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Quality properties of oil Produced from irradiated Syrian thyme meal

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Abstract

This study was planned to irradiate the green thyme meal (GThM) and red thyme meal (RThM) at 15 kGy (gamma irradiation) and stored in poly ethylene (PET) materials for a storage period of 12 months. Set of GThM and RThM packed in PET without irradiation served as non-irradiated sample (NIR). At 0, 6, and 12 months of storage, the samples in different treatments were drawn for biochemical changes (Acidity value, peroxide value (PV), Iodine value (IV), saponification value (SV), the refractive index (RI), as fatty acid profile were noticed in oil produced from treated with gamma irradiation and non-irradiated samples of GThM and RThM at different period of storage. The physicochemical properties of the oil produced from GThM and RThM) samples were: AV (1.73 and 1.55 mg KOH g^{-1} oil), PV (7.11 and 7.11 mEqO_2 kg^{-1} oil), TBA (0.0084 and 0.0095 mg MDA kg^{-1} oil), IV (112.82 and 108.98 g^{-1} oil), SV (176.44 and 172.62 mg KOH g^{-1} oil), RI (1.474 and 1.474) respectively. The overall physicochemical properties values of oil produced from GThM and RThM) treated with 0, and 15 kGy and stored for 0, 6 and12 months were falls within the recommended codex for edible vegetables oils. The current study demonstrated that the effect of irradiation with 15 kGy of gamma ray and storage up to 12 months on the fatty acid profile of oil produced from GThM and RThM) was minimized.

Keywords: Produced Oil, Oxidation, Storage period, Thyme meal, Syria.

1. Introduction

Common thyme (*Thymus vulgaris* L.) is native to Mediterranean region, and as an aromatic plant that used for nutritional purpose since ancient time [1]. This aromatic plant added to dishes and foodstuff improves food sensorial properties [2]. The raw and dried leaves thyme has been of interest worldwide due to the nutritional properties of the natural product, and the pharmaceutical properties of derivatives, such as dried plants and its extracts [3].

Thyme meal is considered to be the staple food for most people in Syria as well as in regional countries. It is considered as a good source of needed nutrient elements [4].

The chemical constituents and content of vegetable oils, particularly the type of fatty acids (FAs) are considered important criteria for quality of oils and their health benefits [5]. Nutritionally vegetable oils is quite rich source of essential FAs including unsaturated fatty acids (USFA), and that makes it a valuable source of oil for human nutrition [6]. Fats, FAs and their metabolic secondary products have various significant functions in the human metabolism [7].

Vegetable oils are recommended for a healthy lifestyle due to their high content of unsaturated fatty acids (USFAs), particularly polyunsaturated fatty acids (PUSFAs). Since PUSFAs cannot be synthesized by the human body, they are considered essential fatty acids and play a crucial role in human metabolism [8]. Diets high in saturated fatty acids (SFAs) are a major contributor to coronary heart diseases. The ratio of SFAs to USFAs is an important indicator of nutritional quality. Therefore, increasing the intake of unsaturated fats, especially PUSFAs, while reducing SFAs, lowers the risk of cardio-vascular diseases [9]. Thyme is a valued crop and an important agricultural product both in industry as a food ingredient and in human nutrition and health in terms of its role as a functional food. Thyme oil is rich in healthy polyunsaturated fatty acids (PUFA) contains phenolic compounds and has antimicrobial properties [1].

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The current century has witnessed innovations and techniques that have been introduced
in the field of food preservation in human study. Today, irradiation techniques play an important role in food preservation, in which offers a potential benefit to enhance safety of food, and accept nutritional and sensory quality through losses reduction and extending their shelf-life [10]. Advantages over other treatments include tolerance by most food products, ability to process in the final packaging food products, and absence of pesticide residues [11]. There is limited information on physic0-chemical properties of thyme meal used as prepared food (ready to eat meal). Although irradiation treatments were proven to be useful in extending the storage time of many food products, to the best of our knowledge, the effect of irradiation on the chemical composition of thyme meal has not been evaluated. Therefore, the major purpose of the current study was to evaluate the oil characteristics and FAs profile of oil produced from green thyme meal (GThM) and red thyme meal (RThM) samples irradiated at 15 kGY of gamma irradiation dose..

