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Comparative study on fatty acid compounds of olive oil from syrian irradiated and stored olive fruits

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Abstract

The aim of this study was to assess the effect of gamma irradiation treatment at doses of 0, 1, 2 and 3 kGy, storage time of fruits for 0, 30 and 45 days and storage time of oils for 0, 6 and 12 months on fatty acid profile of olive oil produced in Syria. Results of this study showed that fatty acid composition was different based on irradiation dose and storage time of fruits and oils. Small change were observed in saturated, monounsaturated and polyunsaturated fatty acid components due to irradiation and storage. However, the changes in fatty acids composition of oil extracted from irradiated and stored fruits or oils were sometimes significant ($P<0.05$). The composition of fatty acids of analyzed oil samples was determined as palmitic acid (C16:0) from 13.25% to 14.60%; palmitoleic acid (C16:1) from 0.82% to 1.43%; stearic acid (C18:0) from 2.43% to 3.83%; oleic acid (C18:1) 68.95% to 72.64%; linoleic acid (C18:2) 7.65% to 11.93%; Linolenic acid (C18:3) from 0.41% to 1.09%. The present study demonstrated that the effect of gamma irradiation, fruit and oil storage on the fatty acid profile of virgin olive oil (VOO) was minimized.

Keywords: Olive oil, Fatty acid profile, Syria, fruit storage, oil storage

1. Introduction

Food and its manufacture are currently attracting significant scientific and public interest due to extensive media coverage of diet-related disease and their influence on the health and wellbeing of communities [1]. Vegetable oils are an indispensable part of everyday meal in most part of the world. Vegetable oils consist of a mixture of saturated fatty acids (SFA) and unsaturated fatty acids (USFA) such as palmitic (16:0), stearic (18:0), oleic (18:1), linoleic (18:2), linolenic (18:3) and archidonic (20:4) acids with different percentage, and differs from one oil to other [2]. The majority of olive oil fatty acid chains contain 16 or 18 carbon atoms. Olive oil not only contains oleic acid (18:1), but also small amounts of other fatty acids, such as palmitic, palitoleic, stearic, linoleic, and linolenic acids and squalene [3]. The importance of virgin olive oil (VOO) is related to its high levels of monounsaturated fatty acids (mainly oleic acid), and several antioxidants. Oil with higher monounsaturated fatty acids (MUFAs) and lower saturated fatty acids (SFAs) are preferred because of the proven beneficial effect of MUFAs on serum cholesterol levels [4, 5]. Although fatty acids are relatively similar in structure, there are some variation that have a strong influence on the properties [6, 7]. Fatty acids having less than 10 carbon atoms are liquids, and those having more than 10 carbon atoms are solids [2].

During ripening, olive fruit changes in terms of chemical composition. These changes also affect the oil composition; changes in fatty acids have been described during olive ripening [8]. Fatty acid composition has been shown to influence the stability of oils, and polyunsaturated fatty acids have been found to contribute to the rancidification of several oils [9].

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Food irradiation is proven to be the best technology in eliminating disease-causing pathogens from raw food products [10, 11]. Gamma irradiation at medium dose can be applied for improving the microbiological safety of raw food products [11]. Ionizing irradiation can chemically modify foods at high dosage, especially under aerobic conditions [12]. Lipids, including unsaturated fatty acids, are easily decomposed, saturated and isomerized by gamma irradiation [13, 14]. Alfaia et al. (2007) [15] showed that cis/trans conjugated linoleic acid decreased by irradiation. Additional, Hammer an Wills (1979) [16] reported that polyunsaturated fatty acids were destroyed in various oils in response to irradiation. Although irradiation has been found to be a useful process to increase the longevity of several agricultural products [17-19] but the effect of gamma irradiation and storage time on the fatty acids of olive oils produced or marked in Syria or in the regional countries has not been investigated. Therefore, this study investigated some changed induced in fatty acid profile of olive oil due to gamma irradiation and storage time of fruit and oils.

2. Materials and methods

The studied olive cultivar was Kaissy, the most widespread in Syria. The olive fruits of good quality and in the mature firm condition were harvested in the crop year 2008/2009, from the trees grown in grove located at Deer Al Hajar research station, southeast Damascus, Syria (33o 21´ N, 36o 28´ E) at 617 m above sea level, under conventional agriculture practices. Then olive fruits were weighed as in the sampling plan and transferred into polyethylene pouches for irradiation. Each pouch of olive fruits (1 kg) was considered as a replicate. The samples were then divided into four groups: group 1 (control) and groups 2, 3 and 4 were irradiated with 1, 2 and 3 kGy of gamma irradiation.

2.1. Irradiation treatments

Samples of olive fruits were exposed to gamma radiation at doses of 0, 1, 2 and 3 kGy in a ^{60}CO package irradiator (ROBO, Techsnabexport, Moscow, Russia). Irradiation was carried out in the stationary mode of operation with the possibility of varying dose rate (10.846 to 3.921 kGy h^{-1}) depending on the location and the distance from the source (10 to 40 cm).

