Influence of Olive Cultivar on Oil Attributes in the Arid Region of Qom, Iran

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Summary

Olive cultivation has economic and health implications. The quality of harvested oil is affected by the type of cultivar and the climate in which the trees are cultivated. This study was carried out to determine quality indices (peroxide value, K_{232}, and K_{270}), fatty acid composition, and pigment profiles in some cultivars grown in an arid region in central Iran. These are cultivated in completely different climatic conditions than the major olive growing areas of Iran. The results have illustrated that there are significant differences between the cultivars in oil quality, pigments content, and fatty acid composition. Oil quality of all studied cultivars falls within the established ranges for extra virgin olive oil. Oleic acid levels of the 'Beledy' and 'Leccino' cultivars are below the International Olive Council (IOC) established limit. Oils of the 'Mari', 'Koroneiki', and 'Mission' cultivars had the highest monounsaturated fatty acids (MUFA) content. However, polyunsaturated fatty acid (PUFA) content for Mission oil was considerably higher than 'Koroneiki' and 'Mari' oils. The ratio of MUFA/PUFA for 'Mari' and 'Koroneiki' was higher among all the cultivars studied. Furthermore, these two cultivars presented higher oleic/linoleic acid ratio and lower Cox values. Based on our findings, 'Mari' and 'Koroneiki' are among the best performing cultivars for producing olive oil in intensely hot and arid regions.

Key words

arid region, cultivars, fatty acids, quality indices, virgin olive oil

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Received: May 1, 2015 | Accepted: October 28, 2015

ACKNOWLEDGEMENTS
This research was funded by Gorgan University of Agricultural Sciences and Natural Resources. We thank Ahmad Bolandnazar, the owner and manager of Fadak olive grove, for his permission to access the grove. We would like to express our sincere gratitude to Justin Parker for proofreading the manuscript and also Sousan Bolandnazar for her assistance during sampling stage. We thank two anonymous reviewers for their constructive comments.

Introduction

Olive oil is a key component of the world-renowned Mediterranean diet, which has a global interest from scientists and the health-conscious consumers for its health benefits (Visioli and Galli, 1998; Perez-Jimenez, 2007). It contributes about 2-2.5% of the total world production of vegetable oils and is economically and nutritionally one of the most important vegetable oils (Visioli and Galli, 1998). Olive oil is the only vegetable oil that can be used in its natural state and contains nutritionally important elements such as vitamins and antioxidants (Baccouri et al., 2008).

Sensory quality, health properties, and oxidative stability of virgin olive oil are dependent on its chemical composition (Bendini et al., 2007). The well-balanced composition of fatty acids in olive oil results in high stability against thermo-oxidation and consequently is of great benefit for human health and diet (Visioli and Galli, 1998; Sanchez and Hardwood, 2002). High oxidative stability is primarily due to elevated levels of monounsaturated fatty acids (mostly oleic acid), low linoleic and linolenic acid content, and the presence of biophenols and tocopherols (Kalua et al., 2007; Haghighat Kharazi et al., 2012). The ratio of monounsaturated fatty acid (MUFA) and saturated fatty acid (SFA) is important in evaluating the health benefits of olive oil. Higher levels of MUFAs and lower levels of SFAs have demonstrated effects on serum cholesterol levels (Baccouri et al., 2008).

Quality indices are influenced by several factors including olive variety (Cerretani et al., 2006; Frankel, 2011), climatic conditions (Tura et al., 2007), maturity index (Salvador et al., 2001), irrigation management (Tovar et al., 2001), and oil extraction systems (Ranalli et al., 2001). Some studies indicate that oil quality is only dependent on the interaction between cultivar and environment, and particularly on the nature of fruit ripening, which changes with cultivar variation, environmental conditions, and horticultural practices (Pannelli and Montedoro, 1988).

Various local cultivars take up most of the olive-growing area in Iran (Hashempour et al., 2010a). Roghani, Shengeh, and Mari are among the cultivars specific to Iran. There are also many cultivars imported from other countries such as 'Arbequina' and 'Picual' (Spain), 'Beledy' (Syria), 'Koroneiki' (Greece), 'Frantoio', 'Nociara', 'Oblonga', and 'Leccino' (Italy), and 'Mission' (USA). The Iranian Government aspires to see about a six-fold increase in olive cultivated lands, i.e. from approximately 103,000 in 2014 to 600,000 ha by 2025, starting at 4,800 ha in 1993 at the launch of The Expansion of Olive Cultivation Plan (Omrani-Sabbaghi et al., 2007; Ministry of Agriculture of Iran, 2015). To achieve this, ascertaining the cultivars that have the highest oil quality and good yield under vastly different climatic conditions is of vital importance.