2. Materials and method

2.1. Thyme meal preparation

In 2021, a study was conducted in the Radiation Technology Department of the Atomic Energy Commission to examine green thyme meal (GThM) and red thyme meal (RThM). These thyme meals were generously provided by a company for industry and trade from the Damascus countryside, Syria. As a local ethnic ready-to-eat meal, thyme meal consists of several dried ingredients, including sesame (44%), thyme leaves (32%), sumac (16%), coriander (0.5%), aniseed (0.5%), fennel (0.5%), cumin (0.5%), pistachio (5%), vegetable oil (0.5%), salt (0.5%), and caraway (0.5%). GThM and RThM samples were weighed, placed in polyethylene bags, and prepared for irradiation. Each 500 g bag of thyme meal was treated as an individual replicate, and all treatments were analyzed in triplicate.

2.2. Irradiation Treatment

The GThM and RThM samples were subjected to irradiation at doses of 0 and 15 kGy, with a dose rate of 7.775 kGy per hour, using a cobalt-60 source (ROBO, Russia). The absorbed dose was measured with an alcoholic chlorobenzene dosimeter. After irradiation, the samples were stored in polyethylene bags under laboratory conditions (18–25°C) with relative humidity (50–70%), alongside a control sample (0 kGy), for a period of 12 months.

2.3. Oil Extraction

Oils from both control and irradiated samples of GThM and RThM, after grinding, were extracted using a manual Soxhlet apparatus (Scientific Apparatus Manufacturing Company, Glas-Col Combo Mantle, USA) for 16 hours. Distilled analytical-grade n-hexane was used as the solvent [12]. The physico-chemical properties of the oils extracted from irradiated and non-irradiated thyme meal samples were analyzed immediately after irradiation, and again after 6 and 12 months of storage.

2.4. Chemical Analysis

The acidity value (AV), expressed in mg KOH per g of oil, peroxide value (PV) in meq O2 per kg of oil, iodine value (IV) in g I2 per 100 g, saponification value (SV) in mg KOH per g of oil, and refractive index (RI) at 25°C were determined following standard methods [12]. Lipid oxidation was evaluated using the 2-thiobarbituric acid (TBA) method as described by Al-Bachir and Koudsi [13], with the TBA value expressed as milligrams of malonaldehyde per kilogram of thyme meal sample.

2.5. Fatty Acid Determination

Fatty acid composition of the thyme samples was analyzed according to the method previously outlined by Al-Bachir [14]. The fatty acids, converted into methyl esters, were analyzed using a Shimadzu Model 17 gas chromatography apparatus (Shimadzu Corp., Kyoto, Japan) equipped with a flame ionization detector and a CBP20-S25-050 capillary column (Shimadzu, Australia). Fatty acids were identified by comparing retention times with known standards, and the results were reported as grams of fatty acid per 100 g of total fatty acids (%) using the CLASS-VP 4.3 software (Shimadzu Scientific Instruments, Inc., Columbia, MD).

2.6. Statistical Analysis

All data were statistically analyzed using analysis of variance (ANOVA) with the SUPERANOVA software package (Abacus Concepts Inc, Berkeley, CA, USA; 1998). Significant differences between means ($p < 0.05$) were determined using Duncan's test.

3. Results and Discussion

3.1. Effect of irradiation and storage in acid value of GThMO and RThMO

Acid value (AV), and presents free fatty acid (FFA) content due to enzymatic activity is usually, indicative of spoilage [15]. FFA linked with the quality and commercial value of fat or oil and FFAs

are indicators of deterioration of fat, which produced by the hydrolysis of oils and fats [16]. Oil produced from irradiated and non-irradiated GThM and RThM samples were analyzed for AV in term of mg KOH g^{-1} oil, and the results are given in Table 1.

