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# Comparison and Evaluation of Oil Content, Composition and Antioxidant Properties of *Pistacia atlantica* and *Pistacia khinjuk* Grown as Wild

**Saeid Hazrati[1*], Mostafa Govahi[2], Mohammad-Taghi Ebadi[3] and Farhad Habibzadeh[4]**

*1. Department of Agronomy, Faculty of Agriculture, Azarbaijan Shahid Madani University, 53714-161, Tabriz, Iran*

*2. Department of Nanobiotechnology, Faculty of Biotechnology, Amol University of Special Modern Technologies, Amol, Iran*

*3. Department of Horticulture, Faculty of Agriculture, Tarbiat Modares University, Tehran, Iran*

*4. Department of Genetics and Plant Breeding, Faculty of Agriculture and Natural Resources, Imam Khomeini International University, Qazvin, Iran*

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**Abstract**

The growing demands of consumers for edible seed oils containing high unsaturated fatty acid and antioxidant content have resulted in considerable efforts to investigate plants as possible sources of oils and nuts. In this research, the amount of fatty acid compositions, total flavonoid, phenol and antioxidant properties of *Pistacia atlantica* and *Pistacia khinjuk* were evaluated. The kernel oil content of *P. atlantica* and *P. khinjuk* were 24.33 ± 0.333% and 31.00 ± 0.577%, respectively. Palmitic acid, Stearic acid, Oleic acid, Linoleic acid, and Palmitoleic acid were the main components in the oil of the two *Pistacia* species. The results showed that unsaturated fatty acids accounted for approximately 77.65% and 74.87% of total fatty acids in *P. atlantica* and *P. khinjuk*, respectively. The two *Pistacia* species were rich in phenolic compounds (130.77± 3.11 and 126.91± 4.41 mg quercetin/100 g oil) and had high antioxidant properties (4.545± 0.655 and 15.733± 0.689 mg/g oil) in *P. atlantica* and *P. khinjuk*, respectively. Oil content and Oleic acid of the two species of *Pistacia* are shown/known to be higher than some other edible oils. This research showed that the kernel oil of the two species of *Pistacia* have the same value in terms of quality, taste and natural antioxidant qualities with other edible oils.

**Keywords:** DPPH, Fatty acids, Flavonoid, Phenolic content, *Pistacia*.



## Introduction

The genus *Pistacia* belongs to the Anacardiaceae family, which contains about 15 species. Among them, *P. atlantica*, *P. vera* and *P. khinjuk* are grown as wild in Iran (Mozaffarian, 2005). *P. atlantica* and *P. khinjuk*, are also known in Persian as "Baneh" and "Kolkhoung", respectively, which are widely distributed in the Zagrossian region of Iran (Bozorgi et al., 2013; Ezatpour et al., 2015). Different parts of these plants, including the fruit, leaf, resin,

* Corresponding Author, Email: saeid.hazrati@azaruniv.ac.ir

bark and aerial parts, have been largely used as folk medicines for the treatment of various health problems related to cutaneous, respiratory, gastrointestinal, infectious and renal diseases (Soleiman-Beigi and Arzehgar, 2013; Ezatpour et al., 2015). Their fruits and oil are eaten as nuts, and are used for the treatment of heart, stomach and respiratory system disorders, wound healing and gastrointestinal disorders (Hatamnia et al., 2016 a and b).

Previous studies have shown antioxidant, anti-inflammatory and antimicrobial properties of *P. atlantica* and *P. khinjuk* fruit, as well as revealed that they are rich in fatty acids such as Linoleic acid and Oleic acid (Dorehgirae and Pourabdolah, 2015; Hacıbekiroğlu et al., 2015).

These species of *Pistacio* grow to 5-15 m tall. The leaves are alternate and pinnate, and can be either evergreen or deciduous, depending on species. The mentioned species of *Pistacia* are known as the origin of Pistachio. Fruits of *P. atlantica* and *P. khinjuk* used as edible wild nuts. From ancient times, the fruits of these plants have been used as snacks and in cooking (Ghasemi Pirbalouti and Aghaee 2011; Bozorgi et al., 2013; Hacıbekiroğlu et al., 2015).

Vegetable oils are normally extracted from plant fruits and have high nutritional value. In addition to widespread uses in human diet and also in industry, the oils have many applications in the pharmaceutical industry due to the numerous therapeutic effects of their natural ingredients. Lack of essential fatty acids in the human diet can be responsible for the development of disorders such as cardiovascular disease, viral infections, certain types of cancers, eczema, diabetes mellitus, rheumatoid arthritis and autoimmune diseases (Moazzami et al., 2015).

The content of bioactive compounds in the seed oils is affected by climatic conditions, species and variety of the *Pistacia* genus (Asadollahzadeh and Shamspur, 2013;Hatamnia et al., 2016a; Hatamnia et al., 2016b; Tavakoli et al., 2016; ).

