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RESEARCH PAPER

HORTICULTURAL STUDIES

Determination of Oil Content and Fatty Acid Composition of Twenty-Six Pecan Cultivars Grown in Türkiye

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Abstract

The aim of this study was to investigate the total oil content and fatty acid composition of 26 pecan cultivars oils. Significant differences were observed between the total oil contents and fatty acid composition of pecan cultivars ($P<0.05$). The oil contents of the cultivars changed between 69.35 (Comanche) and 77.08% (Curtis). The fatty acid composition of the pecan oils ranged from 56.17 to 71.55% monounsaturated fatty acids, from 20.23 to 34.78% polyunsaturated fatty acids, and 7.34 to 9.49% saturated fatty acids. The major fatty acid was oleic acid (55.91-71.27%), followed by linoleic (19.38-33.45%), palmitic (5.05-6.68%), stearic (1.97-3.42%), linolenic (0.79-1.55%), 11-Eicosenoic (0.22-0.30%) and arachidic acids (0.10-0.33%), respectively. The highest oleic acid content was found in the Choctaw cultivar. Tejas and Western cultivars showed the highest levels of linoleic acid. As a result, the data of this study may contribute to future breeding programs and the food industry regarding the selection of pecans with improved health and nutritional quality. It is suggested that pecan oil should be consumed due to its high-unsaturated fatty acid content for health benefits.

1. Introduction

Pecan [*Carya illinoinensis* (Wangenh) C. Koch] belongs to the Juglandaceae family and is native to North America. It has been cultivated in many countries including USA, Mexico, Australia, South Africa, Israel, Argentina, and Brazil (da Parto et al., 2013). The South of Turkey has very favorable climatic characteristics for the pecan cultivation. Firstly, the pecan was brought to Türkiye in 1953 as a seed from the USA. Then, adaptation studies on pecans were started in Antalya with 14 cultivars brought from Israel through FAO in 1969 (Alkan et al., 2014). Recently, pecan cultivation areas have been increased especially in the Aegean, Mediterranean, and Southeast Anatolia Regions (Apak and Akşit, 2016). Pecans contain major nutrients, such as carbohydrates, proteins, dietary fiber, and fat. In addition, they are a rich source of phenolics, phytosterols, tocopherols, and minerals (Atanasov et al., 2018; Ribeiro et al., 2020). Pecans are known to have a higher oil content than many other nuts. The amount of pecan oil varies between 65 and 75% (Wakeling et al., 2001). Pecan oil is added to salad sauces and meals due to its distinctive flavor, and is also used as an ingredient in lotions, soaps, perfumes, and massage oils in the cosmetic industry (Salvador et al., 2016). Pecan oil is one of the healthy oils because of its high content of unsaturated fatty acids (UFAs) and low amounts of saturated fatty acids (SFAs) (Rivera-Rangel et al., 2018). The fatty acid composition of pecan oil generally consists of oleic, linoleic and linolenic, palmitic, and stearic acids (Jia et al., 2019). Consumption of oils rich in UFAs is associated with positive health effects. Recent studies have shown

that the consumption of monounsaturated fatty acids (MUFAs) can lower LDL (low-density lipoprotein) cholesterol, defend against coronary heart disease, modulate blood pressure, and may have notable effects on coagulation factors, inflammation, and endothelial activation (Rajaram et al., 2001; Alonso et al., 2006). Similarly, the intake of polyunsaturated fatty acids (PUFAs) in the daily diet has beneficial effects on reducing the risk of cardiovascular and inflammatory diseases (Finley and Shahidi, 2001). Besides, PUFAs have antithrombotic and antiatherosclerotic properties and may inhibit the development of some diseases such as arterial hypertension and insulin resistance (Simopoulos, 1991; Hermansen, 2000; Manco et al., 2004). Moreover, Garman et al. (2009) reported that PUFAs exhibit protective effects against diabetic kidney diseases. The amount and composition of pecan oil can vary widely depending on the cultivar, as well as environmental and agricultural practies such as growing region and conditions, harvest year, maturity state, and the age of trees (Toro-Vazquez, 1999; Alvarez-Parrilla et al., 2018). Although there are many studies on pecan cultivars in the world, few comprehensive studies are available about the fatty acid composition of pecan cultivars in Türkiye. This study aimed to determination of the total oil content and the fatty acid composition of the oils obtaining from twenty-six pecan cultivars grown in Antalya province.