Table.1 Effect of gamma irradiation treatment and storage time on biochemical properties of oil produced from green thyme meal (GThM) and red thyme meal (RThM) products.

Treatments	Green thyme meal (GThM)		Red thyme meal (RThM)		P-level
	Control	15 KGY	Control	15 KGY	
Storage period /(Months)	**Acid value (mg KOH g^{-1} oil)**				
0 Months	1.73 ± 0.04^{bB}	1.93 ± 0.09^{aB}	1.55 ± 0.01^{cC}	1.69 ± 0.05^{bB}	**
6 Months	1.78 ± 0.02^{bA}	1.96 ± 0.02^{aA}	1.67 ± 0.03^{cB}	1.96 ± 0.02^{dC}	**
12 Months	2.41 ± 0.01^{aB}	2.07 ± 0.01^{bB}	1.93 ± 0.04^{cA}	1.79 ± 0.03^{dA}	**
P-level	**	*	**	**	
	Peroxide value ($mEqO_2$ kg^{-1} oil)				
0 Months	7.11 ± 0.39^{cC}	6.87 ± 0.31^{bC}	7.11 ± 0.39^{bC}	8.10 ± 0.19^{aC}	**
6 Months	9.53 ± 0.15^{cB}	11.20 ± 1.03^{bA}	10.63 ± 0.65^{bcB}	12.59 ± 0.32^{aB}	**
12 Months	17.50 ± 0.31^{bA}	19.09 ± 0.75^{aB}	16.85 ± 0.64^{bA}	17.00 ± 0.82^{bA}	*
P-level	**	**	**	**	
	TBA value (mg MDA kg^{-1} oil)				
0 Months	0.084 ± 0.00^{aC}	0.087 ± 0.002^{aC}	0.095 ± 0.01^{aB}	0.100 ± 0.02^{aB}	**NS**
6 Months	0.126 ± 0.01^{aB}	0.126 ± 0.00^{aB}	0.123 ± 0.00^{aA}	0.125 ± 0.00^{aA}	**NS**
12 Months	0.138 ± 0.00^{abA}	0.139 ± 0.00^{aA}	0.135 ± 0.00^{bA}	0.141 ± 0.00^{aA}	**NS**
P-level	**	**	**	**	

^{abc}Mean values within the same column that do not share a superscript are significantly different.
^{ABC} Mean values within the same row that do not share a superscript are significantly different.
NS: not significant.
* Significant at $p<0.05$.
** Significant at $p<0.01$.

The AV of GThMO and RThMO were 1.73 mg KOH g^{-1} oil and 1.55 mg KOH g^{-1} oil, respectively. The AV in this study increased significantly ($p<0.05$) due to irradiation and storage in oil produced from both types of thyme meal (GThM and RThM) (Table 1), however the changes in AV at the end of storage period were significantly less in oil produced from irradiated (1.79 mg KOH g^{-1} oil) and non-irradiated RThM (1.93) as compared to those of oil produced from irradiated (2.07 mg KOH g^{-1} oil) and non-irradiated GThM (2.41 mg KOH g^{-1} oil). The changes between the treatments (0, and 15 kGy) as well as between the storage duration (0, 6, and 12 months) were found to be significant ($p<0.05$) (Table 1). The AV level should not exceed 1.5% for noticeable rancidity [17]. The increase in AV for GThMO and RThMO produced from gamma irradiated samples (at 15 kGy), or stored for up to 12 months, might be attribute to small random hydrolysis of tri-glycerol molecules to FFAs and diacylglycerols [18]. Also, the increasing acid value in oil produced from irradiated products may be due to the fragmentation of big lipid molecules producing moderate or smaller molecules including FFAs [11].

3.2. Effect of irradiation and storage in peroxide value of GThMO and RThMO

The effect of gamma irradiation process and storage periods on the peroxide value (PV) of the GThMO and RThMO is presented in Table 1.

