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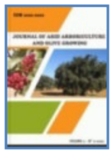

Physico-chemical characteristics of pistachio kernel accessions growing under South Mediterranean conditions

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Abstract

In the Mediterranean region, pistachio mainly grows under rainfed conditions generating relatively low and alternating yields. This study focused on kernel quality assessment for their possible valorization to compensate for these low performances. The biochemical and mineral characteristics of seven pistachio kernel accessions (Mateur', 'El Guettar', 'Meknassy', 'Achouri', 'Kermezi', 'TLII/3', and 'TL6/6') were determined. The studied parameters were moisture content, fat content, biochemical analyses of the oil, and mineral composition of kernel powder after oil extraction. Results showed that all studied accessions ranged in the quality level of international standards for moisture rates (37- 4.7%). Fat content varied from 28% (TL 6/6) and 61.3% (Achouri). The oil's fatty acid compositions exhibited high variations in oleic, linoleic, and linolenic acids between the studied accessions. The oleic/linoleic (O/L) acid ratios, commonly used to predict the oil's chemical stability and shelf life, were comparable to those reported in other producing countries and ranged between 2.7 and 4.9. The obtained results distinguish a few varieties according to their kernel qualities: Achouri for the oil chemical stability and the high fat and oleic acid contents; TL II/3 was the richest in chlorophylls, carotenoids, and polyphenols indicating high antioxidant capacities; Meknassy for its richness in potassium and calcium and its high oil yield; and El Guettar for the yield and stability of its oil and the richness of its kernels in proteins and potassium.

Keywords: Pistachio; Kernel quality; Oil content; Fatty acids; Mineral compositions.

1. Introduction

Pistachio (*Pistaciavera* L.) crop cultivation gains interest in many arid and semi-arid regions for ecological and economic reasons (Yarahmadi and Amini, 2021). Due to its adaptation ability to dry conditions, this species can play a major role in rehabilitating low-productive lands for other species with higher bioclimatic and agronomic needs (Moriana et al., 2018). The nutritional value and gustative features of pistachio kernels make it a highly sought-after product in the luxury confectionery and pastry industry sectors. Pistachio kernel oil is rich in monounsaturated fatty acids and polyphenols which have beneficial effects on the cardiovascular system (Esteki et al., 2018).

In the Mediterranean region, pistachio is mainly growing under rainfed conditions generating relatively low and alternating yields. Under these conditions, producing fruits that can be used in the agro-food, pharmaceutical, and/or cosmetic industries would contribute to an added socio-economic value that could compensate for the relatively low yields in these growing conditions (Ouni et al., 2022).

The objective of this work was to determine the qualitative characteristics of different accessions (cultivars and local genotypes) of pistachio trees conducted under rainfed conditions in the experimental orchards of the National Institute of Agronomic Research of Tunisia (INRAT) in the Mornag North-Eastern area. The distinctive physico-chemical characteristics of each accession were determined in order to seek ways for their valorisation.

2. Materials and methods

2.1. Plant material

This study is carried out on shelled pistachios of seven accessions (5 cultivars and 2 local types). 'Mateur', 'El Guettar', and 'Meknassy' are native cultivars. 'Achouri' and 'Kermezi' cultivars originated from Syria and Turkey, respectively. The local types are 'TLII/3' and 'TL6/6' (fig. 1). Fruits were sampled from collections of pistachio cultivars and ecotypes of the INRAT (National Institute of Agronomic Research of Tunisia) in the northeasternMornag area. Trees were conducted under rainfed conditions. After de-hulling, nuts were firstly air dried at the physical laboratory conditions for 5 days before being submitted to a second drying process in an oven at 50°C ± 2°C for 24 hours. After nut shelling, kernels have been used for various analyses. Experiments were carried out on at least three replicates per accession.

Fig. 1: Pistachio kernels of studied accessions (bars represent 1cm)

2.2. Kernel moisture rate

Moisture content of kernels was determined by considering the weight before and after drying in the oven at 105°C until weight stabilization. The humidity rate (H) wascalculatedaccording to *Equation (1):*

$$H\% = (M - DW) * 100/M$$

Where M= Mass before drying (g)
DW= Dry weight (g)

2.3. Fat content

Kernel oil was extracted using the Soxhlet apparatus with hexane as the organic solvent. The fat yield is expressed as a percentage of fruit weight before oven drying. The oil obtained was used to determine the biochemical characteristics of studied accessions.