The most fascinating oleaginous compounds in different species of the *Pistacia* fruit oil include unsaturated fatty acids, phenolic compounds, tocochromanols, and phytosterols (Tavakoli and Pazhouhanmehr 2010). Among the *Pistacia* seed oil fatty acids, Oleic acid level was found to be higher than most of the other frequently used edible oils (Salvador et al., 2019).

*Pistacia* nuts are considered as a great source of biologically active compounds, due to their high essential unsaturated fatty acid content, as well as phenolic compounds (Ghasemynasabparizi et al., 2015; Martínez et al., 2016). Plant oil antioxidants play an important role in protecting health. Among seed oils, *Pistacia* spp exhibit interesting nutritional properties because they contain cardio-protective constituents, such as high Oleic acid, phytosterols, phenolics, tannins, flavonoid and tocopherols, make them as high antioxidant food product (Amarowicz et al., 2004; Matthäus and Özcan, 2006; Ramadan, 2019).

In light of the above mentioned facts, antioxidant activities and phenolic compounds in genus *Pistacia* have been the subject of various research studies (Farhoosh et al., 2011; Gourine et al., 2010; Hatamnia et al, 2014; Hatamnia et al., 2016a; Hatamnia et al., 2016b; Hossein et al., 2005; Tomaino et al., 2010).

Regarding the fact that *P. khinjuk* and *P. atlantica* nuts and oils are widely used, as well as by their potential nutritional properties, resulting in novel gourmet and healthy oils, with added value for the consumers as compared to the most common industrial refined vegetable oils, the present study was conducted to provide information on the content and composition of the oil in two *Pistacia* species, and secondly to evaluate the total phenol and flavonoid content, also their antioxidant activity as a source of edible or non-edible oils.

## Materials and Methods

### *Plant material*

To determine the amount of oils, fatty acid compositions and antioxidant properties of two *Pistacia* species in Iran including *P. atlantica* and *P. khinjuk* were investigated. Fruits were collected in September of 2017 from natural forests in the mountains surrounding Kazerun city (Fars Province; Latitude 30° 2' 42.21" N and longitude 52° 16' 34.44" E, at an elevation of 860 meter). The sampling was done by randomized collection from 10–15 trees in an area of about 5000 $m^2$. Fruits were isolated manually from the panicle in the laboratory to obtain a weight of 1000–1200 g for each sample.

### *Oil extraction*

The fruits were milled using a grinder to obtain a fine powder. 30 g of a powdered sample from each species of plant fruits were extracted with n-hexane, using a Soxhlet extractor for 8 h. After extraction, the solvent was evaporated under reduced pressure at 60 °C to compute oxidizability (Cox), values for the oil samples were computed according to the formula proposed by Fatemi and Hammond (1980): Cox = [1(18 : 1%) + 10.3(18 : 2%) + 21.6(18 : 3%)]/100

### *Fatty acid profile*

Fatty acid composition was transformed into the corresponding methyl esters (FAME) using the method proposed by Metcalf et al. (1966), and analyzed using a gas chromatography system (Unicam 4600) equipped with a FID detector. A fused silica capillary column BPX70 [(30 m×0.22 mm i.d, 0.25 µm film thickness (SGE)] was used as the stationary phase and 0.2 µL of the FAME sample was injected into the chromatograph using a micro-syringe. Helium was the carrier gas with a head pressure of 18 psi and injector and detector temperatures were adjusted at 250 and 300 ºC, respectively. Oven temperature was set to 160 ºC for 5 min and subsequently increased by 2.0 ºC/min to 200 ºC and held at that level for 40 min. The FAME samples were identified through comparison of standards Sigma-Aldrich and the closest match to the retention time data. Fatty acid patterns were calculated and evaluated from the identified fatty acids.

### *Total phenol content*

Total phenolic compounds were determined using Folin-Ciocalteu reagent (Liu and Yao, 2007). Briefly, 0.5 mL diluted extract solution was shaken for 1 min in a reaction mixture contained 250 µL of Folin–Ciocalteau reagent, and 3 mL of distilled water. After 3 min, 2 mL of 20% $Na_2CO_3$ was added and the mixture was shaken once again for 0.5 min. Absorbance was determined at 750 nm after 1.5 h of reaction at ambient temperature. After which total phenolic content was expressed as mg Gallic acid equivalent per gram of the oil using the standard curve.

### *Total flavonoid content*

Total flavonoid content was determined by utilizing aluminum chloride ($AlCl_3$) and using quercetin as a standard (Ordonez et al., 2006) The plant extract (400 µL) was added to 0.3 Ml distilled water followed by 5% $NaNO_2$ (0.03 ml). After 5 min rest at 25 °C, $AlCl_3$ (0.03 mL, 10%) was added. After a further 5 min rest, the reaction mixture was treated with 0.2 mL of 1 mM NaOH. Finally, the reaction mixture was diluted to 1 mL with water and the absorbance was measured at 510 nm. The results were expressed as mg quercetin QE/g of extract.