2. Material and Methods

In this study, 26 pecan cultivars (Big Z, Bradley, Burkett, Cape Fear, Cheroke, Cheyenne, Choctaw, Comanche, Curtis, Desirable, Green River, Harris Super, Hasting, Mahan, Mohawk, Mahan*Stuart, Moneymaker, Royal, Schley, Shannee, Shoshoni, Stuart, Tejas, Western, Wichita, Woodard) grown in the Kayaburnu genetic resources parcel of the Batı Akdeniz Agricultural Research Institute in Antalya were used as materials. All cultivars were collected from mature trees (30 years old) in the 2018 and 2019 harvesting seasons (20 November-1 December). Twenty fruits per cultivar were used for each experiment.

2.1. Oil extraction

The fruits were shelled, and the edible parts were dried in a hot air oven at 70°C until reaching final dry matter content about 96% w.b. (weight basis). Dried samples were ground with a laboratory type miller (Retsch Grindomix GM200, Retsch GmbH & Haan, Germany) before oil extraction. Then, the oils were extracted with petroleum ether in a soxhlet fat extractor (E-500, Buchi, Flawil, Switzerland) for 3 hours.

The total oil content of pecan cultivars was expressed as a percentage of dry matter according to AOAC (2005).

2.2. Analysis of fatty acid composition

Firstly, fatty acid methyl esters (FAMEs) were prepared from pecan oils for the fatty acid composition analysis (Da Porto et al., 2012). Briefly, the oil samples (0.1 g) were mixed in a screw cap tube with 200 mL of methanolic potassium hydroxide (2N). Then, 2 mL of n-hexane was added. After separation of phase, the supernatant containing methyl esters was transferred into a vial for analysis.

Fatty acid methyl esters of samples were analyzed by gas chromatography (GC) system (Agilent 7890A) equipped with flame-ionization detector (FID) and mass spectrometry (Agilent 5975C). An HP Innowax capillary column (60.0 m*0.25 mm; film thickness: 0.25 µm) was used for the separation. Helium was used as a carrier gas at a flow rate of 0.8 mL min^{-1} and an average velocity was set to 19.314 cm sec^{-1}. The temperatures of the injector and detector were 250°C and 260°C, respectively. The column temperature program employed in the analysis was as follow; started from 150°C and raised to 200°C with an increment of 10°C per minute, hold at 200°C for 5 minute, then increased to 250°C with 5°C per minute increments and hold 250°C at 15 minute. The total analysis time was 35 minutes. The split ratio was 1:40 and the injection volume was 1 µL. Mass spectra were obtained by scanning in the mass range 35-450 AMU (Atomic Mass Unit) and the ionization mode used was electronic impact at 70 eV. The percentages of the fatty acid components were calculated from the integration of the peaks in FID chromatograms. The identification of the peaks was performed using WILEY7N, NIST05 and OIL ADAMS libraries of the MS (Mass Spectrometric) detector (Gölükcü et al., 2016).

2.3. Statistical analysis

The oil extractions were carried out in duplicate and the fatty acid analyses were performed in two replicates for each year. Results were expressed as mean values ± standard errors of two years. Data were subjected to analysis of variance using SAS software (Version 6.12, SAS Institute, Cary, NC, USA). The differences were determined by Duncan's Multiple Range Tests at $P<0.05$ confidential interval.

3. Results and Discussion

3.1. Oil contents of pecan cultivars

Total oil contents of pecan samples ranged from 69.35 to 77.08% (Figure 1). The highest oil content was found in Curtis (77.08%), followed by Stuart (75.67%), Green River (75.27%), Mohawk (75.23%) and Woodard (73.97%). The lowest oil content was obtained from the cultivar Comanche (69.73%).