The samples were irradiated at place (15 cm from source) with a dose rate of 9.571 kGy h^{-1}. The irradiations were carried out at room temperature (20 – 25 ºC) and atmospheric pressure. The absorbed dose was determined using alcoholic chlorobenzene dosimeter [17].

2.2. Oil extraction

The oils from control and irradiated olive fruits were extracted from olives stored at ambient temperature for 0, 30 and 45 days after irradiation using a mechanical and physical processes [20]. Olive fruits were crushed with hummer crusher and slowly mixed for about 30 min at 27 ºC, Then, the past mixed was centrifuged at 3000 rpm for 3 min without addition of water to extract the oil. Finally, the oils were decanted and immediately transferred into dark glass bottles and stored at room temperature (20 – 25 ºC). Fatty acid determination analysis of oils extracted from irradiated and non-irradiated olive fruit samples were performed immediately after irradiation, and after 6 and 12 months of storage.

2.3. Fatty acids (FA) determination

The fatty acid methyl esters (FAME) were prepared [11]. The fatty acids (FAs) profile was determined by gas chromatography in a GC- 17 A Shimadzu chromatograph (Shimadzu Corp., Koyoto, Japan) equipped with a flame ionization detector and a capillary column (CBP20-S25- 050, Shimadzu, Australia). The selected chromatographic conditions were; oven temperature 190 ºC, detector temperature 250 ºC, injector temperature 220 ºC; N2 was used as a carrier gas with split ratio 29:1, the sample volume injected was 1 µl. Peak areas were integrated and converted to FA percentages (direct area normalization) by means of the CLASS – VP 4.3 program (Shimadzu Scientific Instruments, Inc., Columbia, MD). The FA identification was carried out by retention times and by addition of standards.

2.4. Statistical analysis

The four treatments were distributed in a completely randomized design with three replicates. Data were subjected to the analysis of variance test (ANOVA) using the SUPERANOVA computer package (Abacus Concepts Inc, Berkeley, CA, USA; 1998). The p value of less than 0.05 was considered statistically. The degree of significance was denoted as: p<0.05*, p<0.01** [21].

3. Results and discussion

3.1. Effect of storage time on fatty acid profile of olive oil

Olive oils samples obtained from the olive fruits that stored at ambient temperature for 0, 30 and 45 days before extraction, and from oil that stored for 0, 6 and 12 months after extraction were analyzed for the composition of fatty acids using gas chromatographic methods. The mean FAME composition of a total of 54 samples of the oils from both irradiated and stored fruits is shown in Table 1. The palmitic acid (C16:0), palmitoleic acid (C16:1), stearic acid (C18:0), oleic acid (C18:1), linoleic acid (C18:2) and Linolenic acid (C18:3) of oil extracted from olives immediately after harvest (at day zero) were 13.92, 1.18, 2.87, 70.47, 10.87 and 0.69%, respectively. The results from this study, showed that the behavior of those fatty acids did not present a general trend and only slight differences, but sometime significant ($p<0.05$) have been found between the mean values observed for each analyzed samples (treatments). However, the palmitic, palmitoleic, stearic, oleic acid, linoleic and Linolenic acids were significantly ($p<0.05$) changed by storage time of olives. While only the palmitoleic and linoleic acids were significantly ($p<0.05$) changed by storage time of oils. The percentage of the fatty acids in the 54 analyzed samples ranged from 13.81 to 14.47% for palmitic acid (C16:0), from 0.83 to 1.43% for palmitoleic acid (C16:1), from 2.56 to 3.68% for stearic acid (C18:0), from 68.99 to 72.38% for oleic acid (C18:1), from 8.11 to 11.79 % for linoleic acid (C18:2), and from 0.48 to 1.09% for linolenic acid (C18:3) (Table 1). These value fall within the recommended International Oil Council for olive oils (IOC, 2015) [22]. Similar results were reported for fatty acid profile of virgin olive oils (Bajoub et al., 2015) [23]. Generally, olive oil contains 9.48-15.60% palmitic acid (C16:0), 0.67-1.40% palmitoleic acid (C16:1), 1.71-3.63% stearic acid (C18:0), 67.43-78.44% oleic acid (C18:1), 4.67-15.10% linoleic acid (C18:2), 0.03-1.15% linolenic acid (C18:3) and 0.17-0.90% arachidic acid (C20:0) (Sakar et al., 2014) [24]. Olive oil differs from the other vegetable oils by its high content in monounsaturated fatty acids (18:1, 16:1) and relatively low polyunsaturated acids (18:2, 18:3) [25]. The fatty acid composition of olive oil has been frequently used to group olive oil according to the cultivar of origin [26].

Tanilgan et al. (2007) [27] reported that fatty acids content of Turkish olive oil samples collected from five cultivar, oleic acid (65.7-83.6%) was present in the highest concentration followed by palmitic (8.1-15.2%), Linoleic (3.5-15.5%), stearic (2.0-5.6%), and linolenic (0.1-3.0%). The allowable fatty acids, according to the national and international regulations, ranges for extra virgin olive oil edible: (Palmitic (C16:0) (7.5-20.0%); Palmitolic (C16:1) (0.3-3.5%); Stearic (C18:0) (0.5-5.0%); Oleic (C18:1) (55.0-83.0%); Linoleic (C18:2) (3.5-21.0%); Linolenic (C18:3) (<1.0%); Arachidic (C20:0) (<0.6%); Gadoleic (C20:1) (<0.4%) [22]. The results are well within the IOC standards, implying that all oils sampled were of extra virgin quality [22].