### *DPPH (2, 2'-diphenyl-1-picrylhydrazyl) radical scavenging assay*

Antioxidant activity was measured through use of the DPPH free radical scavenging method (Akroum et al., 2010). The stock solution of the oil was prepared at 2 mg/mL of ethanol. Then a serial dilution of 50% was made to obtain 8 concentration ranges (1000-7.8 µg/mL).

After that, 550 µL of the DPPH solution (1 mg/10 mL) was mixed with 50 µL of the oil solution. After 30 min of incubation in the dark, at room temperature, the absorbance of the mixture was read at 517 nm using a spectrophotometer. Radical scavenging activity was gauged based on the following equation:

Percentage of radical scavenging activity = $(Abs_{blank} - Abs_{sample})/Abs_{blank} \times 100$

where $A_{blank}$ is the absorbance of the control reaction, and $A_{sample}$ is the absorbance of the test compound. The extract IC50 values were calculated from the graph plotting inhibition percentage against extract concentration.

### *β-carotene-linoleic acid assay*

The antioxidant activity of the extract was determined using *β*-carotene Linoleic acid model system (Jayaprakasha et al., 2001). The carotene solution was prepared by dissolving 0.2 mg $mL^{-1}$ in chloroform. All the samples were assayed in triplicate. The antioxidant activity (AA) was calculated in terms of the percentage inhibition relative to the control, using the following equation:

$AA = (R_{control} - R_{sample})/R_{control} \times 100.$

where $R_{Control}$ and $R_{Sample}$ are average bleaching rates of the negative control and the antioxidant (plant extracts or BHT), respectively.

### *Statistical analysis*

Statistical analysis of data was performed using a T-test by SPSS version 16. (SPSS Inc., Chicago, USA).The analysis was performed in triplicate and the mean values and standard error were reported.

## Results

### *Oil content*

The results of statistical analysis showed significant differences in the oil content between the two species of *Pistacia*. The Soxhlet extraction gave higher oil yield for *Pistacia khinjuk* (31.00 ± 0.577%) when compared to *Pistacia atlantica* (24.33 ± 0.333%) (Table 1).

**Table 1. The amount of oil extracted from the kernel samples**

| Sample | Oil Content (%) |
|---|---|
| *P. atlantica* | 24.33 ± 0.333 |
| *P. khinjuk* | 31.00 ± 0.577 |

### *Fatty acid composition*

The fatty acid compositions (% weight of FAME) of the two investigated *Pistacia* species are summarized in Table 2. Results indicated that kernels of *Pistacia* species are identifiable by the presence of Palmitic, Oleic, Stearic, Linoleic and Palmitoleic acids. Gas chromatography analysis indicated that oils of both investigated species contained high amounts of monounsaturated fatty acids (MUFA) followed by saturated fatty acids (SFA), while polyunsaturated fatty acids (PUFA) were presented in lower contents. Unsaturated fatty acids comprised around 80% of the fatty acids in both of the assayed oils (Fig. 1).

The most dominant fatty acids in *P. atlantica* and *P. khinjuk* were Oleic acid (53.15% and 51.49%), Linoleic acid (20.41% and 16.43%) and Palmitic acid (20.20% and 23.32%), respectively. Saturated fatty acid (SFA) contents of *P. atlantica* and *P. khinjuk* were 22.59% and 25.22%, respectively.

The results showed that *P. atlantica* and *P. khinjuk* are rich in these types of fatty acids with amounts of 21.12% and 17.32%, respectively. USFA/SFA ratio is considered as a normative of the tendency of oils to self-oxidative reactions. These amounts in *P. atlantica* and *P. khinjuk* were 3.43 and 2.97, respectively (Table 2).