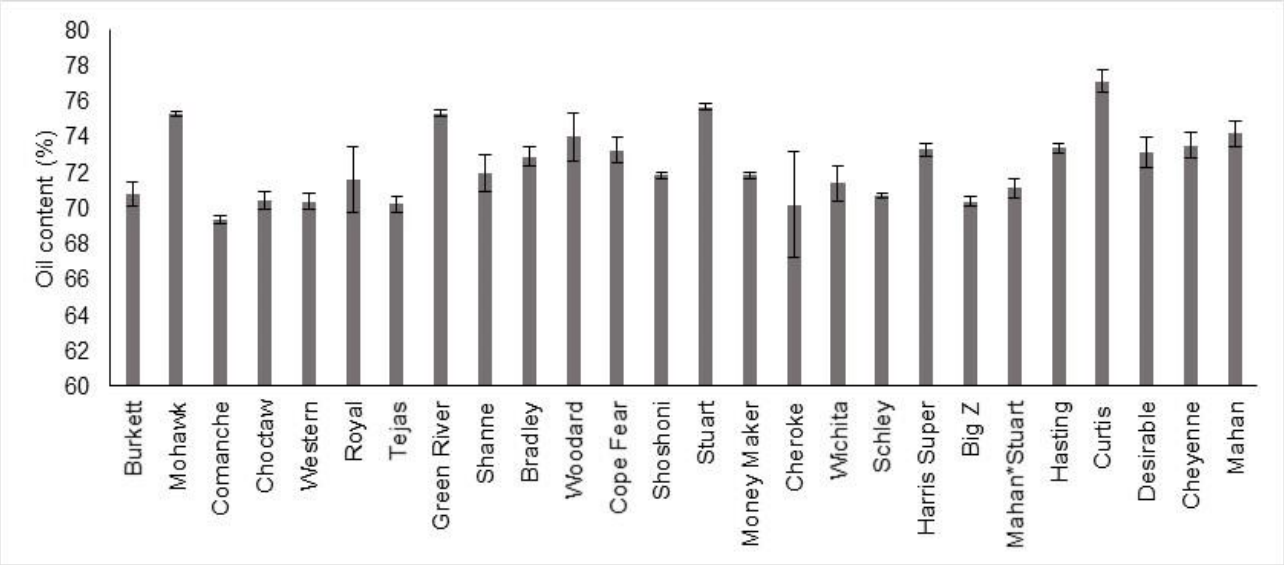

Figure 1. Total oil contents of 26 pecan cultivars.

Previously, Jia et al. (2019) reported the oil contents of fourteen pecan cultivars grown in China ranged from 70.1 to 79.7%. Oil content of desirable cultivar was reported as 66.18 % by Venkatachalam and Sathe (2006). Toro-Vazquez et al. (1999) reported total lipid contents in pecan kernels obtained from central Mexico was found between 70 and 79% on dry basis. In another study, Ribeiro et al. (2020) determined that the total lipid contents of eleven pecan cultivars varied between 52.69-69.76% grown in Brazil.

Our results are compatible with previous reports mentioned above. In addition, the pecan cultivars analyzed in the current study had a higher oil content than the other nuts (pistachios, hazelnuts, almonds, macadamias, pinenuts, walnuts, cashew nuts, Brazil nuts) reported in the literature (Yıldız et al., 1998; Amaral et al., 2006; Sathe et al., 2008; Venkatachalam and Sathe, 2006; Doğan and Akgül, 2005; Bakkalbaşı et al., 2010). The oil content and fatty acid composition of pecans can vary depending on cultivar, harvest year, growing location and condition, ripening, extraction method, soil type and climate (Wakeling et al., 2001; Villarreal-Lozoya et al., 2007; Bouali et al., 2013; Dominguez-Avila et al., 2013; Rivera-Rangel et al., 2018; Ribeiro et al., 2020).

3.2. Fatty acid composition

The UFAs and SFAs of oil from twenty-six cultivars are presented in Table 1 and Table 2, respectively. The results revealed that there are statistically significant differences in fatty acid composition among the pecan cultivars ($P<0.05$). Seven fatty acids were determined in the oils of pecans. The oils of all pecan cultivars was mainly composed of UFAs which account for 90.51-92.66% of total fatty acids (Table 1). The highest UFAs were determined in Cape Fear (92.30%), Harris Super (92.33%), Woodard (92.66%) and Shoshoni (92.57%) cultivars. Monounsaturated fatty acids were dominant over PUFAs in all pecan samples (Figure 2). The major MUFA in the cultivars was oleic acid which ranged between 55.91% (Tejas) and 71.27% (Choctaw). Oleic acid was also the predominant fatty acid detected in the analyzed pecan oils. The percentages of 11-Eicosenoic acid, another MUFA, were between 0.22% (Wichita) and 0.30% (Western and Burkett).