3.1. Effect of gamma irradiation on fatty acid profile of olive oil

The composition of saturated, monounsaturated and polyunsaturated fatty acids of oil separated from non-irradiated and irradiated olive fruits under investigation that obtained by gas chromatography are listed in Table 2, 3 and 4, respectively. As shown in Tables, at all used irradiation doses and at all extracted and stored times of fruits and oils, small change were observed in saturated monounsaturated and polyunsaturated fatty acids components, but this small changes in fatty acids composition were sometimes significant ($P<0.05$). However, at day zero of fruit harvest and at month zero of oil storage, irradiation at 3 kGy significantly ($p<0.05$) increased the percentage of palmitic acid (C16:0) and Linoleic acid (C18:2).

The mean total saturated fatty acid (SFA), total unsaturated fatty acids (USFA) and the values of un-saturated/saturated index (USFA/SFA) of olive oils samples obtained from irradiated and non-irradiated olive fruits that stored at ambient temperature for 0, 30 and 45 days before extraction, and from oil that stored for 0, 6 and 12 months after extraction is shown in Table 5. Lipids of the olive oil samples had high content of unsaturated fatty acids (UFA) ranged from 81.59 and 84.02%, and low content of saturated fatty acids (SFA) ranged from 16.01 to 18.41%. Meanwhile, the values of un-saturated/saturated index (USFA/SFA) ranged from 4.43 to 5.21 (Table 5).

Table 1. Effect of storage period on fatty acids content (%) of Olive oil.

Storage period/Months	0 Month	6 Months	12 Months	P-Value
Type	**C16:0**			
0 days	13.92.±0.19^{aB}	13.81±0.20^{aA}	14.02±0.23^{aA}	NS
30 days	14.47.±0.11^{aA}	14.00±0.21^{bA}	14.38±0.10^{aA}	**
45 days	14.11±0.04^{aB}	13.92±0.60^{aA}	14.02±0.37^{aA}	NS
P-Value	**	NS	NS	
	C16:1			
0 days	1.18±0.07^{abA}	1.13±0.06^{bA}	1.35±0.14^{aA}	*
30 days	0.87±0.03^{cB}	1.17±0.06^{bA}	1.43±0.08^{aA}	**
45 days	0.83±0.02^{cB}	1.11±0.03^{bA}	1.25±0.04^{aA}	**
P-Value	**	NS	NS	
	C18:0			
0 days	2.87±0.38^{aB}	2.67±0.10^{aB}	3.01±0.01^{aA}	NS
30 days	3.68±0.02^{aA}	2.56±0.10^{bA}	2.87±0.03^{cB}	**
45 days	3.68±0.04^{aA}	2.80±0.23^{bAB}	2.83±0.07^{bB}	**
P-Value	**	NS	**	
	C18:1			
0 days	70.47±0.28^{aB}	71.00±0.55^{aA}	71.38±0.83^{aA}	NS
30 days	72.38±0.16^{aA}	69.12±0.20^{bA}	68.99±0.14^{bB}	**
45 days	72.21±0.28^{aA}	70.05±1.74^{aA}	70.12±1.41^{aAB}	NS
P-Value	**	NS	*	
	C18:2			
0 days	10.87±0.13^{aA}	10.30±0.57^{abB}	9.56±0.45^{bA}	**
30 days	8.11±0.02^{bC}	11.79±0.18^{aA}	11.67±0.18^{aB}	**
45 days	8.84±0.03^{bB}	11.38±0.94^{aAB}	11.19±1.00^{aB}	**
P-Value	**	*	*	
	C18:3			
0 days	0.69±0.04^{aA}	1.09±0.57^{aA}	0.68±0.05^{aA}	NS
30 days	0.48±0.03^{bB}	0.77±0.01^{aA}	0.69±0.13^{aA}	**
45 days	0.49±0.03^{bB}	0.74±0.05^{aA}	0.60±0.13^{abA}	*
P-Value	**	NS	NS	

^{abc} Means values in the same column not sharing a superscript are significantly different.
^{ABC} Means values in the same row not sharing a superscript are significantly different.
NS: not significant. * Significant at p<0.05. ** Significant at p<0.01.

Table 2. Effect of gamma irradiation and storage period on saturated fatty acids (%) (palmitic (C16:0) and stearic (C18:0) acid content) on olive oil.