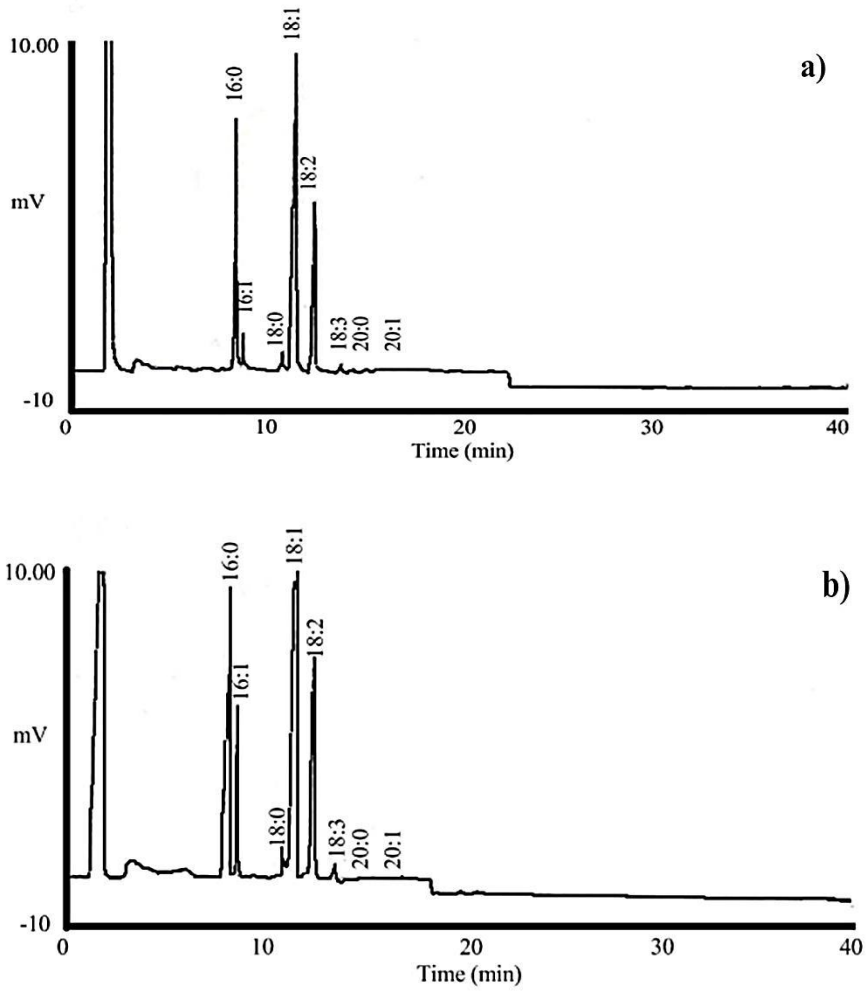


**Fig. 1. Chromatograms of fatty acids composition of oil extracted from kernels of *Pistacia atlantica (*a) and *Pistacia khinjuk* (b) fruits.**

**Table 2. Fatty acid composition of oils obtained from kernels of two *Pistacia* species**

| Fatty acid | Symbol | Content (%) | |
|---|---|---|---|
| | | *P. atlantica* | *P. khinjuk* |
| Palmitic acid | C16:00 | 20.20± 0.035 | 23.32± 0.026 |
| Palmitoleic acid | C16:01 | 2.97± 0.041 | 5.83± 0.023 |
| Heptadecanoic acid | C17:00 | 0.06± 0.017 | 0.03± 0.002 |
| *cis*-10-heptadecenoic acid | C17:01 | --- | 0.09± 0.002 |
| Stearic acid | C18:00 | 2.02± 0.088 | 1.84± 0.049 |
| Oleic acid | C18:01 | 53.15± 0.195 | 51.49± 0.041 |
| Linoleic acid | C18:02 | 20.41± 0.168 | 16.43± 0.039 |
| α-linolenic acid | C18:03 | 0.71± 0.036 | 0.89± 0.011 |
| Arachidic acid | C20:00 | 0.15± 0.027 | 0.03± 0.019 |
| *cis*-11-Eicosenoic acid | C20:01 | 0.32± 0.058 | 0.11± 0.003 |
| ΣSFA | / | 22.59 | 25.22 |
| ΣMUFA | / | 56.44 | 57.52 |
| ΣPUFA | / | 21.12 | 17.32 |
| USFA/SFA ratio | / | 3.43 | 2.97 |
| Oxidizability (Cox) value | / | 2.79 | 2.40 |

Note: *SFA*, saturated fatty acids; *MUFA*, monounsaturated fatty acids; *PUFA*, polyunsaturated fatty acids; *Cox*, calculated oxidizability.

***Total phenol and flavonoid***

According to the obtained results, total phenol and flavonoid contents showed significant differences between the two species of *Pistacia* (Table 3). Total phenol content of *P. atlantica* and *P. khinjuk* were 130.77± 3.11 mg gallic acid/100 g oil and 126.91 ± 4.41 mg quercetin/100 g oil, respectively. Total flavonoid content of *P. atlantica* and *P. khinjuk* were 302.64 ±21.87 mg gallic acid/100 g oil and 255.29 ± 40.41 mg quercetin/ 100 g oil, respectively (Table 3).

***DPPH radical scavenging assay***

DPPH radical scavenging assay showed significant differences between the two species of *Pistacia*. The concentration of *P. atlantica* and *P. khinjuk* extracts, which resulted in 50% of radical inhibition, is shown in Table 3. The range of antioxidant potential revealed in the research showed *P. khinjuk* extract with 15.733 ± 0.689 mg/g having higher inhibitory power than *P. atlantica* extract, with a value of 4.545 ± 0.655 mg/g.