Some investigations have already been carried out on the influence of cultivar and agronomic factors on the quality of olive oil from Spanish and Italian varieties (e.g. Salvador et al., 2001; Cerretani et al., 2006). There also have been some studies on the importance of olive cultivars in oil characteristics in main olive growing regions of Iran, namely north and south of the country (e.g. Hashempour et al., 2010b; Haghighat Kharazi et al., 2012). Nevertheless, there is very scarce literature regarding the quality and composition of virgin olive oil in minor growing regions of Iran. With the prospect of the intended expansion of olive cultivation by the government, studies to establish quality olive cultivars under different climatic conditions seem to be a priority.

The aim of this study is to gain information about the quality of oils of some olive cultivars and to understand which cultivars would be superior under similar climatic conditions, and also to study some local cultivars to see whether these are suitable for cultivation in other hot and arid regions of the world. Since all sampled olive trees in this study were under very similar pedo-climatic conditions, this study will try to highlight the impact of cultivars on oil attributes in a hot and arid region.

Materials and methods

This study was conducted in Fadak olive grove (34° 30' N, 51° 00' E). The grove is located about 15 km south of Qom, a city ~150 km south of Tehran, in the central hyper-arid to arid parts of Iran. Based on the climate and physiography of the region and the fact that the grove lies about 25 km SSE of Qom Weather Station, even harsher and drier conditions than Qom Weather Station (Table 1) are likely to be in the research area. Having completely different climate than typical olive growing regions, it mainly relies on irrigation sourced from underground aquifers. The grove was established 20 years ago and now covers about 120 ha with over 100 cultivars from around the world and includes 18 local cultivars.

In the present study, quality indices including peroxide value (PV) and UV spectrophotometric indices (K_{232}, K_{270}), fatty acid composition, chlorophyll and carotenoids were investigated.

Sampling

Olive fruits of 12 varieties, including the local cultivars: 'Mari', 'Shengeh', and 'Roghani', and the imported cultivars: 'Arbequina', 'Beledy', 'Koroneiki', 'Mission', 'Frantoio', 'Nociara', 'Leccino', 'Picual', and 'Oblonga' were hand-picked from Fadak grove located near Qom according to their maturity index (pulp and skin color (Table 2)) at monthly intervals in the period from 17th of August to 24th of November 2012. An attempt was made to collect ~500 gr sample for each cultivar, however, for 'Leccino' and 'Picual' only ~200 gr was available for collection. The olive ripening index was calculated according to the method proposed by the International Olive Council (IOC), formerly known as the International Olive Oil Council (IOOC, 1984).

Oil extraction

Following handpicking, olive fruits were immediately transferred to the laboratory. For oil extraction, only sound and undamaged fruits were used. They were washed and de-leafed, and then crushed in a hammer mill (IKA heavy-duty mill; capacity: 250 mL; USA) to form a paste. The paste was malaxed at 30°C, then centrifuged at 4000 rpm for 10 minutes. Extracted oil was collected by a pipette and stored in dark glass jars in a refrigerator until they were analyzed. Since the extracted oils of 'Leccino' and 'Picual' were thought not to be enough for all measurements, only the fatty acid composition was analysed in these two cultivars.

Determination of quality parameters

Peroxide values of oil of 10 olive cultivars were measured using the methods of Garcia et al. (1996). Coefficients of specific

Table 1. Climatic averages recorded at Qom Weather Station (34° 42' N and 50° 51' E) from March 1986 to the end of 2010 (IRIMO, 2014)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average of mean daily temp (°C)	4.2	7.1	12	18.3	23.6	29.1	31.8	30.3	25.2	19	11.5	6.1
Average of minimum daily temp (°C)	-1.9	0.6	5	10.5	15.4	20.2	23.4	21.2	15.6	10.3	4.1	-0.1
Average of maximum daily temp (°C)	10.2	13.6	19.1	26	31.8	37.9	40.3	39.4	34.9	27.7	18.9	12.2
Monthly precipitation (mm)	25.4	20.5	27.7	20.2	10.4	2.3	0.7	0.3	0.8	6.2	14.3	19.4
No. of days with precipitation ≥ 5mm	1.8	1.4	1.8	1.4	0.7	0.1	0	0	0	0.4	0.9	1.3

Table 2. Quality parameters of virgin olive oil samples of 10 olive cultivars (mean values*)