Treatments		Control	1 KGY	2 KGY	3 KGY	P-Value
Type		**C16:0**				
0 days	**0 months**	13.92.±0.19^{bcA}	13.60±0.36^{cA}	13.74±0.06^{cB}	14.21±0.14^{abA}	**
	6 months	13.81±0.20^{aA}	13.53±0.75^{aA}	13.63±0.05^{aB}	13.58±0.16^{aA}	NS
	12 months	14.02±0.23^{aA}	14.02±0.23^{aA}	14.04±0.10^{aA}	14.07±0.74^{aA}	NS
	P-Value	NS	NS	**	NS	
30 days	**0 months**	14.47.±0.11^{aA}	14.46±0.6^{aA}	14.59±0.08^{aA}	14.60±0.13^{aA}	NS
	6 months	14.00±0.21^{aB}	13.25±0.13^{bC}	13.43±0.19^{bC}	14.22±0.12^{aB}	**
	12 months	14.38±0.10^{aA}	13.69±0.06^{bB}	13.75±0.09^{bB}	14.29±0.10^{aB}	**
	P-Value	*	**	**	*	
45 days	**0 months**	14.11±0.04^{aA}	14.19±0.20^{aA}	13.96±0.07^{bA}	13.99±0.13^{bA}	*
	6 months	13.92±0.60^{aA}	13.36±0.37^{aB}	13.55±0.08^{aB}	13.61±0.54^{aA}	NS
	12 months	14.02±0.37^{aA}	13.61±0.06^{bB}	13.58±0.13^{bB}	13.89±0.57^{aA}	NS
	P-Value	NS	*	**	NS	
		C18:0				
0 days	**0 months**	2.87±0.38^{aA}	2.66±0.04^{aB}	2.55±0.07^{aB}	2.54±0.03^{aB}	NS
	6 months	2.67±0.10^{aA}	2.51±0.28^{aB}	2.65±0.25^{aAB}	2.43±0.07^{aB}	NS
	12 months	3.01±0.01^{aA}	3.01±0.01^{aA}	2.91±0.06^{bA}	2.88±0.07^{bA}	**
	P-Value	NS	*	*	**	
30 days	**0 months**	3.68±0.02^{aA}	3.73±0.04^{aA}	3.82±0.16^{aA}	3.71±0.02^{aA}	NS
	6 months	2.56±0.10^{cbC}	2.87±0.38^{acB}	3.23±0.11^{abB}	3.30±0.14^{aB}	**
	12 months	2.87±0.03^{abB}	2.80±0.06^{bB}	2.93±0.06^{aC}	2.80±0.08^{bC}	*
	P-Value	**	**	**	**	
45 days	**0 months**	3.68±0.04^{aA}	3.33±0.4^{bA}	3.52±0.06^{aA}	3.53±0.05^{aA}	NS
	6 months	2.80±0.23^{bB}	3.32±0.29^{aA}	2.96±0.16^{abB}	3.13±0.06^{abB}	*
	12 months	2.83±0.07^{aB}	2.84±0.05^{aA}	2.81±0.07^{aB}	2.77±0.14^{aC}	NS
	P-Value	**	NS	**	**	

^{abc} Means values in the same column not sharing a superscript are significantly different.
^{ABC} Means values in the same row not sharing a superscript are significantly different; NS: not significant; ** Significant at p<0.01.

Table 3. Effect of gamma irradiation and storage period on monounsaturated fatty acids (%) (palmitoleic (C16:1) and oleic (C18:1) acids content) on olive oil.

Treatments		Control	1 KGY	2 KGY	3 KGY	P-Value
Type			C16:1			
0 days	0 months	1.18±0.07^{abAB}	1.12±0.05^{abA}	1.23±0.13^{aA}	1.05±0.08^{bA}	NS
	6 months	1.13±0.06^{aB}	1.16±0.16^{aA}	1.07±0.01^{aA}	1.02±0.10^{aA}	NS
	12 months	1.35±0.14^{aA}	1.35±0.14^{aA}	1.25±0.10^{aA}	1.05±0.40^{aA}	NS
	P-Value	*	NS	NS	NS	
30 days	0 months	0.87±0.03^{aC}	0.88±0.01^{aB}	0.89±0.04^{aC}	0.90±0.02^{aC}	NS
	6 months	1.17±0.06^{aB}	1.10±0.08^{aA}	1.07±0.01^{aB}	1.10±0.06^{aB}	NS
	12 months	1.43±0.08^{aA}	1.19±0.14^{bA}	1.31.±0.14^{abA}	1.30±0.02^{abA}	NS
	P-Value	**	*	**	**	
45 days	0 months	0.83±0.02^{aC}	0.83±0.06^{aC}	0.87±0.02^{aC}	0.95±0.11^{aB}	NS
	6 months	1.11±0.03^{aB}	1.07±0.01^{abB}	1.04±0.06^{abA}	1.00±0.10^{bAB}	NS
	12 months	1.25±0.04^{aA}	1.27±0.10^{aA}	1.25±0.10^{aB}	1.17±0.11^{aA}	NS
	P-Value	**	**	**	*	
			C18:1			
0 days	0 months	70.47±0.28^{bcA}	71.94±0.30^{aA}	71.75±0.11^{aA}	70.06± 0.41^{cA}	**
	6 months	71.00±0.55^{aA}	71.66±1.51^{aA}	71.33±0.23^{aB}	71.13±0.28^{aA}	NS
	12 months	71.38±0.83^{aA}	71.38±0.83^{aA}	70.63±0.26^{aC}	70.18±1.35^{aA}	NS
	P-Value	NS	NS	**	NS	
30 days	0 months	72.38±0.16^{aA}	72.35±0.02^{aAB}	72.64±0.13^{bA}	72.32±0.12^{aA}	**
	6 months	69.72±0.72^{aB}	71.53±0.52^{bAB}	72.01±0.14^{abB}	69.05±0.37^{cB}	**
	12 months	68.99±0.14^{dcC}	70.85±0.51^{bB}	71.41±0.26^{abC}	68.95±0.38^{cB}	**
	P-Value	**	*	**	**	
45 days	0 months	72.21±0.28^{aA}	72.31±0.11^{bA}	71.86±0.61^{abA}	72.12±0.05^{aA}	NS
	6 months	70.05±1.74^{aA}	71.27±0.15^{aB}	70.83±0.19^{aB}	70.20±1.30^{aA}	NS
	12 months	70.12±1.41^{aA}	71.60±0.24^{aB}	70.72±0.36^{aB}	70.22±1.06^{aA}	NS
	P-Value	NS	**	*	NS	