The PV of GThMO and RThMO before irradiation were, 7.11 and 7.11 mEq O_2 kg^{-1} oil, respectively. It was found that the influence of irradiation at 15 kGy and storage on PV of GThMO and RThMO was significantly important ($p<0.05$), which increased ($p<0.05$), during the 12 months of storage, from 7.11 to 17.5 and 16.85 mEq O_2 kg^{-1} oil, respectively. Several other studies have also indicated the rising of lipid oxidation in different kinds of food due to irradiation treatment and storing for long periods [11]. However, hydrolysis of glycerides to yield FA occurs during storage [19].

One of the most important differences often indicated in irradiated food commodities is the

production formation of free radicals, which become reactive molecules that damage cellular contents and cause oxidative stress [20]. This leads to lipid oxidation, [21]. However, irradiation at medium and lower doses also aids lipid oxidation by decreasing the levels of peroxides and other reactive dried products including species [22].

3.3. Effect of irradiation and storage on (TBA) of GThMO and RThMO

Lipid oxidation in GThMO and RThMO was determined in terms of thiobarbituric acid (TBA) values expressed as mg malonaldehyde (MDA) kg^{-1} oil. Data for TBA value of GThMO and RThMO are present in Table 1. As shown in Table the TBA value of non-irradiated GThMO and RThMO was 0.084 and 0.095 mg MDA kg^{-1} oil, respectively. The results indicated that after irradiation and during storage, the TBA of GThMO and RThMO increased significantly ($p<0.05$). Present oxidation results of GThMO and RThMO are in general agreement with those of Al-Bachir and Othman, [23] who reported that the TBA of sunflower oil increased upon storage in accord with double bond shifts of FAs and production decomposition components forming during oxidation of oils. This result may be attributed to the higher amount of oleic acid (38.32% and 40.47%), and. Linoleic acid (45.28% and 44.07%) in GThMO and RThMO, as suggested by Al-Bachir and Koudsi, [24]. Gamma irradiation was suggested to induce some effect that produces more reactive oxygen spices (ROS) that react with structural and functional components [25].

3.4. Effect of irradiation and storage on iodine value (IV) of GThMO and RThMO

The IV profile of oil produced from irradiated and non-irradiated GThM and RThM, soon after irradiation and after 6, and 12 months of storage are presented in Table 2.

Table.2 Effect of gamma irradiation and storage period on biochemical properties of oil produced from green thyme meal (GThM) and red thyme meal (RThM) products.

Treatments	Green thyme meal (GThM)		Red thyme meal (RThM)		P-level
	Control	15 KGY	Control	15 KGY	
Storage period /(Months)	**Iodine value (g I_2 100g^{-1} oil)**				
0 Months	112.82 ± 0.59^{aB}	111.11 ± 0.90^{bB}	108.98 ± 0.66^{cA}	106.72 ± 0.19^{dC}	**
6 Months	115.84 ± 0.36^{aA}	114.87 ± 0.12^{aB}	108.54 ± 0.98^{bA}	110.90 ± 0.79^{cB}	**
12 Months	112.98 ± 0.40^{aB}	110.71 ± 2.53^{abA}	109.60 ± 1.68^{bA}	112.23 ± 0.09^{abA}	**NS**
P-level	**	*	**NS**	**	
	Saponification value (mg KOH g^{-1} oil)				
0 Months	176.44 ± 0.68^{aA}	174.14 ± 0.32^{bB}	172.62 ± 0.89^{cC}	176.00 ± 0.77^{aA}	**
6 Months	176.44 ± 1.99^{aA}	177.87 ± 0.34^{aA}	173.97 ± 0.49^{bB}	173.79 ± 0.72^{bB}	**
12 Months	177.01 ± 0.54^{aA}	177.25 ± 0.66^{aA}	177.28 ± 0.32^{aA}	176.84 ± 1.02^{aA}	**NS**
P-level	**NS**	**	**	*	
	Refractive Index (nD 25 ^{0}C)				
0 Months	1.474 ± 0.00^{aA}	1.474 ± 0.00^{aA}	1.474 ± 0.00^{aA}	1.474 ± 0.00^{aA}	**
6 Months	1.471 ± 0.00^{aA}	1.470 ± 0.00^{aB}	1.470 ± 0.00^{aA}	1.470 ± 0.00^{aC}	**
12 Months	1.471 ± 0.00^{bA}	1.472 ± 0.00^{bC}	1.474 ± 0.00^{aA}	1.472 ± 0.00^{bB}	*
P-level	**	**	**	**	