Cultivars	PV (meq.O^2 kg^{-1})	K_{232}	K_{270}	Chlorophyll (mg kg^{-1})	Carotenoid (mg kg^{-1})	Maturity index
Arbequina	6.53 cd	1.32 bc	0.14 bc	2.12 d	1.51 ef	3.93
Koroneiki	6.96 bcd	0.82 g	0.12 cde	2.20 d	1.52 ef	3.84
Mission	7.33 abcd	1.13 de	0.081 f	2.22 cd	1.79 d	4.23
Beledy	7.73 abc	1.64 a	0.15 ab	3.20 b	2.44 c	4.08
Roghani	6.86 bcd	1.03 ef	0.12 cde	4.30 a	2.88 b	4.14
Frantoio	7.90 ab	0.90 fg	0.11 ed	2.15 d	1.69 ed	3.90
Mari	6.70 bcd	1.23 cd	0.13 cd	2.60 c	1.61 def	4.23
Shengeh	6.40 d	0.98 ef	0.10 e	1.98 d	1.44 f	3.95
Nociara	7.73 abc	1.21 cd	0.17 a	2.60 c	2.26 c	3.88
Oblonga	8.36 a	1.45 b	0.13 bcd	4.51 a	3.77 a	4.12
IOOC limits	≤ 20	≤ 2.5	≤ 0.22			

*Means within a column followed by the same letter are not significantly different at $P < 0.05$ (PV) and at $P < 0.01$ (chlorophyll, carotenoids, K_{232}, and K_{270}).

extinction at 232 and 270 nm were measured by the methods reported in Regulation EEC/2568/91 of the European Union Commission (EEC, 1991).

Determining oil chlorophyll and carotenoid content

Pigment contents were assayed according to spectrophotometric method of Minguez–Masquera et al. (1991). One gram of oil was dissolved in 10 ml of isooctane and the resulting solution transferred to a cuvette. Absorbance at 470 and 670 nm (for carotenoid and chlorophyll, respectively) was measured in a spectrophotometer (unico/2800 uv/VIS) using pure isooctane as a blank. The results were expressed as milligram of carotenoid or chlorophyll per kilogram of oil.

Fatty acid composition

For determination of fatty acid composition in oils of the 12 olive cultivars, methyl esters were prepared by vigorous shaking of a solution of oil in hexane (0.5 gr in 7 ml) with 2 ml of 2N methalonic potash, and analyzed by gas chromatography (GC) according to AOCS Official Method Ce 2-66 (1997).

Chromatographic analysis was performed on a Trace GC gas chromatograph, equipped with a flame ionization detector and split/splitless injector (Trace GC; ThermoFinnigan; Italy), using a silica capillary column, BPX-70 (30 m × 0.25 mm i.d. × 0.25 µm film thickness). The injector temperature was set at 250°C and samples were injected manually (1 µL) with a split ratio of 1:80. The oven temperature was held at 175°C for 2 min, then increased gradually to 230°C at 3°C/min and held for 10 min. Nitrogen was used as carrier gas at a flow rate of 0.8 ml/min. The detector temperature was maintained at 270°C. Fatty acids were identified by comparing retention times with those of standard compounds.

Oxidizability (Cox value) was calculated based on the fatty acid content of three unsaturated fatty acids (oleic acid (C18:1), linoleic acid (C18:2), and linolenic acid (C18:3)) using following relation (Fatemi and Hammond, 1980):

Oxidizability = [1 × (C18:1%) + 10.3 × (C18:2%) + 21.6 × (C18:3%)]

Statistical analysis

The results are demonstrated as mean values. Significance of the differences between the means was determined using the least significant difference (LSD) test at $P < 0.05$ for PV and at $P < 0.01$ for chlorophylls, carotenoids, K_{232}, and K_{270}.

Results

Peroxide Value (PV) and UV spectrophotometric indices

Quality parameters of olive oil of 10 cultivars and related IOC limits are shown in Table 2.

In the samples investigated in the present study, PVs of the oils were all below the limit of 20 meq O^2kg^{-1} of oil, which is the limit established by the IOC standards to categorize the quality of virgin olive oil. Peroxide value for 'Oblonga' cultivar was the highest, while 'Shengeh', 'Arbequina', and 'Mari' were three cultivars with the lowest PVs. The differences between different cultivars were statistically significant ($P < 0.05$).

With regard to K_{232} and K_{270}, all cultivars were below the upper established limits for extra virgin oil and statistically significant differences were observed between the studied cultivars ($P < 0.01$).