***β-carotene-linoleic acid assay***

The result is the loss of conjugation and, therefore, a decrease in absorbance at 470 nm. Antioxidants present in the solution can prevent the destruction of *β*-carotene reaction with the linoleate free radical or any other radical formed in the solution. The inhibition ratios of the oxidation of Linoleic acid by *P. atlantica* and *P. khinjuk* were 38±0.57% and 62±1.20%, respectively (Table 3).

**Table 3. Comparison of total phenol, total flavonoid and antioxidant activity of kernels belonging to two *Pistacio* species**

| Sample | β-Carotene linoleic acid Inhibition (%) | DPPH assay IC50 (mg/g) | Phenol content (mg Gallic acid/100 g oil) | Total Flavonoids (mg Quercetin/ 100 g oil) |
|---|---|---|---|---|
| *P. atlantica* | 38.00±0.57 | 4.545 ± 0.655 | 130.77 ± 3.11 | 126.91 ± 4.41 |
| *P. khinjuk* | 62.00±1.20 | 15.733 ± 0.689 | 302.64 ±21.87 | 255.29 ± 40.41 |

## Discussion

The main reasons for increased interest in *Pistacia* nuts are due to their high oil content and healthy fatty acid profile. According to the obtained results, the two species of *Pistacia* can be considered as good sources of vegetable oils. Although the amount of oil is lower when compared to yields from *Pistacia vera*, it generally contains 50-62 % of oil (Satil et al., 2003; Catalán et al., 2017; Ojeda-Amador et al., 2018). The same results were reported by other studies on *P. khinjuk*, *P. vera* and *P. atlantica* (Mortazavi et al., 2015; Dini et al., 2016; Mohammadi et al., 2019; Labdelli et al., 2019). The high amounts of oil in the kernels of these plants, especially when compared to other oil seed crops; highlight them as possible commercial sources of plant oil.

Numerous studies have reported that the fatty acid composition of *Pistacia* oils shows a high Oleic acid content, from 51% to 81% (Arena et al., 2007; Sena-Moreno et al., 2015; Esteki et al., 2019), which is higher than many other seed oils (FAO-WHO Codex Stan 210-1999). An investigation into the fatty acid composition of three *Pistacia* species revealed that the main fatty acid component found in *P. khinjuk*, *P. vera* and *P. atlantica* oils is Oleic acid, while Linoleic acid is a secondary most abundant fatty acid in *P. vera* and *P. atlantica* oils, whereas in *P. khinjuk* oil there was no significant difference between Linoleic acid and Palmitic acid contents (Tavakoli and Pazhouhanmehr, 2010). Among nuts, *Pistacia* (*Pistacia* spp.) exhibit interesting nutritional properties because they contain cardioprotective constituents, such as a high Oleic acid content, phytosterols, phenolics

and tocopherols, making it potentially as a high antioxidant and anti-inflammatory food product (Tavakoli and Pazhouhanmehr 2010).

Oleic acid is an essential fatty acid that plays a vital and effective role in the maintenance of the human health. Its high oxidative stability is due to low PUFA contents. The important role of this essential fatty acid in the human body means that natural materials containing this fatty acid may be of strategic importance. Essential fatty acids are only absorbed by the human body from food stuffs; the human body is not capable of synthesizing them.

One of the most important fatty acids for lowering blood cholesterol is α-linolenic acid (ω-3 fatty acid). Foods containing ω-3 are recommended for health, especially for the prevention of cardiovascular disease. Due to the existence of α-linolenic acid, *P. atlantica* and *P. khinjuk* can also be identified as a good plant source of ω-3. The fatty acid composition of *Pistacia* oil is important for edible source seed oils.

Fatty acids that contain several unsaturated bunches, which play vital and effective roles in lowering blood plasma cholesterol levels (Mattson and Grundy, 1985). *Pistacia* is rich in unsaturated fatty acid. The high unsaturated/saturated fatty acid ratio found in *P. atlantica* (3.43) and *P. khinjuk* (2.97) make them to be a worthwhile source of unsaturated fatty acids. Regarding the well-documented harmful effects of SFA and food values of PUFA, the optimum oil in terms of food value is reported to be *P. atlantica*, based on the obtained result in the present study.

The oxidizing index indicates the sensitivity of the oil to oxidation (Parker et al., 2003). According to the above index, both species *P. atlantica* (2.79) and *P. khinjuk* (2.40) can be considered as sources of stable oils. A similar result has been reported in *P. khinjuk* (Tavakoli et al., 2016). There is usually a reverse relationship between the PUFA/SFA ratio and the oxidizability value from edible oils and their oxidative stability (Tavakoli et al., 2016). According to the obtained results, it is expected that *P. atlantica* contains oil with appropriate oxidative stability, when compared to *P. khinjuk.*

There is a positive correlation between phenols and antioxidant activity for different nuts (Akbari et al., 2012; Hatamnia et al., 2014; Hatamnia et al., 2016b). High amounts of polyunsaturated fatty acids result in poor oxidative durability and short shelf life of oils (Bodoira et al., 2017). Previous studies have shown that high levels of phenolic compounds are a major cause of the antioxidant activity of seed oils. Phenolic compounds are natural antioxidants and key factors for estimating the quality of edible seed oils. According to this study, *P. atlantica* and *P. khinjuk* fruits are good sources of phenolic compounds, which are well known for their antioxidant attributes. Higher antioxidant activity of *P. atlantica* seed oil, compared to the *P. khinjuk* kernel oil, could be because of its higher amounts of phenolic content.