^{abc} Means values in the same column not sharing a superscript are significantly different.
^{ABC} Means values in the same row not sharing a superscript are significantly different.
NS: not significant; ** Significant at p<0.01

Table 4. Effect of gamma irradiation and storage period on polyunsaturated fatty acids (%) (linoleic (C18:2) and Linolenic (C18:3) acids content) on olive oil.

Treatments		Control	1 KGY	2 KGY	3 KGY	P-Value
Type			C18:2			
0 days	0 months	10.87±0.13^{bA}	9.97±0.20^{cA}	10.00±0.17^{cB}	11.35±0.38^{aA}	**
	6 months	10.30±0.57^{aAB}	10.51±2.09^{aA}	10.67±0.20aA	11.12±0.21^{aA}	NS
	12 months	9.56±0.45^{cB}	9.56±0.45^{cA}	10.35±0.19^{bAB}	11.07±0.18^{aA}	**
	P-Value	*	NS	*	NS	
30 days	0 months	8.11±0.02^{aB}	8.10±0.02^{aB}	7.65±0.05^{cC}	8.02±0.02^{bB}	**
	6 months	11.79±0.18^{aA}	10.59±0.14^{bA}	9.63±0.17^{cB}	11.60±0.51^{aA}	**
	12 months	11.67±0.18^{aA}	10.83±0.31^{bA}	9.99±0.20^{cA}	11.93±0.54^{aA}	**
	P-Value	**	**	**	**	
45 days	0 months	8.84±0.03^{aB}	8.88±0.12^{aB}	9.04±0.34^{aB}	8.82±0.23^{aB}	NS
	6 months	11.38±0.94^{aA}	10.26±0.21^{aA}	10.94±0.30^{aA}	11.32±0.60^{aA}	NS
	12 months	11.19±1.00^{abA}	10.08±0.25^{cA}	10.96±0.30^{bA}	11.35±0.81^{aA}	NS
	P-Value	*	**	**	**	
			C18:3			
0 days	0 months	0.69±0.04^{aA}	0.71±0.05^{aA}	0.74±0.02^{aA}	0.79±0.14^{aA}	NS
	6 months	1.09±0.57^{aA}	0.68±0.05^{aA}	0.65±0.06^{aB}	0.72±0.02^{aA}	NS
	12 months	0.68±0.05^{bA}	0.68±0.05^{bA}	0.81±0.01^{aA}	0.75±0.05^{abA}	*
	P-Value	NS	NS	**	NS	
30 days	0 months	0.48±0.03^{aB}	0.48±0.01^{aC}	0.41±0.03^{bB}	0.45±0.01^{aB}	**
	6 months	0.77±0.01^{aA}	0.67±0.01^{bA}	0.63±0.01^{bA}	0.74±0.05^{aA}	**
	12 months	0.69±0.13^{aA}	0.64±0.01^{aB}	0.60±0.06^{aA}	0.73.±0.09^{aA}	NS
	P-Value	**	**	**	**	
45 days	0 months	0.49±0.03^{aB}	0.48±0.01^{aB}	0.75±0.29^{aA}	0.60±0.01^{aB}	NS
	6 months	0.74±0.05^{aA}	0.71±0.09^{aA}	0.69±0.05^{aA}	0.74±0.03^{aA}	NS
	12 months	0.60±0.13^{aAB}	0.60±0.03^{aC}	0.67±0.02^{aA}	0.60±0.11^{aB}	NS
	P-Value	*	**	NS	*	

^{abc} Means values in the same column not sharing a superscript are significantly different.
^{ABC} Means values in the same row not sharing a superscript are significantly different.
NS: not significant; ** Significant at p<0.01.

Table 5. Effect of gamma irradiation and storage period on total saturated fatty acids (SFA), unsaturated fatty acids (USFA) and (USFA/ SFA) of olive oil.