Table 3. Fatty acid composition and allowable ranges for extra virgin olive oil (IOOC, 2003)

	Palmitic acid	Oleic acid	Linoleic acid	Myristic acid	Palmitoleic acid	Heptadecanoic acid	Heptadecenoic acid	Linolenic acid	Arachidonic acid
Arbequina	16.629 e	60.765 e	15.961 d	0.028 bc	2.512 b	0.070 a	0.169 a	0.683 i	0.159 i
Koroneiki	12.481 h	74.848 a	6.500 h	0.030 bc	0.798 h	0.031 bc	0.050 bcd	0.761 h	0.379 g
Mission	11.109 i	72.960 b	10.467 g	0.010 e	0.730 h	0.025 bc	0.044 cd	1.050 ef	0.409 g
Beledy	20.339 b	54.503 g	17.336 b	0.070 a	2.859 a	0.027 bc	0.053 bcd	1.299 d	0.512 f
Roghani	16.597 e	60.388 e	16.363 cd	0.027bcd	1.009 g	0.071 a	0.028 d	0.870 g	0.601 de
Frantoio	16.950 e	63.035 cd	14.495 e	0.020cde	1.531 e	0.022 a	0.041 cd	1.084 e	0.566 e
Mari	12.500 h	75.662 a	6.290 h	0.010 e	0.966 g	0.031 bc	0.062 bc	0.990 f	0.644 cd
Shengeh	14.627 g	63.393 c	15.994 d	0.014 e	1.208 f	0.039 b	0.057 bc	0.644 i	0.688 bc
Nociara	18.378 c	63.746 c	10.217 g	0.028bc	2.137 c	0.032 bc	0.050 bcd	1.704 c	0.704 b
Oblonga	17.970 d	59.437 f	13.470 f	0.028bc	2.090 c	0.040 b	0.070 b	2.871 a	1.100 a
Picual	15.252 f	62.479 d	16.626 c	0.016 de	1.884 d	0.026 bc	0.060 bc	1.039 ef	0.321 h
Leccino	21.633 a	52.323 h	18.099 a	0.035 b	2.206 c	0.029 bc	0.052 bcd	2.384 b	0.658 bc
IOOC limits	7.5-20.0	55.0-83.0	3.5-21	< 0.05	0.3-3.5	< 0.3	< 0.3	< 1.0	< 0.2

*Significant differences in a same column are shown by different letters ($P < 0.05$)

Table 4. Fatty acid compositions and oxidizability in studied cultivars

	∑SFA	∑MUFA	∑PUFA	MUFA/PUFA	Oleic/Linoleic acid	Cox value
Arbequina	18.732 f	63.561 f	16.807 e	3.783 ed	3.808 g	2.399 ef
Koroneiki	16.514 h	75.834 b	7.646 i	9.925 a	11.511 b	1.583 h
Mission	14.255 i	73.753 c	11.927 h	6.184 b	6.971 c	2.034 g
Beledy	23.259 b	57.556 h	19.148 b	3.006 f	3.144 h	2.611 b
Roghani	19.980 e	61.938 g	17.835 f	3.473 e	3.691 g	2.477 d
Frantoio	19.112 f	64.693 e	16.146 f	4.006 d	4.348 ef	2.357 f
Mari	15.197 i	76.833 a	7.925 i	9.694 a	12.029 a	1.618 h
Shengeh	17.841g	64.764 e	17.347 de	3.733 ed	3.964 fg	2.424 e
Nociara	21.218 c	66.077 d	12.626 g	5.233 c	6.239 d	2.057 g
Oblonga	20.649 d	61.796 g	17.442 cd	3.543 e	4.413 e	2.602 bc
Picual	17.490 g	64.511 e	17.987 c	3.587 e	3.758 g	2.562 bc
Leccino	24.052 a	54.721 i	21.142 a	2.588 g	2.891 h	2.902 a

*Significant differences in a same column are shown by different letters ($P < 0.05$)

Pigments content

Chlorophyll and carotenoid contents of the studied oils ranged from 1.98 to 4.51 mg kg^{-1} oil and 1.44 to 3.77 mg kg^{-1} oil, respectively. 'Oblonga' had the highest amount of both pigments, and 'Shengeh' had the lowest amount. Significant differences are observed between some cultivars based on the pigments content (Table 2). We did our utmost to collect the samples at similar stages of maturity in order to reduce its interference with the results.

Fatty acid composition

Major fatty acids that occur in all the studied cultivars include: oleic (C18:1), linoleic (C18:2), and palmitic (C16:0) acids (Table 3). Results demonstrate significant differences in the amount of fatty acids between cultivars ($P < 0.01$). The highest concentrations of oleic acid were found in 'Mari', 'Koroneiki', and 'Mission'. The cultivars with the least amount of oleic acid include 'Leccino', 'Beledy', and 'Oblonga'.

Palmitic acid varied from 11.11 to 21.63% in the studied cultivars. 'Leccino' had the highest mean value and 'Beledy' the second highest, while 'Mission' had the lowest amount. Palmitic acid content of 'Leccino' and 'Beledy' were slightly higher than recommended by the IOC standards (Table 3).