DPPH radical scavenging activity is enhanced by the total phenolic content. Obtained results are in agreement with that reported by Won et al. (2013) and Dong et al. (2015), who reported a positive relationship between antioxidant activity and phenol contents.

*β*-carotene-linoleic acid assay is based on the change in the color of *β* -carotene in reaction with Linoleic acid free radical. This radical is formed at high temperature by removing the hydrogen atom between two double bonds of Linoleic acid (Amarowicz et al., 2004). The antioxidant activity of *P. khinjuk* was higher than that of *P. atlantica*. *β* -carotene/linoleic acid model system are in consistent with the data obtained from DPPH assay.

## Conclusion

*P. atlantica* and *P. khinjuk* kernels are good sources of food oil because of their

proper oil content, essential fatty acids including Oleic acid, Palmitic acid, Linoleic acid, α-Linolenic acid (ω-3) and polyunsaturated fatty acids as well as their high antioxidant properties. Fatty acid composition and high levels of antioxidants are the most important factors for oxidative stability of the *Pistacia* oil and the cause of longer shelf-life of the oil of wild *Pistacia* types, when compared to other commercial varieties. Nowadays, the consumption of foods containing ω-3 is recommended for health, especially for the prevention of cardiovascular diseases. It is also possible to use *P. atlantica* and *P. khinjuk* as a seed oil source containing ω-3. According to the obtained data and previous reports, it can be concluded that the use of *P. atlantica* and *P. khinjuk* oils is characterized as good plant oil in respect to their quality and taste when compared to other edible oils and their oils can be considered as good oils with multiple nutritional values. Therefore, due to high oil content in *P. atlantica* and *P. khinjuk*, which characterized with high nutritional value (high levels of unsaturated and essential fatty acids), cultivation and development of these plants as new oil sources for industrial use and as a substitute for the other oils can be recommended.

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## Conflict of interest

The authors declare that they have no conflict of interest.

## References

1. Akbari V, Jamei R, Heidari R. Esfahlan A.J. 2012. Antiradical activity of different parts of Walnut (*Juglans regia* L.) fruit as a function of genotype. Food Chemistry 135(4), 2404–2410.
2. Akroum S, Bendjeddou D, Satta D, Lalaoui K. 2010. Antibacterial, antioxidant and acute toxicity tests on flavonoids extracted from some medicinal plants. International Journal of Green Pharmacy 4(3), 165-169.
3. Amarowicz R, Pegg R.B, Rahimi Moghaddam P, Barl B, Weil J.A. 2004. Free radical scavenging capacity and antioxidant activity of selected plant species from the Canadian prairies. Food Chemistry 84(4), 551–562.
4. Arena E, Campisi S, Fallico B, Maccarone E. 2007. Distribution of fatty acids and phytosterols as a criterion to discriminate geographic origin of pistachio seeds. Food Chemistry 104(1), 403–408.
5. Asadollahzadeh H, Shamspur T. 2013. Chemical composition of the extracts of fruits of *Pistaciaatlantica* Desf. from Kerman Province in Iran. Journal of Essential Oil Bearing Plants16 (2), 243-246.
6. Bodoira R.M, Penci M.C, Ribotta P.D, Martinez M.L. 2017. Chia (*Salvia hispanica* L.) oil stability: Study of the effect of natural antioxidants'. The Journal of Food Science and Technology 75(2017), 107- 113.
7. Bozorgi M, Memariani Z, Mobli M, Salehi Surmaghi M.H, Shams Ardekani M.R, Rahimi R. 2013. Five *Pistacia* species (*P. vera*, *P. atlantica*, *P. terebinthus*, *P. khinjuk*, and *P. lentiscus*): a review of their traditional uses, phytochemistry, and pharmacology. Scientific World Journal 2013,1-33.Article ID 219815.
8. Catalán L, Alvarez-Ortí M, Pardo-Giménez A, Gómez R, Rabadán, A, Pardo J. E, 2017. *Pistachio* oil: A review on its chemical composition, extraction systems, and uses. European Journal of Lipid Science and Technology 119(5), 1–8.
9. Dini A, Farrokhi H, Sedaghat N, Bagheri M, Mohammad khani N. 2016. Evaluation of oxidative stability and shelf-life prediction of *Pistachio* oil using Rancimat. Journal of Rafsanjan University of Medical Sciences 15(5), 399-412.
10. Dong H, Zhang Q, Li L, Liu J, Shen L, Li H,Qin W. 2015. Antioxidant activity and chemical compositions of essential oil and ethanol extract of *Chuanminshenviolaceum*. Industrial Crops and Products 76, 290–297.
11. Dorehgirae A, Pourabdolah E. 2015. Composition of chemical profile of oil extracted from *Pistacia atlantica*s ubsp. cabulica with *Pistacia atlantica*s ubsp. *mutica*. Pakistan Journal of Biological Sciences 25(1), 1-6.