2.4. Biochemical characteristics of the oil

2.4.1. Fattyacid composition

The fatty acid methyl esters (FAME) compositions of oils were determined by gas chromatography. A volume of 0.25 ml of oil was added to 0.3 ml of KOH (2N) methanolic solution and 3 ml of hexane in a test tube. After stirring for 3 minutes and decantation, one microliter of the supernatant was injected into a Shimadzul17A apparatus with a flame ionization detector and capillary column. The detector placed at the outlet of the column makes it possible to identify the concentration of each component and convert it into an electrical signal.Peaks of recordedcurvesrepresenteach component.

2.4.2. Carotenoids

To determine the carotenoid content, the absorbance at 470 nm was measured for an oil-cyclohexane solution containing 3 g of oil and 10 ml of cyclohexane (Minguez-Mosquera et al., 1991).The carotenoid fraction is calculated according to *Equation (2)*.

$$\text{Carotènes (ppm)} = \frac{\boldsymbol{A470 \times 25 \times 1000}}{\boldsymbol{E0 \times 7{,}5}}$$

Where, A470: Absorbance at 470 nm

E0: Specific extinction =2000

2.4.3. Chlorophylls

The total chlorophyll (Chl) contents were determined according to the method described by Wolff (1968), based on quantification using a spectrophotometer in the visible range. The concentration of chlorophyll pigments was calculated according to *Equation 3*.

$$\text{Chl (ppm)} = \frac{\boldsymbol{A670 - \frac{A630 + A710}{2}}}{(\boldsymbol{0{,}1086 \times L})}$$

Where, A 630: Absorbance at 630 nm

A 670: Absorbance at 670 nm

A710: Absorbance at 710 nm

L (cm): Cuve thickness

2.4.4. Polyphenol contents

The quantitative determination of phenolic compounds was carried out according to the colorimetric method using the FolinCiocalteu reagent. A mass of 2.5 g of the oil sample was placed in a conical tube in which was added 5 ml of hexane then 5 ml of a methanolic solution (60% methanol and 40% water). After vortexing for 2 min, the mixture was centrifuged at 3500 rpm for 10 min. A volume of 0.2 ml was recovered from the methanolic phase and poured into a 10 ml volumetric flask where were added 0.5 ml of the Folinciocalteu reagent and 1 ml of a 30% sodium carbonate solution. The volume is adjusted to 10 ml with distilled water. After incubation in the dark for 2 hours, the absorbance is measured at 726 nm. The concentration of total polyphenols (TP) was expressed in equivalent gallic? acid and calculated according to *Equation (4)*.

(4) $P(ppm) = (833.3 * A726) + 10.25$

Where, A726: Absorbance at 726 nm

2.5. Mineral composition

Kernel mineral compositions were determined using the vegetable powder remaining after fat extraction. The total nitrogen (N) was determined after mineralization of plant ash with sulfuric acid followed by digestion using the Kjehldahl technique. Protein content was determined by converting N value using the coefficient 5.3 (FAO, 2020). For phosphorus (P), potassium (K), calcium (Ca) and sodium (Na) analyses an extract of the vegetable powder was obtained after calcination at 450°C then mineralization. For digestion, a mass of 0.5 g of each sample was dissolved in 10 ml of nitric acid solution (1N) then heated at 70°C until boiling. Solutions were filtered and conserved in 100 ml flasks before use. The colorimetric method of Olsen was used for P determination. The dosage of K and Na was carried out by flame photometry. Ca content wasdeterminedusingatomic absorption spectrophotometer.

2.6. Statistics

Data were analyzed by one-way analysis of variance (ANOVA) using SPSS 20 software of Windows. For mean comparisons, the Duncan multiple range test was used at $p \leq 0.05$.

3. Results and discussions

3.1. Moisture rate and fat content

The moisture rates of all studied kernels ranged between 3.7% and 4.7%. These rates were below the maximum moisture threshold level of 6.5% defined by the United Nations Economic Commission for Europe (UNECE, 2010). The two local accessions TL6/6 and TLII/3 exhibited the highest and lowest values, respectively. Fat content varied between 28% and 61.3% with Achouri, Meknassy and TLII/3 having the significantly highest percents compared to the other studied accessions. A high significant negative correlation (Pearson, r = -0.582) was found between moisture and fat content.