The highest percentages of linoleic acid, the predominant polyunsaturated fatty acid in this study, were observed in 'Leccino' and 'Beledy' cultivars, while 'Mari' and 'Koroneiki' had the lowest levels. The linoleic acid levels in this study were in accordance with the IOC recommendations (Table 3).

The levels of other fatty acids including: linolenic, myristic, palmitoleic, heptadecanoic, heptadecenoic, and arachidonic acids were low (Table 3). They showed significant differences between the olive cultivars ($P < 0.01$).

Linolenic acid content ranged from 0.66 to 2.87%. The highest linolenic acid content was observed in the oil of the 'Oblonga' cultivar, and the 'Shengeh' cultivar had the lowest content. 'Picual', 'Mission', 'Frantoio', 'Beledy', 'Nociara', 'Leccino', and 'Oblonga' had mean linolenic acid concentrations above the limits established by the IOC (Table 3).

The levels of SFAs, MUFAs and polyunsaturated fatty acids (PUFA), MUFA/PUFA and oleic/linoleic acids ratios, and Cox values were calculated (Table 4). The oils of the 'Leccino', 'Beledy', and 'Nociara' cultivars had the highest SFA concentration due to their higher palmitic acid content. The cultivars: 'Mari', 'Koroneiki', and 'Mission' contained the highest percentages of MUFA due to high levels of oleic acid. 'Leccino' oil was

the richest in total PUFAs and 'Beledy' was the second highest owing to their high major fatty acid - linoleic acid - content. The cultivars 'Koroneiki' and 'Mari' showed significantly higher ratios of MUFA/PUFA compared to the others ($P < 0.05$). Also, the studied cultivars demonstrated statistically significant differences in MUFA/PUFA ratios between most cultivars (Table 4). The oleic/linoleic acid ratio had wide ranges from 2.89 for the 'Leccino' oil to 12.02 for the 'Mari' oil. Significant differences were observed among the studied cultivars in Cox values. 'Koroneiki' and 'Mari' had the lowest Cox values, which indicate higher oil stability.

Discussion

Peroxide Value and UV spectrophotometric indices

Hydroperoxide content is evaluated by PV and used as a benchmark to estimate lipid oxidation (Haghighat Kharazi et al., 2012). Peroxide value is used to determine total hydroperoxide levels as the primary oxidation products to assess the degree of oxidative decline of oil. Some information about freshness and storage of oil can be obtained from this factor.

The degree of olive oil oxidation can also be evaluated through UV spectrophotometric indices of K_{232} and K_{270}. K_{232} is associated with the earliest oxidation of oil and demonstrates the conjugation of polyunsaturated fatty acids, while K_{270} indicates carbonylic compounds (aldehydes and ketones) in olives and shows the secondary oxidation products (Boskou, 1996; Garcia et al., 1996).

The quality parameters determined for 10 olive cultivars showed statistically significant differences between some cultivars. They are all categorized as extra virgin olive oil.

Pigments content

Chlorophyll and carotenoids are common pigments responsible for color of vegetables and several fruits. They also play key roles in photosynthesis. The composition of chlorophyll and carotenoids significantly affects the color of olive oil (Moyano et al., 2008), with the former pigments accounting for the greenness of oil and the latter bringing about its yellowness (Escolar et al., 2007). Color is one of the most important sensory characteristics evaluated by consumers (Criado et al., 2008).

Plant pigments play important roles in human health (Mayne, 1996). Studies have reported the potential health benefits of a diet rich in carotenoids due to their antioxidant nature in the dark and pro-oxidant nature in the light (Gutierrez-Rosales et al., 1992), and as agents preventing cardiovascular diseases (Landrum and Bone, 2001).

Regarding chlorophyll content, no significant differences were observed between 'Arbequina', 'Frantoio', 'Koroneiki', 'Mission', and 'Shengeh' cultivars; however 'Frantoio' showed a significant difference from the mentioned four cultivars in carotenoid content at the $P < 0.01$ level. According to Hashempour et al. (2010b), the cultivars 'Beledy' and 'Arbequina' from northern Iran have higher levels of chlorophyll and carotenoid pigments than in our study, which could be due to differences in environment and maturity level. Haghighat Kharazi et al. (2012) found significant differences among some local cultivars in Roodbar, northern Iran.

According to Psomiadou and Tsimidou (2001), the type and amount of chlorophyll and carotenoid pigments in olive oil depends on genetic factors (olive variety), stage of fruit ripeness, environmental factors, extraction process, and storage conditions. In this study, all the aforementioned factors were similar. Therefore, the similarities and differences observed indicate the role of cultivar in determining chlorophyll and carotenoid level.