Polyunsaturated fatty acids contents of the cultivars changed between 20.23% and 34.78% (Figure 2). Polyunsaturated fatty acids detected in the analyzed oils of pecan cultivars were linoleic and linolenic acids. Linoleic acid was the most prevalent PUFA in the all pecan oils. Linoleic acid, also known as omega 6, is an essential fatty acid that cannot be synthesized by the animal and human organism. Therefore, it must be taken by the diet (Atanasov et al., 2018). The highest linoleic acid was found in Western (33.45%), the lowest was in Choctaw (19.38%). Linolenic acid content varied from 0.79% (Mahan*Stuart) to 1.55% (Wichita) (Table 1).

The percentages of SFAs (7.34-9.49%) were lower than the mono and polyunsaturated fatty acids (Table 2). Palmitic acid was determined to be the predominant SFA and ranged between 5.05 and 6.68%. Tejas had the highest palmitic acid content, while Bradley had the lowest palmitic acid content. In addition, stearic acid was the second SFA and changed between 1.97 and 3.42%. The contents of arachidic acid in the pecan oils varied between 0.10 and 0.33%, and that of the Curtis cultivar was significantly higher than the others ($P<0.05$).

Venkatachalam et al. (2007) found that the dominant fatty acid in 24 different pecan cultivars grown in the USA was oleic acid (52.52-74.09%), followed by linoleic (17.69-37.52%), palmitic (4.16-7.36%), stearic (1.00-3.15%), linolenic (0.65-1.64%) and arachidic acid (0.06-0.13%). Villarreal-Lozoya et al. (2007) reported that seven pecan

Table 1. Unsaturated fatty acid components (%) of 26 pecan cultivars*.

Cultivars	Linoleic acid (C:18:2)	Oleic acid (C:18:1)	Linolenic acid (C:18:3)	11- Eicosenoic acid (C:20:1)	ΣUFAs
Cheroke	30.75±4.20 ac	59.01±4.78 ej	1.35±0.12 ae	0.28±0.00 af	91.39±0.62 ad
Comanche	26.98±1.57 bg	63.26±1.66 ch	1.10±0.04 ci	0.26±0.002 cf	91.60±0.07 ae
Cape Fear	20.46±1.56 hi	70.72±1.74 ab	0.84±0.05 gi	0.28±0.004 af	92.30±0.15 a
Cheyenne	28.85±0.97 af	61.47±1.00 dj	1.01±0.004 di	0.29±0.01 ad	91.62±0.04 ae
Green River	25.32±0.27 ci	64.77±0.39 ag	1.14±0.02 bi	0.28±0.01 ae	91.51±0.11 ae
Harris Super	22.49±0.92 fi	68.73±0.95 ac	0.83±0.03 hi	0.28±0.01 af	92.33±0.08 a
Hasting	31.23±0.27 ac	58.83±0.36 fj	1.15±0.05 bh	0.25±0.008 eg	91.46±0.03 ae
Mahan*Stuart	19.90±0.54 i	69.58±0.18 ac	0.79±0.05 i	0.24±0.01 fg	90.51±0.42 f
Desirable	25.71±1.99 ch	65.04±2.14 ah	1.05±0.07 ci	0.27±0.007 af	92.07±0.35 ac
Mohawk	26.45±3.01 ch	64.15±3.46 ah	0.85±0.09 gi	0.28±0.009 ae	91.73±0.35 ad
Mahan	26.63±1.22 ci	63.05±1.35 ci	1.19±0.008 bg	0.24±0.008 fg	91.11±0.14 bf
Money Maker	25.32±0.23 ci	64.92±0.24 ag	1.06±0.01 ci	0.27±0.002 af	91.57±0.02 ae
Royal	30.09±1.39 ae	59.90±1.50 dj	1.38±0.07 ac	0.30±0.007 ab	91.67±0.07 ae
Shanne	24.14±0.93 di	66.32±0.68 ae	1.19±0.02 bg	0.29±0.009 ac	91.94±0.47 ac
Schley	23.90±1.40 ei	66.91±1.57 ad	0.91±0.09 fi	0.27±0.006 af	91.99±0.08 ac
Shoshoni	27.26±2.75 ag	63.92±3.03 bh	1.12±0.10 ci	0.27±0.01 af	92.57±0.20 a
Stuart	30.47±1.47 ad	59.27±1.98 gj	1.36±0.01 ad	0.27±0.01 af	91.37 ±0.65 ae
Tejas	33.29±2.55 ab	55.91±2.80 j	1.49±0.11 ab	0.26±0.01 df	90.95±0.16 cf
Western	33.45±1.89 a	56.18±1.83 ji	1.32±0.06 ae	0.30±0.008 a	91.25±0.13 bf
Wichita	31.47±0.94 ac	57.50±0.73 hj	1.55±0.22 a	0.22±0.002 g	90.74±0.19 ef
Woodard	29.86±0.84 ae	61.19±0.95 dj	1.32±0.07 ae	0.29±0.006 ad	92.66±0.05 a
Burkett	26.79±3.31 ch	63.63±3.59 bh	1.23±0.09 ae	0.30±0.008 a	91.95±0.21 ac
Bradley	23.88±3.69 ei	67.08±4.08 ad	1.00±0.08 ei	0.27±0.01 bf	92.23±0.33 ab
Big Z	31.74±0.69 ac	58.84±0.96 fj	1.16±0.13 bh	0.28±0.007 af	92.02±0.14 ac
Choctaw	19.38±2.06 i	71.27±2.20 a	0.85±0.06 gi	0.28±0.01 ae	91.78±0.15 ad
Curtis	22.07±0.72 gi	67.49±1.65 ae	1.33±0.38 ae	0.26±0.01 df	91.15±1.00 bf
Retention time (min)	18.923	18.156	19.973	21.591	