Treatments		Control	1 KGY	2 KGY	3 KGY	P-Value
Type				SFA		
0 days	0 months	16.48 ± 0.13^{aA}	16.27 ± 0.34^{bAB}	16.29 ± 0.13^{bB}	16.75 ± 0.11^{aA}	*
	6 months	16.48 ± 0.48^{bB}	16.04 ± 0.60^{bB}	16.28 ± 0.27^{aB}	16.01 ± 0.23^{aA}	NS
	12 months	17.03 ± 0.23^{aA}	17.03 ± 0.23^{aA}	16.96 ± 0.05^{aA}	16.95 ± 0.81^{aA}	NS
	P-Value	*	*	**	NS	
30 days	0 months	18.16 ± 0.09^{bA}	18.19 ± 0.03^{bA}	18.41 ± 0.08^{aA}	18.32 ± 0.12^{abA}	**
	6 months	16.56 ± 0.13^{bcC}	16.11 ± 0.42^{cB}	16.66 ± 0.27^{bB}	17.52 ± 0.23^{aB}	**
	12 months	17.25 ± 0.08^{aB}	16.49 ± 0.10^{bB}	16.68 ± 0.14^{bB}	17.09 ± 0.25^{aC}	**
	P-Value	**	**	**	**	
45 days	0 months	17.79 ± 0.01^{aA}	17.52 ± 0.28^{aA}	17.48 ± 0.03^{aA}	17.52 ± 0.17^{aA}	NS
	6 months	16.72 ± 0.82^{aB}	16.68 ± 0.13^{aB}	16.51 ± 0.12^{aB}	16.75 ± 0.54^{aA}	NS
	12 months	16.85 ± 0.33^{aAB}	16.46 ± 0.09^{aB}	16.39 ± 0.19^{aB}	16.65 ± 0.65^{aA}	NS
	P-Value	*	**	**	NS	
				USFA		
0 days	0 months	83.22 ± 0.21^{bAB}	83.74 ± 0.25^{aB}	83.72 ± 0.12^{aA}	83.25 ± 0.11^{bA}	*
	6 months	83.53 ± 0.12^{aA}	84.02 ± 0.53^{abA}	83.72 ± 0.27^{aA}	84.00 ± 0.23^{aA}	NS
	12 months	82.97 ± 0.23^{aB}	82.97 ± 0.24^{aB}	83.05 ± 0.05^{aB}	83.04 ± 0.82^{aA}	NS
	P-Value	*	*	**	0.1196	
30 days	0 months	81.85 ± 0.11^{aC}	81.81 ± 0.03^{aB}	81.59 ± 0.08^{bB}	81.68 ± 0.12^{abC}	*
	6 months	83.45 ± 0.13^{aA}	83.89 ± 0.09^{aA}	83.34 ± 0.27^{bA}	82.48 ± 0.22^{cB}	**
	12 months	82.78 ± 0.11^{bB}	83.51 ± 0.09^{aA}	83.32 ± 0.13^{aA}	82.91 ± 0.14^{bA}	**
	P-Value	**	**	**	**	
45 days	0 months	82.37 ± 0.27^{aA}	82.49 ± 0.29^{aB}	82.52 ± 0.03^{aB}	82.49 ± 0.16^{aA}	NS
	6 months	83.28 ± 0.82^{aA}	83.32 ± 0.13^{aA}	83.50 ± 0.11^{aA}	82.25 ± 0.53^{aA}	NS
	12 months	83.16 ± 0.33^{aA}	83.56 ± 0.07^{aA}	83.61 ± 0.19^{aA}	83.35 ± 0.35^{aA}	NS
	P-Value	NS	**	**	NS	
				USFA/SFA		
0 days	0 months	4.96 ± 0.08^{bAB}	5.15 ± 0.13^{aAB}	5.14 ± 0.05^{aA}	4.97 ± 0.04^{bA}	*
	6 months	5.07 ± 0.05^{aA}	5.25 ± 0.23^{aA}	5.15 ± 0.10^{aA}	5.25 ± 0.09^{aA}	NS
	12 months	4.87 ± 0.08^{aB}	4.87 ± 0.08^{aB}	4.90 ± 0.02^{aB}	4.91 ± 0.29^{aA}	NS
	P-Value	*	*	**	NS	
30 days	0 months	4.51 ± 0.03^{aC}	4.50 ± 0.01^{aB}	4.43 ± 0.02^{bB}	4.46 ± 0.04^{abB}	*
	6 months	5.04 ± 0.05^{abA}	5.21 ± 0.16^{aA}	5.00 ± 0.10^{bA}	4.71 ± 0.07^{cC}	**
	12 months	4.80 ± 0.03^{bB}	5.07 ± 0.04^{aA}	5.00 ± 0.05^{aA}	4.85 ± 0.09^{bA}	**
	P-Value	**	**	**	**	
45 days	0 months	4.63 ± 0.01^{aA}	4.71 ± 0.09^{aB}	4.72 ± 0.01^{aB}	4.71 ± 0.06^{aA}	NS
	6 months	4.99 ± 0.30^{aA}	4.99 ± 0.05^{aA}	5.06 ± 0.04^{aA}	4.98 ± 0.19^{aA}	NS
	12 months	4.94 ± 0.12^{aA}	5.08 ± 0.03^{aA}	5.10 ± 0.07^{aA}	5.01 ± 0.23^{aA}	NS
	P-Value	NS	**	**	NS	

^{abc} Means values in the same column not sharing a superscript are significantly different.
^{ABC} Means values in the same row not sharing a superscript are significantly different.
NS: not significant.
* Significant at p<0.05.
** Significant at p<0.01.