Fatty acid composition

The studied cultivars showed some differences in oleic acid content from the IOC limits for extra virgin olive oil. The oleic acid content in the 'Leccino' and 'Beledy' oils was less than IOC standards (Table 3). Contents of oleic acid in 'Mari' and 'Roghani' from Kazeroon (77.92 and 72.6%, respectively) in southern Iran (Hashempour et al., 2010a) are significantly higher than the same cultivars from the Qom region, especially for 'Roghani'. Similar results were observed when comparing oleic acid contents of 'Arbequina' and 'Beledy' oils (76.81 and 76.08%, respectively) from Roodbar, north of Iran, with our results (Hashempour et al., 2010b). These differences in fatty acid composition of the same and also different cultivars from different areas could be due to complex interplay between genetic and environmental factors during the ripening and maturity process (Haghighat Kharazi et al., 2012). Conversely, the content of linoleic and linolenic acids in oils from the same cultivars in Qom region were much higher than those from Kazeroon (Hashempour et al., 2010a).

According to Gutierrez et al. (1999), oleic acid is transformed into linoleic acid by the activity of the oleate desaturase during fruit ripening, increasing the content of linoleic acid. The differences in the level of fatty acids could be partly due to different activities of the oleate desaturase enzyme during triacylglycerol biosynthesis in analyzed cultivars.

Palmitic acid is the main saturated fatty acid of olive oil (Aguilera et al., 2005). Other than 'Leccino' and 'Beledy', all cultivars were well within the IOC standards for their palmitic acid content. The impact of the genotype in palmitic acid content was statistically significant between most cultivars (Table 3).

Polyunsaturated fatty acids have been demonstrated to have nutritional benefits (Ben Temime et al., 2006). Linoleic acid is the most predominant PUFA in the investigated olive cultivars and is more susceptible to oxidation than MUFAs (Manai et al., 2008). The lowest values of linoleic acid were in 'Mari' and 'Koroneiki'. Therefore, these cultivars indicate potentially higher stability against oxidation.

The linolenic acid contents in 'Koroneiki' and 'Arbequina' are higher than the same cultivars grown in other countries (Bacouri et al., 2008; Allalout et al., 2009). In addition, the levels of linolenic acid in oil from all studied cultivars are higher than reported for the 'Koroneiki' (0.26%) cultivar from Greece, and the 'Arbequina' (0.63%) and 'Arbosana' (0.54%) cultivars from Spain (Allalout et al. 2009). Although linolenic acid is considered to be nutritionally beneficial, it is a polyunsaturated acid with three double bonds that results in instability and rancidity of oil.

The differences in the fatty acid composition between the studied cultivars and varieties grown in different countries are likely due to both genetic factors and environmental conditions throughout the ripening and maturity process (Allalout et al., 2009). These findings strengthen the claim that fatty

acid composition of olive oil could be altered by several agronomic factors such as cultivar and origin, fruit ripening, harvest period, and pedo-climatic conditions (Deidda et al., 1994; Morello et al., 2004).

Because of the higher palmitic acid content, olive oils of 'Leccino', 'Beledy', and 'Nociara' have the highest SFA concentration, which is not favorable (Hashempour et al., 2010a). The cultivars 'Mari', 'Koroneiki', and 'Mission' demonstrated highest percentages of MUFA. Again as with SFA, the 'Leccino' and 'Beledy' olive oils contained the highest PUFA. The reason was the higher levels of linoleic acid in their oils.

The ratio of MUFA/PUFA suggests potential oxidative stability of the olive oil. A higher value indicates higher stability and resistance to oxidation (Haghighat Kharazi et al., 2012). The oil of 'Koroneiki' and 'Mari' indicate higher oxidative stability than of the other cultivars.

The oil of 'Mari' showed the highest oleic/linoleic acid ratio, followed by 'Koroneiki' with a statistically significant difference. The oleic/linoleic acid ratio has an effect on the virgin olive oil taste and is responsible for positive health effects associated with the Mediterranean diet (Boskou, 1996). This ratio could prove valuable for characterizing olive cultivars and can also be used to represent the stability of the oil (Manai et al., 2008). The Cox value could also indicate the stability of the oil - the lower is the value, the higher is the stability of the olive oil (Haghighat Kharazi et al., 2012). Again, 'Koroneiki' and 'Mari' had lower Cox values. Our results are consistent with those of Haghighat Kharazi et al. (2012) who found that the cultivar 'Mari' had the lowest Cox value.