^{abc}Mean values within the same column that do not share a superscript are significantly different.
^{ABC} Mean values within the same row that do not share a superscript are significantly different.
NS: not significant.
* Significant at $p<0.05$.
** Significant at $p<0.01$.

The IV was 112.82, and 108.98 I_2 100 g^{-1} oil for control samples of GThMO and RThMO, respectively. While it was 111.11, and 106.72 I_2 100 g^{-1} oil for oil produced from GThM and RThM irradiated with 15 kGy, respectively. These results indicate a higher percentage of un-saturation, which might have been due to a higher Linoleic acid (C18:2) in GThMO and RThMO (45.28% and 44.07%), and oleic acid (C18:1) (38.32% and 40.47%) contents (Table 3).

Gamma irradiation with 15 kGy decreased the IV of GThMO and RThMO. The decrease in IV of GThMO and RThMO upon irradiation could be attributed to some loss in the un-saturated fatty acids of GThMO

Table.3 Effect of gamma irradiation treatment and storage time on fatty acid content (%) of oil produced from green thyme meal (GThM) and red thyme meal (RThM) products.

Treatments	Green thyme meal (GThM)		Red thyme meal (RThM)		P-level
	Control	15 KGY	Control	15 KGY	
Storage period /(Months)		**C16:0**			
0 Months	11.32±1.97^{aA}	8.86±0.12^{bB}	10.04±0.47^{abA}	9.69±0.09^{abA}	**NS**
6 Months	10.84±1.97^{aA}	9.06±0.45^{aB}	9.60±0.05^{aA}	9.76±0.14^{aA}	**NS**
12 Months	12.41±2.52^{aA}	10.17±0.48^{abA}	9.98±0.15^{bA}	9.72±0.05^{bA}	**NS**
P-level	**NS**	*	**NS**	**NS**	
		C18:0			
0 Months	4.39±0.16^{cA}	4.26±0.04^{cB}	4.96±0.13^{bA}	5.29±0.12^{aA}	**
6 Months	4.21±0.16^{bA}	4.17±0.44^{bB}	4.69±0.12^{abAB}	5.10±0.06^{aB}	**
12 Months	4.12±0.16^{bA}	4.80±0.09^{aA}	4.36±0.25^{bB}	4.81±0.06^{aC}	**
P-level	**NS**	*	*	**	
		C18:1			
0 Months	38.47±0.64^{cA}	40.18±0.06^{bA}	40.47±0.06^{bA}	41.70±0.32^{aA}	**
6 Months	38.10±0.19^{cAB}	38.77±0.99^{bcB}	39.56±0.19^{bAB}	40.84±0.44^{aA}	**
12 Months	37.04±0.90^{cB}	39.75±0.32^{abAB}	38.51±0.96^{bcB}	40.92±1.10^{aA}	**
P-level	**NS**	**NS**	*	**NS**	
		C18:2			
0 Months	45.28±0.80^{bA}	46.70±0.03^{aA}	44.07±0.33^{cC}	42.66±0.33^{dB}	**
6 Months	45.21±0.20^{aA}	47.89±1.60^{bA}	45.21±0.20^{abB}	42.84±0.54^{bAB}	*
12 Months	46.08±1.16^{aA}	44.48±0.45^{bB}	46.50±0.52^{aA}	44.09±0.87^{bA}	*
P-level	**NS**	*	**	**NS**	
		C18:3			
0 Months	0.63±0.08^{aAB}	0.64±0.01^{aA}	0.71±0.05^{aA}	0.65±0.03^{aA}	**NS**
6 Months	0.58±0.03^{abB}	0.52±0.15^{bA}	0.86±0.18^{aA}	0.80±0.25^{bA}	**NS**
12 Months	0.83±0.20^{aA}	0.68±0.16^{aA}	0.86±0.18^{aA}	0.80±0.25^{aA}	**NS**
P-level	**NS**	*	**NS**	**NS**	