Table 1. Moisture and fat content of pistachio kernels

Variety/Accession	Humidity %	Fat content %
Mateur	$4.1^{bc} \pm 0.4$	$43.8^{b} \pm 6.7$
El Guettar	$4.5^{ab} \pm 0.2$	$36.0^{bc} \pm 17.4$
Meknassy	$4.4^{ab} \pm 0.2$	$56.9^{a} \pm 0.1$
Kermezi	$4.5^{a} \pm 0.0$	$37.0^{bc} \pm 5.7$
Achouri	$4.4^{ab} \pm 0.2$	$61.3^{a} \pm 6.3$
Tl6/6	$4.7^{a} \pm 0.0$	$28.0^{c} \pm 3.8$
TLII/3	$3.7^{c} \pm 0.2$	$57.8^{a} \pm 0.6$

3.2. Biochemical analyses

3.2.1. Fattyacid compositions

The fatty acid compositions of the studied accession kernels are shown in Table 2.Among all samples, oleic acid (C18:1) followed by linoleic acid (C18:2) and palmitic acid (C16:0) were the main fatty acids with respective rates varying from 64.6 to 74.3%; 15.1-24.0% and 7.9-8.6%.The highest variations between the pistachio accessions were noted for oleic, linoleic and linolenic acids. No significant differences were recorded for palmitic, pamitoleic, and heptadecanoic acids. The highest amount of oleic acid was found in Achouri kernel oil which recorded the lowest content in linoleic acid. Inversely, Meknassy oil was the poorest in oleic acid but the richest in linoleic acid among the all studied accessions. For fat-quality assessment and to predict chemical stability and shelf life of the oil, the oleic/linoleic (O/L) acid ratio is commonly used (Esteki et al., 2018). For the studied samples, this ratio ranged between 2.7 (for Meknassy) and 4.9 (for Achouri). These values were in similar ranges found on other pistachio varieties from different origins (Tsantili et al., 2010; Esteki et al., 2018; Yahyavi et al., 2020).

Table 2. Fatty acid composition of kernels of pistachio accessions

Accessions	C16:0	C16:1	C17:0	C17:1	C18:0	C18:1	C18:2	C18:3	C20:0	C20:1	O/L	U/S
Mateur	8,24^{a}	0,78^{a}	0,04^{ab}	0,07^{a}	1,31^{b}	68,11^{bc}	20,56^{bc}	0,29^{d}	0,12^{bc}	0,49^{b}	3.3	9.3
El Guettar	8,17^{a}	0,65^{a}	0,05^{a}	0,07^{a}	1,66^{ab}	70,28^{b}	18,04^{d}	0,37^{b}	0,18^{a}	0,50^{b}	3.9	8.9
Meknassy	7,87^{a}	0,70^{a}	0,06^{a}	0,06^{a}	1,64^{ab}	64,55^{d}	23,96^{a}	0,41^{a}	0,11^{cd}	0,62^{a}	2.7	9.3
Kermezi	7,92^{a}	0,85^{a}	0,04^{ab}	0,06^{a}	1,47^{ab}	70,15^{b}	18,84^{cd}	0,33^{c}	0,15^{ab}	0,48^{b}	3.7	9.5
Achouri	7,96^{a}	0,78^{a}	0,02^{b}	0,06^{a}	1,72^{ab}	74,32^{a}	15,09^{e}	0,25^{e}	0,11^{cd}	0,49^{b}	4.9	9.3
TL6/6	8,55^{a}	0,64^{a}	0,05^{a}	0,06^{a}	1,54^{ab}	67,37^{c}	21,42^{b}	0,39^{ab}	0,08^{d}	0,40^{c}	3.1	8.8
TLII/3	8,33^{a}	0,68^{a}	0,05^{a}	0,06^{a}	1,95^{a}	68,84^{bc}	19,09^{b-d}	0,36^{bc}	0,16^{ab}	0,50^{b}	3.6	8.5

C16 :0 : Palmitic acid ; C16 :1 : Palmitoleic acid ; C17 :0 : Heptadecanoïc acid ; C18 :0 : Stearic acid ; C18 :1 : Oleic acid ; C18 :2 : linoleic acid ; C18 :3 : linolenic acid ; C20 :0 : arachidic acid ; C20 :1 : Gadoleic acid; O/L: Oleic acid/Linoleic acid; U/S: Unsaturated fatty acids/Saturated fatty acids.