Conclusions

The quality indices of the olive cultivars were all within the established range for extra virgin olive oil. Regarding the fatty acid composition, oils of the Mari, Koroneiki, and Mission cultivars were of higher quality due to their high levels of oleic acid and low palmitic acid content. However, the content of linolenic acid in the Mission oil was slightly higher than the IOC limit. Leccino and Beledy had the lowest oil quality with regard to fatty acid content, having levels of oleic acid below and palmitic acid above the IOC limits. The Mari and Koroneiki oils showed lower Cox values indicating that these cultivars could potentially have a higher stability against oxidation. These cultivars also demonstrated higher ratios of MUFA/PUFA and oleic/linoleic acids, hence have superior taste and higher stability. Our results show that Mari and Koroneiki are the best performing olive varieties in the region, and Mari as a local cultivar shows potential for cultivation and olive oil production in hot and arid climatic conditions elsewhere in the world.

References

AOCS Official Method Ce 2-66. (1997). Preparation of methyl esters of long-chain fatty acids from sampling and analysis of commercial fats and oils. AOCS Press, Champaign, IL

Aguilera M. P., Beltran G., Ortega D., Fernandez A., Jimenez A., Uceda M. (2005). Characterisation of virgin olive oil of Italian olive cultivars, Frantoio and Leccino, grown in Andalusia. Food Chem 89: 387-391

Allalout A., Krichene D., Methenni K., Taamalli A., Oueslati I., Daoud D., Zarrouk M. (2009). Characterization of virgin olive oil from super intensive Spanish and Greek varieties grown in northern Tunisia. Sci Hortic 120: 77-83

Baccouri O., Guerfel M., Baccouri B., Cerretani L., Bendini A., Lercker G., Zarrouk M., Ben Miled D. D. (2008). Chemical composition and oxidative stability of Tunisian monovarietal virgin olive oils with regard to fruit ripening. Food Chem 109: 743-754

Bendini A., Cerretani L., Carrasco-Pancorbo A., Gomez-Caravaca A. M., Segura-Carretero A., Fernandez- Gutierrez A., Lercker G. (2007). Phenolic molecules in virgin

olive oils: a survey of their sensory properties, health effects, antioxidant activity and analytical methods. An overview of the last decade. Molecules 12: 1679-1719

Ben Temime S., Campeol E., Cioni P. L., Daoud D., Zarrouk M. (2006). Volatile compounds from Chetoui olive oil and variations induced by growing area. Food Chem 99: 315-325

Boskou D. (1996). Olive oil, chemistry and technology. AOCS Press, Champaign, IL

Cerretani L., Bendini A., Del Caro A., Piga A., Vacca V., Caboni M. F. (2006). Preliminary characterization of virgin olive oils obtained from different cultivars in Sardinia. Eur J Food Res Technol 222: 354-361

Criado M. N., Romero M. P., Casanovas M., Motilva M. J. (2008). Pigment profile and colour of monovarietal virgin olive oils from Arbequina cultivar obtained during two consecutive crop seasons. Food Chem 110: 873-880

Deidda P., Nieddu G., Spano D., Bandino G., Orrù V., Solinas M., Serraiocco A. (1994). Olive oil quality in relation to environmental conditions. Acta Hortic 356: 354-357

EEC (1991). Characteristics of olive oil and olive-residue oil and the relevant methods of analysis. Commission Regulation (EEC) No 2568/1991. Offic J Eur Commun L248: 1-83

Escolar D., Haro M. R., Ayuso J. (2007). The color space of foods: Virgin olive oil. J Agr Food Chem 55: 2085-2093

Fatemi S. H., Hammond E. G. (1980). Analysis of oleate, linoleate and linolenate hydroperoxides in oxidized ester mixtures. Lipids 15: 379-385

Frankel E.N. (2011). Nutritional and biological properties of extra virgin olive oil. J Agr Food Chem 59: 785-92

Garcia J. M., Seller S., Pérez-Camino M. C. (1996). Influence of fruit ripening on olive oil quality. J Agr Food Chem 44: 3516-3520

Gutierrez-Rosales F., Perdiguero S., Gutiérrez R., Olias J. M. (1992). Evaluation of the bitter taste in virgin olive oil. J Am Oil Chem Soc 69: 394-395

Gutierrez F., Jimenez B., Ruiz A., Albi M. A. (1999). Effect of olive ripeness on the oxidative stability of virgin olive oil extracted from the varieties Picual and Hojiblanca and on the different components involved. J Agr Food Chem 47: 121-127

Haghighat Kharazi S., Esmaeilzadeh Kenari R., Raftani Amiri Z., Azizkhani M. (2012). Characterization of Iranian virgin olive oil from the Roodbar Region: A Study on Zard, Mari and Phishomi. J Am Oil Chem Soc 89: 1241-1247