^{abc}Mean values within the same column that do not share a superscript are significantly different.
^{ABC} Mean values within the same row that do not share a superscript are significantly different.
NS: not significant.
* Significant at $p<0.05$.
** Significant at $p<0.01$.

and RThMO by radiation and formation of peroxide compounds. Radiation probably broke some double bonds and induced oxidation processes in FAs resulted in its saturation [4]. Our results in agreement with the results reported previously. Al-Bachir [26] found that a significant decreased in IV was found for irradiated pistachio oil.

3.5. Effect of irradiation treatment and storage time on saponification value (SV) of GThMO and RThMO

SV is measure of the average chain length of FAs present in the oil, Oil containing short chain FAs have higher SVs than those with long chain FAs [25]. The results of SV of oil produced from irradiated and non-irradiated GThM and RThM are shown in Table 2, as function of storage period. The GThMO and RThMO had a SV of 176.44 and 172.62 mg KOH g^{-1} oil, respectively. (Table 2). The comparative high SV in GThMO and RThMO indicates the presence of higher FAs in higher proportions. However, no significant ($p<0.05$) differences was observed in the SV of GTMO ad RThMO treated with 0, and 15 kGy, when the test carried out soon after irradiation and after 6 and 12 months of storage. These results are in agreement with the results obtained by several investigators. Al-Bachir and Othman, [11] reported that both storage time (6 and 12 months) and irradiation doses (3, 6, and 9 kGy) of gamma irradiation had no significant ($p>0.05$) effect on SV of sunflower seeds oil

3.6. Effect of irradiation and storage on refractive index of GThMO and RThMO

RI of oil is an important indicator for determination of the oil quality, and used to measure the change in

un-saturation as the oil is hydrogenated [23]. The RI of oil produced from irradiated and non-irradiated GThM and RThM during storage periods is presented in Table 2. As shown in Table the RI of GThMO and RThMO samples was 1.474 and 1.474, respectively. These values of IR fall within the recommended codex of 1.465 and 1.479 f0r vegetable oil [23]. These results are very similar to those reported for sun flower oil (1.464), brassica oil (1.470), soybean oil (1.472) cottonseed oil (1.474), sesame oil (1.479), linseed oil (1.478), and cherry kernel oil (1.4724) [25]. There were no significant differences in the RI values between irradiated and non-irradiated GThMO and RThMO, indicating that irradiation at 15 kGy did not exert a significant negative effect on this parameter of GThMO and RThMO. Our results are in accordance with the previously reported findings of Al-Bachir, [5] who also did not find any significant change in RI between the irradiated and non-irradiated peanut oils.

3.7. Effect of irradiation and storage in fatty acids profile of GThMO and RThMO

The effect of irradiation at 15 kGy dose of gamma rays and storage on the fatty acid (FA) contents of GThMO and RThMO is presented in Table 3. The major FAs detected in GThMO and RThMO produced from both radiated and non-radiated thyme meal samples were palmitic acid (C16-0), stearic acid (C18-0), oleic acid (C18-1), linoleic acid (C18-2), and linoleic acid (C18-3). The relative percentage of the identified FAs compositions of GThMO and RThMO was given in table 3. Linoleic acid (C18:2) in GThMO and RThMO was the predominant unsaturated fatty acids (USFAs) (45.28% and 44.07%) followed by oleic acid (C18:1) (38.32% and 40.47%) and linolenic acid (C18:3) (0.63% and 0.71%). Palmitic acid (C16:0) in GThMO and RThMO (11.32% and 10.04%) was the major saturated fatty acids (SFA) followed by stearic acid (C18:0) (4.39% and 4.96%), respectively. GThMO and RThMO are quite rich in healthy USFA (Linoleic+Oleic) and considered a good source of FAs which has multiple benefits for human health [18]. However, GThMO and RThMO showed low SFA contents (>15%), and high USFA (<85%). Thyme meal oil is having high oleic and linoleic USFA contents and low palmitic and stearic SFA contents. Linoleic acid (C18:2) content had the highest ratio (45.10% and 44.07%) which is found in GThMO and RThMO is essential FA that is vital in the maintenance of some key physiological functions of the human body. These fatty acid compositions are recognized for their health-promoting capacity, which in turn results in low blood pressure and beneficial effects on heart-related diseases [27].

