalus Batch) genotypes from Yenipazar, Bozdoğan and Karacasu districts of Aydin province. Iğdır Univ J Inst Sci Tech 4(1):9–14

Ichihara K, Shibahara A, Yamamoto K, Nakayama T (1996) An improved method for rapid analysis of the fatty acids of glycerolipids. Lipids 31(5):535–539

Ikinci A, Bolat I, Ercisli S, Kodad O (2014) Influence of rootstocks on growth, yield, fruit quality and leaf mineral element contents of pear cv. 'Santa Maria' in semi-arid conditions. Biol Res 47:71

Imani A, Amani G, Shamili M, Mousavi A, Hamed R, Rasouli M, Martínez-García PJ (2021) Diversity and broad sense heritability of phenotypic characteristic in almond cultivars and genotypes. Int J Hortic Sci Technol 8(3):281–289

Kafkas S, Agar IT, Kaska N, Tatar Y (1995) Lipid characterization of some local and foreign almond cultivars (Amygdalus communis L.) grown in Pozantı-Kamışlı valley and Şanlıurfa-Koruklu. In:

Proceedings of 2nd National Horticulture Conference, vol I, pp 398–402

Karadag MG, Basalan CC (2014) The effect of different fatty acids on cognitive development: A current overview. J Neur 9(3):105–112

Kodad O, Socias i Company R (2004) Fatty acid composition as evaluation criterion for kernel quality in almond breeding. Acta Hortic 663:301–304

Kornsteiner M, Wagner KH, Elmadfa I (2006) Tocopherols and total phenolics in 10 different nut types. Food Chem 98(2):381–387

Li S-C, Liu Y-H, Liu J-F, Chang W-H, Chen C-M, Chen C-Y (2011) Almond consumption improved glycemic control and lipid profiles in patients with type 2 diabetes mellitus. Metabolism 60(4):474–479

Martinez-Gomez P, Sanchez-Perez R, Dicenta F, Howad W, Arus P, Gradziel TH (2007) Fruits and nuts. Chapter: 11. Genome mapping and moleculer breeding in plants, vol 4

Matthaus B, Ozcan MM, Al Juhaimi F, Adiamo OQ, Alsawmahi ON, Ghafoor K, Babiker EE (2018) Effect of the harvest time on oil yield, fatty acid, tocopherol and sterol contents of developing almond and walnut kernels. J Oleo Sci 67(1):39–45

Nadeem MA, Habyarimana E, Ciftci V, Nawaz MA, Karakoy T, Comertpay G, Shahid MQ, Hatipoglu R, Yeken MZ, Ali F, Ercisli S, Chung G, Baloch FS (2018) Characterization of genetic diversity in Turkish common bean gene pool using phenotypic and whole-genome DArTseq-generated silicoDArT marker information. PLoS ONE 13(10):e205363

Sathe SK, Seeram NP, Kshirsagar HH, Heber D, Lapsley KA (2008) Fatty acid composition of California grown almonds. J Food Sci 73(9):C607–C614

Semma M (2002) Trans fatty acids: Properties, benefits and risks. J Health Sci 48(1):7–13

Spiller GA, Jenkins DJ, Cragen LN, Gates JE, Bosello O, Berra K, Rudd C, Stevenson M, Supergo R (1992) Effect of a diet high in monounsaturated fat from almonds on plasma cholesterol and lipoproteins. J Am Coll Nutr 11(2):126–130

Taskesenlioglu MY, Ercisli S, Kupe M, Ercisli N (2022) History of grape in Anatolia and historical sustainable grape production in Erzincan agroecological conditions in Turkey. Sustainability 14:1496

Yang J, Liu RH, Halim L (2009) Antioxidant and antiproliferative of common adible nut seeds. LTW Food Sci Technol 42:1–8

Yildirim AN, Akinci-Yildirim F, San B, Sesli Y (2016) Total oil content and fatty acid profile of some almond (Amygdalus communis L.) cultivars. Pol J Food Nutr Sci 66(3):173–178

Zamany AJ, Samadi GR, Kim DH, Keum YS, Saini RK (2017) Comparative study of tocopherol contents and fatty acids composition in twenty almond cultivars of Afghanistan. J Am Oil Chem Soc 94(6):805–817

Springer Nature oder sein Lizenzgeber (z.B. eine Gesellschaft oder ein*e andere*r Vertragspartner*in) hält die ausschließlichen Nutzungsrechte an diesem Artikel kraft eines Verlagsvertrags mit dem/den Autor*in(nen) oder anderen Rechteinhaber*in(nen); die Selbstarchivierung der akzeptierten Manuskriptversion dieses Artikels durch Autor*in(nen) unterliegt ausschließlich den Bedingungen dieses Verlagsvertrags und dem geltenden Recht.