The high level of UFA in these oil was due to their high levels of oleic acid. This showed that these oil are good source of UFA, mostly MUFA with oleic acid (an essential fatty acid) being the most abundant (around 70 %). Oleic acid is the most important essential fatty acid for it must be got from food [28].

It was shown that monounsaturated- rich diet reduced the susceptibility of low density lipoprotein peroxidation and may be of therapeutic value in the treatment of hypervholestrolemia [1].

As shown in Table 5, irradiation at 2 kGy significantly (p<0.05) increased the percentage of the total unsaturated fatty acids (USFA) and decreased the percentage of total saturated fatty acids (SFA). Our results are in agreement with other studies which, observed that, at low irradiation doses (1 and 3 kGy), small change were observed in saturated and unsaturated fatty acids components, but the changes in fatty acids composition of oil extracted from irradiated pumpkinseeds were not significant (P<0.05) [28]. *Chen et al.* (2007) [13] evaluated the effects of gamma ray irradiation of the muscles of Chinese Yellow Cattle at ranges of 1.13 – 3.17 kGy. They found that the level of total saturated fatty acid (SFA) and monounsaturated fatty acid (MUFA) increased with irradiation, while the ratio of MUFA to SFA were unchanged. On the other hand, the level of total polyunsaturated fatty acids (PUFA) was reduced with irradiation. It was estimated that, the reason for the increase in saturated fatty acids, and decrease in un-saturated fatty acids during the irradiation exposure was because of molecular structure change in fatty acids, the breaking of dual links and radicals and trans fatty acids turning to free condition [29].

The balanced diet ratio of polyunsaturated : monounsaturated : saturated fatty acids is 1:2:1, the olive oil is about 0.5:5:1, while the value of the seed oils of about 5:2:1. From the above relations of fatty acid in olive oil, its stability and resistance against oxidation change are derived, taking into account that the degree of oxidation of linoleic acid to be ten times higher than oleic acid [30]. Changes in the ratio of unsaturated/saturated fatty acids affect organoleptic properties of olive oil, so as with a high content of saturated fatty acids is more viscous and remains longer in contact with mucous membrances of the oral cavity, giving rise to the fatty defect [31].

4. Conclusion

The results of this study demonstrated that the studied olive oil (OO) obtained from cultivar (Kaissy) in Syria shows the best fatty acid composition with low palmitic acid, which is the major saturated fat and they have high levels of mono- unsaturated fat and they have high levels of mono-unsaturated oleic acid. The value of USFA//SEA index which is associated to the impact in the human health is also high ranging from which makes them the most suitable edible oils for mass consumption. The present study demonstrated that the effect of gamma irradiation treatment on the fatty acid profile of VOO was minimized when the irradiation doses of 0, 1, 2 an3 kGy were used.

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human / or animal subjects (if exist) respect the specific regulation and standards.

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References

1. Mahmoud, K.A., Badr, H.M., Quality characteristics of gamma irradiated beefburger formulated with partial replacement of beef fat with olive oil and wheat bran fibers. *Food and Nutrition Sciences* **2011**, *2*, 655-666.
2. Dughaish, Z.H., Effect of gamma irradiation and heat treatment on some physical properties of vegetable oils. *Journal of Natural Sciences and Mathematics* **2010**, *4*(2), 157-170.
3. Waterman, E., Lockwood, B., Active components and clinical applications of olive oil. *Alternative Medicine Review* **2007**, *12*, 331-342.
4. Abouzar Hashempour, R.F.G., Bakhshi, D, Sanam, S.A., Fatty acids composition and pigments changing of virgin olive oil (*Olea europea* L.) in five cultivars grown in Iran. *Aust. J. Crop. Sci* **2010**, *4*, 258-263.
5. Benkhayal, A.A., Bader, N.R., Elsherif, K.M., El-kailany, R., Elmgsbi, S., Evaluation of fatty acids in Libyan olive oils by gas liquid chromatography. *International Journal of Chromatographic Science* **2014**, *4*(1), 1-5.
6. Morello, J.R., Romerom M.P., Motilva, M.J., Effect of crop season on the composition of virgin olive oil with protected designation of origin Les Garrigues. *J. Am. Oil. Chem. Soc* **2003**, *80*, 423-430.
7. Aguilera, M.P., Beltran, G., Ortega, D., Fernandez, A., Jimenez, A., Uceda, M., Characterization of virgin olive oil of Italian olive cultivars: Frantoio and Leccino, grown in Andalusia. *Food Chem* **2005**, *89*, 387-391.
8. Esmaeili, A., Shaykhmoradi, F., Naseri, R., Comparison of oil content and fatty acid composition of native olive genotypes in different region of Liam, Iran. *International Journal of Agriculture and Crop Sciences* **2012**, *4*(8), 434-438.
9. Leon, L.M.U., Jimenez, A., Martin, L.M., Rallo, L., Variability of fatty acid composition in olive (*Olea europaea* L.) Progenies, *Spain J. Agric. Res* **2004**, *2*, 353-359.