12. Esteki M, Ahmadi P, Vander Heyden Y, Simal-Gandara J. 2019. Fatty acids-based quality index to differentiate worldwide commercial Pistachio cultivars. Molecules 24(1), 58.

13. Ezatpour B, SaediDezaki E, Mahmoudvand H, Azadpour M, Ezzatkhah F. 2015. In vitro and in vivo anti-leishmanial effects of *Pistacia khinjuk* against *Leishmania tropica* and *Leishmania major*. Evidence-Based Complementary and Alternative Medicine. Article ID 149707.

14. Farhoosh R, TavassoliKafrani M.H, Sharif A. 2011. Antioxidant activity of the fractions separated from the unsaponifiable matter of benehull oil. Food Chemistry 126(2), 583–589.

15. FAO-WHO Codex Stan 210.1999. Standard for named vegetable oils. Revision 2009 and Amendment 2015.

16. Fatemi S. H, Hammond E.G. 1980. Analysis of oleate, linoleate and linolenate hydroperoxides in oxidized ester mixtures. Journal of Lipids 15(5), 379–385.

17. Ghasemynasabparizi M, Ahmadi A, Mazloomi S.M. 2015. A review on pistachio: Its composition and benefits regarding the prevention or treatment of diseases. Journal of Occupational Health and Epidemiology 4(1):57-69.

18. Ghasemi Pirbalouti A.G, Aghaee K. 2011. Chemical composition of essential oil of Pistacia khinjuk stocks grown in Bakhtiari Zagross Mountains, Iran. Electronic Journal of Biology 7:67-69.

19. Gourine N, Yousfi M, Bombarda I, Nadjemi B, Stocker P, Gaydou E.M. 2010. Antioxidant activities and chemical composition of essential oil of *Pistacia atlantica* from Algeria. Industrial Crop and Products 31(2), 203–208.

20. Hacıbekiroğlu II., Yılmaz P.K, Ha¸imi N, Kılınç E, Tolan V, Kolak U. 2015. In vitro biological activities and fatty acid profiles of *Pistacia terebinthus* fruits and *Pistacia khinjuk* seeds. Natural product research 4; 29(5):444-6.

21. Hatamnia A.A, Abbaspour N, Darvishzadeh R. 2014. Antioxidant activity and phenolic profile of different parts of Bene (*Pistacia atlantica subsp. kurdica*) fruits. Food Chemistry 145, 306–311.

22. Hatamnia A.A, Rostamzad A, Hosseini M, Abbaspour N, Darvishzadeh R, Malekzadeh P, Aminzadeh B.M. 2016a. Antioxidant capacity and phenolic composition of leaves from ten Bene (*Pistacia atlantica subsp. kurdica*) genotypes. Natural Product Research 30(5), 600-604.

23. Hatamnia A, Rostamzad A, Malekzadeh P, Darvishzadeh R, Abbaspour N, Hosseini M, Nourollahi K H, Sheikh AkbariMehr R. 2016b. Antioxidant activity of different parts of *Pistacia khinjuk* Stocks fruit and its correlation to phenolic composition. Natural Product Research 30(12), 1445- 1450.

24. HosseinGoli A, Barzegar M, Sahari M.A. 2005. Antioxidant activity and total phenolic compounds of pistachio (*Pistachiavera*) hull extracts. Food Chemistry 92(3), 521–52.

25. Jayaprakasha G.K, Singh R.P, Sakariah K.K. 2001. Antioxidant activity of grape seed (*Vitisvinifera*).Food Chemistry 73(3), 285-290.

26. Labdelli A, Zemour K, Simon V, Cerny M, Adda A,Merah O. 2019. *Pistaciaatlantica*Desf., a source of healthy vegetable oil. Applied Sciences 9(12), 2552.

27. Liu Q, Yao H. 2007. Antioxidant activities of barley seeds extracts. Food Chemistry 102(3), 732–737.

28. Mattson F.H, Grundy S.M. 1985. Comparison of effects of dietary saturated, monounsaturated and polyunsaturated fatty acids on plasma lipids and lipoproteins in man. Journal of Lipid Research 26(2), 194-202.

29. Matthäus B, Özcan M.M. 2006. Quantitation of Fatty Acids, Sterols, and Tocopherols in Turpentine (*Pistacia terebinthu*s Chia) Growing Wild in Turkey. Journal of Agricultural and Food Chemistry 4;54 (20):7667-7671.