Konuskan *et al.*, [28] stated that linoleic acid is essential for human body to maintain the integrity of the skin, cell membranes, the immune system, and eicosanoids synthesis.

In general, the results showed that gamma irradiation of GThM and RThM at 15 kGy dose had an effect on the individual fatty acids present in GThMO and RThMO. This study showed that the major type of FA in GThMO and RThMO was USFAs (84.38% and 85.24%), namely polyunsaturated fatty acid (PUSFA) (45.91 and 44.74%). While the amount of SFA of the same sample of GThMO and RThMO was found in level of 15.71 and 15.00%), respectively. Also, the TUSFA/TSFA of the GThMO and RThMO was found in level of 2.97 and 2.99, respectively. Furthermore, no significant changes were observed in the levels of unsaturated fatty acids (USAFA), suggesting that irradiation did not affect the GThMO and RThMO (Table 4). Additionally, the level of C18:2 remained unchanged, indicating the absence of oil deterioration caused by the irradiation [29].

Some research has indicated that animal feed with plants of high PUFA content can increase the level of PUFA in meat fats, as well as aroma and flavour [8]. Also, thyme meal was characterized by a high unsaturated fatty acid/saturated fatty acid (USFA/SFA) ratio, which is highly favourable for the reduction of serum cholesterol and atherosclerosis, and the prevention of cardiovascular disease [30]. As shown in Table 4, the USFA/SFA ratio of GThMO and RThMO was 5.45 and 5.69, respectively. Thus, the incorporation of GThMO and RThMO into the diet could bring great health beneficial effects to the cardiovascular system due to the high content of USFA namely PUSFAs. Irradiation treatment caused irregular changes in the contents of individual FAs. Gamma irradiation decreased but not significantly ($p<0.01$) the SFA and increased ($p<0.01$) the USFA. The results of this study indicate that irradiation induced decomposition of the USFAs. Free radicals generated by irradiation react with the double bonds of FAs [13]. We found no study in the literature on the effect of irradiation on FAs composition of the GThMO and RThMO.

Our results, are in contrast with those of Al-Bachir, [31], Al-Bachir, [32], and Zoumpoulaki *et al.* [33]. who reported an increase in saturated fatty acid content and a decrease in mono- and polyunsaturated fatty acid content due to irradiation of almond kernel oil, peanut seed oil, and sesame oil, Another study suggested that, the decrease in USFAs during the irradiation exposure of oil was mainly due to a

molecular structure different in FAs [34]. On other hand, irradiation treatment of sesame, peanut and sunflower seeds at dose levels of 3, 6 and 9 kGy did not significantly affect the FAs percentages.However, the USFAs, SFAs and the ratio of SFAs to USFAs (TU/TS) were changed upon irradiation [14].

Table.4 Effect of gamma irradiation and storage period on total saturated fatty acids (SFA), unsaturated fatty acids (USFA) and (USFA/SFA) (%) of oil produced from green thyme meal (GThM) and red thyme meal (RThM) products.