*Different letters within the same column show significant differences between pecan cultivars (*P<0.05*).

cultivars contained 53-75% oleic, 15-36% linoleic, 5-6% palmitic, 2-3% stearic and 1% linolenic acids. Ribeiro et al. (2020) determined 65.53–72.99% oleic acid, 16.27-22.50% linoleic acid, 5.64-6.53% palmitic acid and 2.46-4.67% stearic acid in oils from eleven pecan cultivars grown in Brazil. They also reported that the pecan cultivars were rich in UFAs. In the study done by Yılmaz et al. (2021) oleic acid and linoleic acids were determined as the major fatty acids in five pecan cultivars. The present study fatty acid results are generally consistent with these literature findings. On the other hand, Rivera-Rangel et al. (2018) reported that the predominant fatty acid in pecan varieties cultured in Chihuahua, Mexico was linoleic acid followed by oleic acid, which is different from our results. In another report, oleic acid contents (47.43-57.18%) found in pecan oils by Dominguez-Avila et al. (2013) were lower than our values. Yılmaz et al. (2021) determined linoleic acids for the Western cultivar as 29.81% which is lower than our result. Wakeling et al. (2001) determined average linolenic acid content to be %1.74 in Western Schley and Wichita pecans. This content was found to be higher compared to the values of our study. These differences can be explained by factors such as genotype, ripening, harvest year, climate, growing region, horticultural practices, oil extraction method, and soil type (Rudolph et al., 1992; Wakeling et al., 2001; Venkatachalam and Sathe, 2006; Dominguez-Avila et al., 2013; Bouali et al., 2013).

Regarding the fatty acid groups, it was revealed that the oils obtained from the pecan cultivars were rich in MUFA and PUFA and contained low levels of SFA (Figure 2). The significant variations were detected among the pecan cultivars in terms of fatty acid groups (*P<0.05*). Tejas and Western cultivars had the highest percentage of PUFAs, known as essential fatty acids, due to their high linoleic content. The highest MUFA was determined in the Choctaw cultivar with the highest oleic acid content. Also, the linoleic acid content of this cultivar had the lowest value. Several studies on pecan oil have reported an inverse relationship between oleic acid and linoleic acid contents (Domínguez-Avila et al., 2013; Ribeiro et al., 2020; Rivera-Rangel et al., 2018). This may be due to the fact that oleic acid is the biosynthetic precursor of linoleic acid (Toro-Vazquez, 1999; Domínguez-Avila et al., 2013). It is a desirable feature that oleic acid is higher than linoleic acid in edible oils since the oils rich in oleic acid have high oxidative stability (Alvarez-Parrilla et al., 2018). In this respect, pecan oil may be used in cooking applications. Many studies on fatty acids

Table 2. Saturated fatty acid components (%) of 26 pecan cultivars*.