30. Martínez M.L, Fabani M.P, Baroni M.V, Huaman R.N, Ighani M, Maestri D.M, Wunderlin D, Tapia A, Feresin G.E. 2016. Argentinian pistachio oil and flour: a potential novel approach of pistachio nut utilization. Journal of Food Science and Technology 53(5):2260-9.

31. Metcalf L.C, Shmitz A.A, Pelka J.R. 1966. Rapid preparation of methyl esters from lipid for gas chromatography analysis. Analytical Chemistry 38, 514 – 515.

32. Moazzami Farida S.H, Radjabian T, Salami S.A.R, Ranjbar M, Taghizadeh M, Rahmani N. 2015. Fatty acid composition and phytosterol contents of the seeds from three *Salvia* L. species growing in Iran. Journal of Plant Research (Iranian Journal of Biology) 28(2), 421-433.

33. Mohammadi B, Maboud H.E, Seyedi S.M. 2019. Nutritional value and antioxidant properties of hull and kernel in *Pistacia*

*atlantica* and *Pistacia khinjuk* fruits. Journal of food science and technology 56(8), 3571-3578.

34. Mortazavi S.H, Azadmard-Damirchi S, Mahmudi R, Sowti M , Mahmoudi R. 2015. Chemical composition and antioxidant properties of hull and core of *Pistacia khinjuk* stocks. Iranian Food Science and Technology Research Journal 11(4), 408.
35. Mozaffarian V. 2005. Trees and Shrubs of Iran. 1st ed. Tehran, Iran.
36. Ojeda-Amador R.M, Fregapane G, Salvador, M.D. 2018. Composition and properties of virgin pistachio oils and their by-products from different cultivars. Food Chemistry 240,123–130.
37. Ordonez A.A.L, Gomez J.D, Vattuone M.A, Isla M.I. 2006. Antioxidant activities of *Sechiumedule* (Jacq.) Swartz extracts". Food Chemistry 97(3), 452-458.
38. Parker T.D, Adams D.A, Zhou K, Harris M, Yu L. 2003. Fatty acid composition and oxidative stability of cold-pressed edible seed oils. Journal of Food Science 68(4), 1240-3.
39. Pietta, P.G. 2000. Flavonoids as antioxidants. Journal of Natural Products 63(7): 1035–1042.
40. Ramadan M.F. 2019. Chemistry and Functionality of Fruit Oils: An Introduction. In: Ramadan M. (eds) Fruit Oils: Chemistry and Functionality. Springer, Cham. https://doi.org/10.1007/978-3-030-12473-1_1.
41. Salvador M.D, Ojeda-Amador R.M, Fregapane G. 2019. Virgin Pistachio (*Pistachia vera* L.) Oil. In: Fruit Oils: Chemistry and Functionality, Springer, Cham, 181-197.
42. Satil F, Azcan N, Baser K.H.C. 2003. Fatty Acid Composition of Pistachio Nuts in Turkey. Chemistry of Natural Compounds 39, 322-324.
43. Sena-Moreno E, Pardo J.E, Catalán L, Gómez R, Pardo-Giménez A, Alvarez-Ortí M. 2015. Drying temperature and extraction method influence physicochemical and sensory characteristics of pistachio oils. European Journal of Lipid Science and Technology 117(5), 684–691.
44. SoleimanBeigi M, Arzehgar Z. 2013. A review study on chemical properties and food indexes of mastic oil compared with olive, sunflower and canola oils. The Ilamian Traditional Uses of Mastic. Sjimu. 21(5), 1-13.
45. Tsantili E, Takidelli C, Christopoulos M V, Lambrinea E, Rouskas D, Roussos P.A. (2010). Physical, compositional and sensory differences in nuts among pistachio (*Pistachia vera* L.) varieties. Scientia Horticulturae, 125(4), 562–568.
46. Tavakoli J, Hamedani F, Haddad khodaparast M.H. 2016. Investigating Chemical properties and oxidative stability of kernel oil from *Pistacia khinjuk* growing wild in Iran. Journal of the American Oil Chemists' Society 93(5), 681–687.
47. Tavakoli J, Pazhouhanmehr S. 2010. Fatty acid composition of oils from fruits of three *Pistacia* species growing in Iran. Chemistry of Natural Compounds. 46 (4), 623-624.
48. Tomaino A, Martorana M, Arcoraci T, Monteleone D, Giovinazzo C, Saija A. 2010. Antioxidant activity and phenolic profile of pistachio (*Pistacia vera* L., variety Bronte) seeds and skins. Biochimie 92(9), 1115–1122.
49. Won T.K, Kim T, Kim C, Park N. 2013. Antioxidant activity of various solvent fractions from edible brown alga. Journal of Food Science 78, C679–C684.