Treatments	Green thyme melal (GThM)		Red thyme meal (RThM)		P-level
	Control	15 KGY	Control	15 KGY	
Storage period /(Months)		**SFA**			
0 Months	15.71 ± 2.10^{aA}	13.12 ± 0.08^{bB}	15.00 ± 0.45^{abA}	14.99 ± 0.03^{abA}	**NS**
6 Months	15.05 ± 2.25^{aA}	13.22 ± 0.61^{aB}	14.29 ± 0.15^{aB}	14.86 ± 0.10^{aA}	**NS**
12 Months	16.54 ± 2.38^{aA}	14.96 ± 0.42^{aA}	14.34 ± 0.12^{aB}	14.53 ± 0.05^{aB}	**NS**
P-level	**NS**	**	*	**	
		USFA			
0 Months	84.38 ± 1.48^{bA}	87.51 ± 0.10^{aA}	85.24 ± 0.34^{bA}	85.01 ± 0.03^{bAB}	**
6 Months	85.41 ± 2.45^{abA}	87.18 ± 0.96^{aA}	85.63 ± 0.13^{abA}	84.48 ± 1.06^{bB}	**NS**
12 Months	83.95 ± 2.13^{aA}	84.90 ± 0.44^{aB}	85.87 ± 0.46^{aA}	85.80 ± 0.30^{aA}	**NS**
P-level	**NS**	**	**NS**	**NS**	
		USFA/SFA			
0 Months	5.45 ± 0.89^{bA}	6.67 ± 0.05^{aA}	5.69 ± 0.19^{bB}	5.67 ± 0.01^{bB}	*
6 Months	5.78 ± 1.05^{aA}	6.60 ± 0.37^{aA}	5.99 ± 0.07^{aA}	5.69 ± 0.04^{aB}	**NS**
12 Months	5.16 ± 0.85^{bA}	5.68 ± 0.18^{abB}	5.99 ± 0.03^{aA}	5.91 ± 0.01^{abA}	**NS**
P-level	**NS**	**	*	**	
		PUSFA			
0 Months	45.91 ± 0.84^{bA}	47.33 ± 0.04^{aA}	44.77 ± 0.29^{cC}	43.31 ± 0.35^{dB}	**
6 Months	47.31 ± 2.28^{aA}	48.41 ± 1.71^{aA}	46.06 ± 0.32^{abB}	43.64 ± 0.73^{bAB}	*
12 Months	46.91 ± 1.33^{aA}	45.16 ± 0.38^{bB}	47.36 ± 0.61^{aA}	44.88 ± 0.80^{bA}	*
P-level	**NS**	*	**	**NS**	
		PUSFA/SFA			
0 Months	2.97 ± 0.48^{bB}	3.61 ± 0.03^{aB}	2.99 ± 0.10^{bC}	2.89 ± 0.03^{bB}	*
6 Months	3.21 ± 0.64^{abA}	3.67 ± 0.28^{aB}	3.22 ± 0.05^{abB}	2.94 ± 0.03^{bB}	**NS**
12 Months	2.88 ± 0.48^{aB}	3.02 ± 0.10^{aA}	3.30 ± 0.07^{aA}	3.09 ± 0.07^{aA}	**NS**
P-level	**	**	**	**	

^{abc}Mean values within the same column that do not share a superscript are significantly different.
^{ABC} Mean values within the same row that do not share a superscript are significantly different.
NS: not significant.
* Significant at $p<0.05$.
** Significant at $p<0.01$.

4. Conclusion

The analytical parameters studies for GThMO and RThMO produced from irradiated and non-irradiated samples during storage including AV, PV, TBA, IV, SV, RI, and FA profile were within the limits recommended by the national and international standards for edible vegetable oil. According to our results, it be suggested that gamma irradiation at 15 kGy that recommended in the literature for decontamination purpose may be useful methods for maintaining GThM and RGtM quality and can be suggesting as alternative method for this kind of prepared meals. Further quantitative and qualitative studies are required on oil from different food sources, with wider irradiation dose ranges, to confirm the fate of each oil parameters change due to gamma irradiation treatment.

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Conflict of interest statement

The author declares no conflicts of interest.

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