3.2.2. Chlorophylls, carotenoids, and polyphenols

The table 3 shows concentrations of chlorophylls, carotenoids and total polyphenols in the kernel oil of studied accessions. Chlorophylls ranged between 0.5 and 4.9 ppm while carotenoids varied between 21.7 and 28.3 ppm and polyphenol content variation was from 68.6 to 176.5 ppm. The TL II/3 accession oil was distinguished by the highest values of these respective components. Achouri and Mateur cultivars exhibited the lowest oil chlorophyll contents. The latter cultivar was the poorest in carotenoid pigments. Meknassy and Kermezi cultivars recorded the minimum values of polyphenol contents.

Table 3. Chlorophylls, carotenoids, and polyphenol contents of pistachio kernel oil of studied accessions

Accessions	Chlorophylls (ppm)	Carotenoids (ppm)	Polyphenols (ppm)
Mateur	1,0[c]	21,7[c]	125,4[ab]
El Guettar	2,1[bc]	24,3[bc]	117,5[ab]
Meknassy	2,8[b]	25,4[ab]	68,6[b]
Kermezi	0,5[c]	22,1[bc]	71,1[b]
Achouri	0,9[c]	22,3[bc]	129,4[ab]
Tl6/6	2,2[bc]	24,3[bc]	102,3[b]
TLII/3	4,9[a]	28,3[a]	176,5[a]

3.2.3. Mineral compositions

The mineral compositions of kernel powder of the studied accessions are shown in the table 4. Nitrogen and protein values (%) varied between 2.52 and 5.04, and 13.3 and 26.7, respectively with Kermezi having the richest nuts while Achouri and TL II/3 showing the lowest values. According to Dreher (2012), dried and roasted pistachio proteins were of 20.8%. Küçüköner and Yurt (2003) analyzed the kernel total protein contents of 5 pistachio varieties and found values ranged from 20.2 to 23.6%. Nut P varied from 0.36 % (El Guettar) to 0.64 % (Achouri). The nuts of Meknassy, Mateur and El Guettar local accessions recorded the highest K content. Those of TL 6/6 local type were the poorest in this component. Calcium content was comparable for all the studied accessions except of Meknassyvariety which showed the significantly highest value. TL 6/6 and El Guettar recorded the highest and lowest Na content respectively.

Table 4. Mineral composition (%DM) of the kernel powder

Accessions	N	Proteins	P	K	Ca	Na
Mateur	3,59[b]	19.0	0,41[b]	1,67[a]	0,10[b]	0,036[bc]
El Guettar	3,76[b]	20.0	0,36[b]	1,67[a]	0,09[b]	0,035[c]
Meknassy	3,37[b]	17.9	0,61[a]	1,79[a]	0,16[a]	0,039[bc]
Kermezi	5,04[a]	26.7	0,43[b]	1,63[ab]	0,08[b]	0,040[b]
Achouri	2,52[b]	13.3	0,64[a]	1,45[bc]	0,10[b]	0,036[bc]
TL6/6	2,86[b]	15.2	0,59[a]	1,34[c]	0,08[b]	0,046[a]
TLII/3	2,52[b]	13.4	0,39[b]	1,43[bc]	0,11[b]	0,036[bc]

4. Conclusion

This study aimed to evaluate the biochemical and mineral quality of pistachio nuts to find ways to promote both native and introduced resources. The obtained results distinguish a few varieties according to their kernel qualities. The Achouri variety was differentiated by the chemical stability of its oil and its high fat and oleic acid content. The local type TL II/3 was the richest in chlorophylls, carotenoids, and polyphenols indicating high antioxidant capacities. The local varieties Meknassy and El Guettar presented interesting characteristics: the first for its richness in potassium and calcium and its high oil yield; the second was for the yield and stability of its oil and the richness of its kernels in proteins and potassium. The potential valorisation of these varieties for their nut characteristics may give an added value to this product and compensate for the relatively low productivity of these accessions in the local cultural conditions. To give further assessment to these genetic resources, the analyses of other fat constituents such as tocopherols, sterols, and waxes are worth studying.

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