Hashempour A., Fotouhi Ghazvini R., Bakhshi D., Aliakbar A., Papachatzis A., Kalorizou H. (2010a). Characterization of virgin olive oils (*Olea europea* L.) from three main Iranian cultivars, 'Zard', 'Roghani' and 'Mari' in Kazeroon Region. Biotechnol Biotec Eq 24: 2080-2084

Hashempour A., Fotouhi Ghazvini R., Bakhshi D., Asadi Sanam S.(2010b). Fatty acids composition and pigments changing of virgin olive oil (*Olea europea* L.) in five cultivars grown in Iran. Aust J Crop Sci 4(4): 258-263

IRIMO (I. R. of Iran Meteorological Organization). (2014). Available at www.chaharmahalmet.ir

IOOC. (1984). Document no 6. International Olive Oil Council, Madrid

IOOC. (2003). International Olive Oil Council activities: World Olive Oil Consumption, available at www.internationaloliveoil.org

Kalua C. M., Allen M. S., Bedgood D. R., Bishop A. G., Prenzler P. D., Robards K. (2007). Olive oil volatile compounds, flavour development and quality: A critical review. Food Chem 100: 273-286

Landrum J. T., Bone R. A. (2001). Lutein, zeaxanthin, and the macular pigment. Arch Biochem Biophys 385: 28-40

Manai H., Mahjoub-Haddada F., Oueslati I., Daoud D., Zarrouk M. (2008). Characterization of monovarietal virgin olive oils from six crossing varieties. Sci Hortic 115: 252-260

Mayne S. T. (1996). Beta-carotene, carotenoids, and disease prevention in humans. FASEB J 10: 690-701

Minguez-Mosquera M. I., Rejano-Navarro L., Gandul-Rojas B., Sanchez-Gomez A. H., Garrido-Fernandez J. (1991). Color-pigment correlation in virgin olive oil. J Am Oil Chem Soc 68: 332-336

Ministry of Agriculture of Iran. (2015). Available at http://horticulture.maj.ir/Portal/Home

Morello J. R., Motilva M. J., Tovar M. J., Romero M. P. (2004). Changes in the commercial virgin olive oil (cv. Arbequina) during storage, with special emphasis on the phenolic fraction. Food Chem 85: 357-364

Moyano M. J., Meléndez-Martínez A. J., Alba J., Heredia F. J. (2008). A comprehensive study on the color of virgin olive oils and its relationship with their chlorophylls and carotenoids indexes (II). CIELUV and CIELAB uniform color spaces. Food Res Int 41: 513-521

Omrani-Sabbaghi A., Shahriari M., Falahati-Anbaran M., Mahammad S. A., Nankali A., Mardi M., Ghareyazie B. (2007). Assessment of genetic diversity in Iranian olive (*Olea europaea* L.) collections. Sci Hortic 112: 439-447

Pannelli G., Montedero G. (1988). Scelte varietali, condizioni pedoclimatiche, maturazione del frutto e caratteristiche qualitative dell'olio di oliva. Alli Convegno Aspetti fisiologici della cascola, della maturazione, delta conservazione e della trasformazione post raccolta dei frutti, Torino, 99-105

Perez-Jimenez F. (2007). Virgin olive oil: its functional capacity. Mol Nutr Food Res 51: 1197

Psomiadou E., Tsimidou M. (2001). Pigments in Greek virgin olive oils: occurrence and levels. J Sci Food Agric 81: 516

Ranalli A., Cabras P., Iannucciand E., Contento S. (2001). Lipochroms, vitamins, aromas and other compounds of virgin olive oil are affected by processing technology. Food Chem 73: 445-451

Salvador M. D., Aranda F., Fregapane G. (2001). Influence of fruit ripening on Corincabra virgin olive oil quality: A study of four successive crop seasons. Food Chem 73: 45-53

Sanchez J., Harwood J. L. (2002). Biosynthesis of triacylglycerols and volatiles in olives. Eur J Lipid Sci Tech 104: 564-573

Tovar M. J., Motilva M. J., Romero M. P. (2001). Changes in the phenolic composition of virgin olive oil from young trees (*Olea europaea* L. cv. Arbequina) grown under linear irrigation strategies. J Agr Food Chem 49: 5502-5508

Tura D., Gigliotti C., Pedo S., Failla O., Bassi D., Serraiocco A. (2007). Influence of cultivar and site of cultivation on levels of lipophilic and hydrophilic antioxidants in virgin olive oils (Olea europaea) and correlation with oxidative stability. Sci Hortic 112: 108-109

Visioli F., Galli C. (1998). The effect of minor constituents of olive oil on cardiovascular disease: new findings. Nutr Rev 56(5): 142-147

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