Cultivars	Palmitic acid (C:16)	Stearic acid (C:18:0)	Arachidic acid (C:20:0)	ΣSFAs
Cheroke	6.44±0.09 ac	2.07±0.01 ef	0.10±0.002 b	8.61±0.11 cg
Comanche	5.81±0.12 ci	2.46±0.09 ce	0.13±0.006 b	8.40±0.03 di
Cape Fear	5.31±0.24 gk	2.27±0.09 cf	0.12±0.006 b	7.70±0.15 km
Cheyenne	6.18±0.03 af	2.10±0.06 ef	0.10±0.004 b	8.38±0.04 di
Green River	5.72±0.06 ej	2.65±0.13 c	0.12±0.002 b	8.49±0.06 di
Harris Super	5.08±0.11 jk	2.45±0.03 ce	0.14±0.008 b	7.67±0.08 km
Hasting	6.45±0.05 ac	1.97±0.002 f	0.12±0.00 b	8.54±0.05 ch
Mahan*Stuart	5.92±0.005 bg	3.42±0.40 a	0.15±0.01 b	9.49±0.42 a
Desirable	5.78±0.15 ci	2.03±0.03 ef	0.12±0.005 b	7.93±0.12 il
Mohawk	5.81±0.37 ci	2.34±0.01 cf	0.12±0.002 b	8.27±0.34 ej
Mahan	6.23±0.05 ae	2.55±0.10 cd	0.11±0.005 b	8.89±0.12 bd
Money Maker	5.76±0.02 di	2.55±0.02 cd	0.12±0.002 b	8.43±0.04 di
Royal	6.27±0.23 ae	1.96±0.12 f	0.10±0.004 b	8.33±0.11 dj
Shanne	5.89±0.15 bg	2.07±0.08 ef	0.10±0.004 b	8.06±0.06 fk
Schley	5.83±0.06 ch	2.07±0.009 ef	0.11±0.004 b	8.01±0.05 hk
Shoshoni	5.15±0.26 ik	2.17±0.08 df	0.11±0.004 b	7.43±0.17 lm
Stuart	6.43±0.19 ad	2.09±0.08 ef	0.11±0.002 b	8.63±0.10 cf
Tejas	6.68±0.16 a	2.26±0.05 cf	0.11±0.00 b	9,05±0,16 ac
Western	6.26±0.10 ae	2.37±0.07 cf	0.12±0.002 b	8.75±0,03 be
Wichita	6.54±0.07 ab	2.61±0.14 c	0.11±0.004 b	9.26±0.22 ab
Woodard	5.18±0.05 hk	2.04±0.02 ef	0.12±0.004 b	7.34±0.04 m
Burkett	5.35±0.56 gk	2.57±0.32 cd	0.13±0.01 b	8.05±0.23 gk
Bradley	5.05±0.35 k	2.59±0.03 cd	0.13±0.004 b	7.77±0.35 jm
Big Z	5.87±0.08 cg	2.00±0.01 f	0.11±0.002 b	7.98±0.10 hl
Choctaw	5.54±0.24 fk	2.56±0.13 cd	0.12±0.006 b	8.22±0.14 ek
Curtis	5.49±0.08 gk	3.03±0.07 b	0.33±0.21 a	8.85±0.08 bd
Retention time (min)	13.792	17.591	21.129	

*Different letters within the same column show significant differences between pecan cultivars (P<0.05).