10. AL-Bachir, M., Zeino, R., Effect of gamma irradiation on some characteristics of shell eggs and mayonnaise prepared from irradiated eggs. *Journal of Food Safety* **2006**, *26*, 348-360.
11. AL-Bachir, M., Zeinou, R., Effect of gamma irradiation on the microbial load, chemical and sensory properties of goat meat. *Acta Alimentaria* **2014**, *43* (2), 72-80.
12. Nawar, W.W., Volatile from food irradiated. *Food Review International* **1986**, *2*, 45-78.
13. Chen, Y.J., Zhou, G.H., Zhu, X.D., Xu, X.L., Tang, X.L., Gao, F., Gamma irradiation on beef quality and fatty acid composition of beef intramuscular lipid. *Meat Sci* **2007**, *75*, 423-431.
14. Fan, X., Kays, S.E., Formation of trans fatty acids in ground beef and frankfurters due to irradiation. *Food Sci* **2009**, *74*, c79-c84.
15. Alfaia, C.M.M., Ribeiro, P.J.L.C., Trigo, M.J.I., Castro, M.L.F., Fontes, C.M.G.A., et al., Irradiation effect of fatty acid composition and conjugated linoleic acid isomers in frozen lamb meat. *Meat Science* **2007**, *77*(4), 689-695.
16. Hammer, C.T., Wills, E.D., The effect of ionizing radiation on the fatty acid composition of natural fats and on lipid peroxide formation. *International Journal of Radiation Biology* **1979**, *35*(4), 323-332.
17. Al-Bachir, M., Effect of gamma irradiation on fungal load, chemical and sensorycharacteristics of walnuts (*Juglans regia* L.). *J. Stored Prod. Res* **2004**, *40*, 355-362.
18. AL-Bachir, M., Microbiological, sensorial and chemical quality of gamma irradiated pistachio nut (*Pistachia vera* L.) *The Annals of the University Dunarea de Jos of Galati - Food Technology* **2015**, *38*(2), 57-68.
19. Al-Bachir, M., Some microbial, chemical and sensorial properties of gamma irradiated sesame (*Sesamum indicum* L.) seeds. *Food Chemistry* **2016**, *197*, 191-197.
20. Blatchly, R.A., Delen, Z., O'Hara, P.B., Making sense of olive oil: Simple experiments to connect sensory observations with the underlying chemistry. *Journal of Chemical Education* **2014**, *91*(10), 1623-1630.
21. Snedecor, G., Cochran, W., Statistical methods. The Iowa State University Press, Ames, Aiwa **1988**, pp. 221-221.
22. International Olive Council (IOC)., Trade standard applying to olive oils and olive pomace oil **2015**, COI/T.15/NC No 3/Rev.9 June 2015. (p. 17).
23. Bajoub, A., Hurtado-Fernandez, E., Ajal, E.A., Fernandez-Gutierrez, A., Carrasco-Pancorbo, A., Ouazzani, N., Quality and chemical profiles of monovarietal north Moroccan olive oils from "Picholine Marocaine" cultivar: Registration database development and geographical discrimination. *Food Chemistry* **2015**, *179*, 127-136.
24. Sakar, E., Arol, Ak.B., Unver, H., Celik, M., Turkoglu, H., Keskin, S., Determination of total olive oil and Cis-Trans fatty acids composition of Sirnak province olive genotypes at southeastern Anatolia. *Journal of Agriculture and Environmental Sciences* **2014**, *3*(4), 119-129.
25. Spangenberg, J.E., Macko, S.A., Hunziker, J., Characteristization of olive oil by carbon isotope analysis of individual fatty acids: Implications for authentication. *J. Agric. Food Chem* **1998**, *46*, 4179-4184.
26. Paz, A.M., Beltran, G., Ortega, D., Fernandez, A., Jimenez, A., Uceda, M., Characterization o virgin olive oil of Italian olive cultivars: Frantoio and Leccino grown in Andalusia. *Food Chem* **2004**, *69*, 387-391.
27. Tanilgan, K., Ozcan, M.M., Unver, A., Physical and chemical characteristics of five Turkish olive (*Olea europea* L.) varieties and their oils. *Grasas y Aceites* **2007**, *58*(2), 142-147.
28. Abd El-Aziz, A.B., Abd El-Kalek, H.H., Antimicrobial proteins and oil seeds from pumpkin (*Cucurbita moschata*). *Nature and Science* **2011**, *9*(3), 105-119.
29. Arici, M., Colak, F.A., Gecgel, U., Effect of gamma radiation on microbiological and oil properties of black cumin (*Nigella sativa* L.). *Grasa y Aceites* **2007**, *58* (4), 339-343.
30. Sarolic, M., Gugic, M., Marijanovic, Z., Suste, M., Virgin olive oil and nutrition. *Food health and disease, scientific-professional journal of nutrition and dietetics* **2014**, *3*(1), 38-43.
31. d,Andria, R., Lavini, A., Morelli, G., Patumi, M., Terenziani, S., Calandrelli, D., d,Fragnito, F., Effects of water regimes on five pickling and double aptitude olive cultivars (*Olea europaea* L.). *J. Hort. Sci. Biotechnol* **2004**, *79*, 18-25.