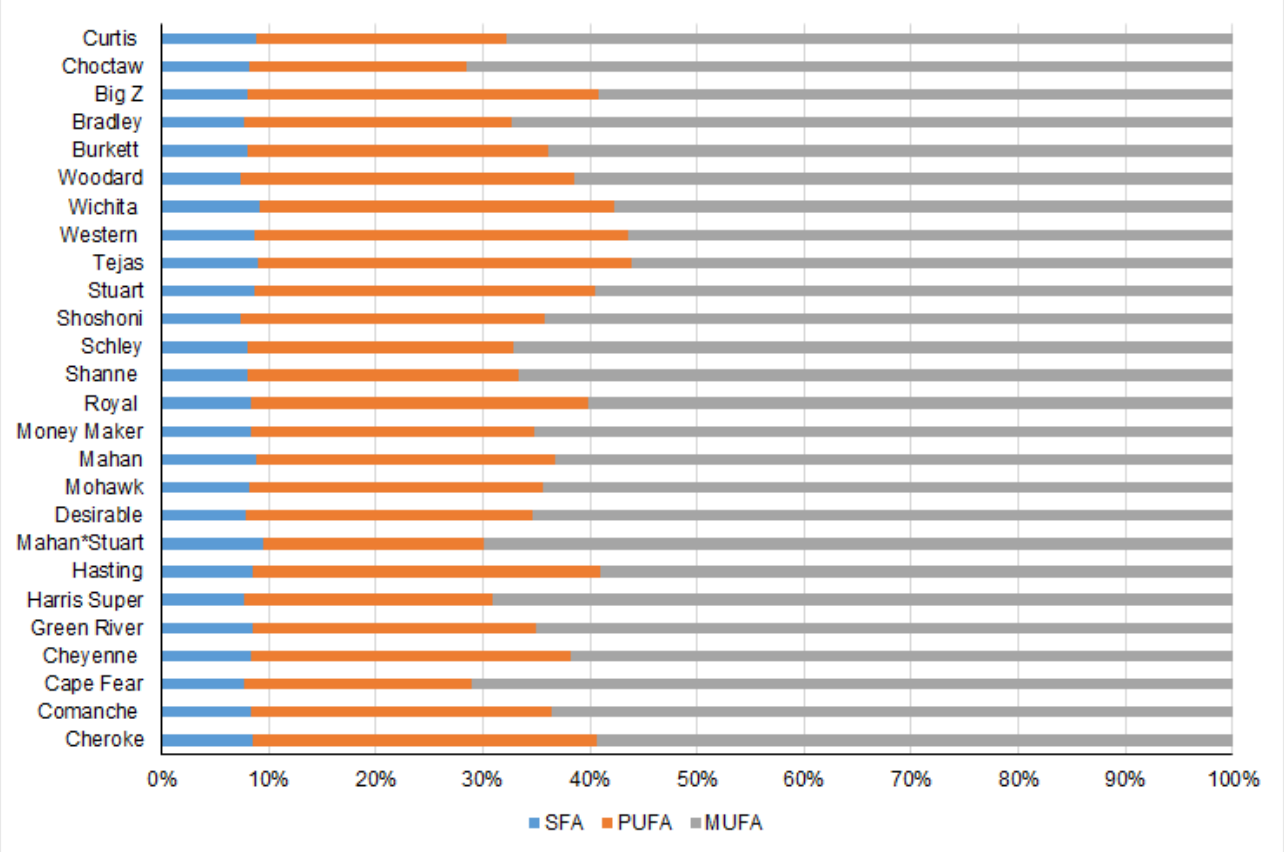

Figure 2. Fatty acid groups of 26 pecan cultivars (SFA: Saturated fatty acids, PUFA: Polyunsaturated fatty acids, and MUFA: Monounsaturated fatty acids).

suggested that diets containing MUFAs and PUFAs have a positive impact on the health of human (Simopoulos 1991; Alonso et al., 2006; Garman et al., 2009). However, high SFA consumption can cause chronic diseases such as obesity, diabetes and cancer (Ribeiro et al., 2020).

4. Conclusion

In this study, the oil contents and fatty acid compositions of 26 pecan cultivars grown in Türkiye were investigated. The results showed that there were significant differences between cultivars in terms of both oil contents and individual fatty acids. The oil contents and fatty acid compositions of pecan oils were generally similar to those previously reported in the literature. Curtis, Stuart, Green River, Mohawk, and Woodard cultivars had high oil content.

Seven fatty acids were detected in the oil samples including oleic, linoleic, palmitic, stearic, linolenic, 11-Eicosenoic and arachidic acids. More than 90% of the oils from the pecan cultivars consisted of UFAs, which protect against coronary heart disease and reduce LDL (low-density lipoprotein) cholesterol. Among the pecan cultivars, Choctaw had the highest MUFAs and oleic acid contents. High levels of PUFAs and linoleic acid were determined in Tejas and Western cultivars. As a result, the data of this study may contribute to future breeding programs and the food industry regarding the selection of pecans with improved health and nutritional quality.

It is suggested that pecan oil should be consumed due to its high unsaturated fatty acid content for health benefits. There is a need for studies investigating the usability of pecan in the food, cosmetic and pharmaceutical industries to improve the production and consumption of pecan in Türkiye.

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