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Study on the effect of incorporation of irradiated sunflower flour on the physico-chemical and sensory properties of biscuits during the storage period

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Abstract

Sunflower seeds are highly popular in food mixes, especially biscuits and are thought to be nutritionally beneficial. These seeds are rich in healthy fats, useful plant compounds and many vitamins and minerals. The present study was conducted to investigate the effect of the incorporation of irradiated sunflower flour on the physico-chemical and sensory properties of biscuits during the storage period. The physical and chemical properties of wheat flour with 72% extraction, nonirradiated sunflower flour and sunflower flour irradiated with 5 kGy and 10 kGy were estimated. Additionally, the physical, chemical and sensory properties of extracted oils from the biscuits were also evaluated during storage periods of two and four months. The refractive index, peroxide value and iodine value decreased as the storage period increased, while acids such as oleic acid and the acid value increased slowly and gradually. Additionally, the fatty acids of the oils extracted from biscuits during storage were high in unsaturated fatty acids at the beginning of storage. After two and four months of storage, an increase in saturated fatty acids and a decrease in unsaturated fatty acids was observed. The results showed that the overall acceptability of sunflower flour biscuits irradiated at a dose of 10 kGy was highest, while the control biscuits had the lowest acceptability after 4 months of storage. It was concluded that the substitution of up to 10% of wheat flour with nonirradiated or irradiated sunflower flour can be a good method for food product development due to the ability of sunflower flour to improve the nutritional value and overall acceptability of biscuits.

1. Introduction

Bakery products, especially biscuits, are one of the most popular foods because they have varied tastes, are easy to consume, are relatively low cost and have long storage life. Efforts are being made to improve the nutritional value of biscuits. This added nutritional value is achieved by increasing the proportions of raw whole-grain materials other than wheat or by using different types of oilseeds in the basic recipes (Bhise and Kaur, 2013; Shafi *et al.*, 2016).

Sunflower seeds are highly popular in food mixes, multi-grain bread and bars and are thought to be nutritionally beneficial. These seeds are rich in healthy fats, useful plant compounds and many vitamins and minerals. These nutrients may play a role in reducing the risk of developing common health problems (Anjum *et al.*, 2012; de Lamo and Gomez, 2018).

Irradiation has the potential to enhance food safety for both fresh foods that will be consumed raw and for raw foods that will be further processed. In addition, irradiation treatment combined with proper refrigeration for storage can prolong the shelf life of these food items without affecting their flavor and acceptability (Al-Bachir, 2004; Gölge and Ova, 2008; Al-Bachir, 2015).

The physical, chemical and biological characteristics of oilseed fat are determined by their fatty acid content, as indicated by Researchers (Hassan *et al.*, 2009; Salem *et al.*, 2012; Yaqoob *et al.*, 2012; Ghosh *et al.*, 2019) who conducted gas chromatographic studies on the fatty acid composition of sunflower oil. These studies found that the unsaturated fatty acid levels of sunflower oil were high, i.e., oleic (C: 18:1) and linoleic (C: 18:2) acids, and their values ranged from 14.65 to 20.75%, respectively.

Reports indicated that the use of radiation may have little impact on the nutritional value of food. However, controlling the irradiation conditions leads to consistent

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results and useful applications of existing radiation technologies. However, the exposure of food to radiation has advantages because, unlike traditional methods of conservation, these methods do not lead to loss of flavor or quality (WHO, 1992; FAO, 2004; Basmacioğlu-Malayoğlu *et al.*, 2011).

The incorporation of sunflower seeds at levels of up to 16% in normal and whole-grain bread enrich the bread in fats with a high linoleic content (Škrbić and Filipčev, 2008).

The objective of this study was to evaluate the physical, chemical and sensory properties of biscuits made with wheat flour and up to 10% nonirradiated and irradiated (doses 5 and 10 kGy) sunflower flour during the storage period.

2. Materials and methods

2.1 Procurement of raw materials

Wheat flour (72% extraction) was obtained from a local market. Sunflowers (Meyake) were obtained from a local market; sunflower seeds were cleaned from impurities and foreign grains, and the seeds were blended for 30 s in a blender and then diluted by hand to obtain kernel flour. This flour was then milled using a laboratory disc mill and sieved through an 8-mm sieve to obtain the sunflower flour.

Sugar, buttermilk, skimmed milk powder, ammonium bicarbonate, sodium bicarbonate, egg and vanilla were purchased from a local market in Riyadh, Saudi Arabia (Table 1).

Table 1. The formula of biscuits prepared with different proportions of wheat flour and sunflower flour

Ingredients (100 g)	Control	Sunflower flour
Wheat flour 72%	100 g	90 g
Sunflower flour	0.0 g	10 g
Sugar	30 g	30 g
Buttermilk	15 g	15 g
Skimmed milk powder	0.5 g	0.5 g
Ammonium bicarbonate	0.66 g	0.66 g
Sodium bicarbonate	0.33 g	0.33 g
Egg (whole, fresh)	24 g	24 g
Vanilla	1 tsp	1 tsp

2.2 Irradiation process

The sunflower flour was divided intO2 portions and treated with gamma radiation at 5.0 and 10.0 kGy with a Gammacell 220. The dose rate of the 60 Co-gamma radiation source was 1 kGy/h at the time of radiation, and the irradiation was performed at King Abdul Aziz City for Science and Technology (KACST), Saudi Arabia.

2.3 Development of biscuits

Sunflower flour irradiated with 5 and 10 kGy was used to replace 10% of the wheat flour in the preparation of sweet biscuits.

The biscuits were prepared according to the standard procedure for semihard biscuits (peti-pier type) at the Nutrition and Food Sciences Department, Princess Noura Bint Abdulrahman University, Riyadh, Saudi Arabia. The biscuit ingredients are shown in Table 1. The usual technological method applied in nutrition and food sciences for creaming, mixing and cutting (½ cm thick and 2 cm in diameter) was used. The biscuits were baked for 12-15 mins at 180°C (Figure 1).

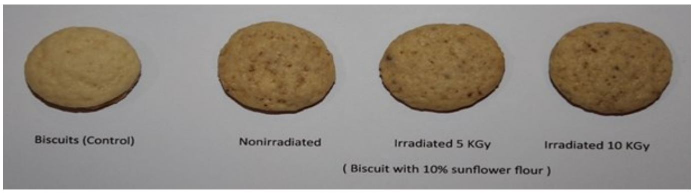

Figure 1. Biscuits supplemented with 10% sunflower flour

2.4 Oil extraction from biscuits

The sunflower biscuits were kneaded, packed in cheesecloth, and then squeezed with a hydraulic laboratory Carver press. The resultant crude extract (vegetation water and oil) was transferred into a separatory funnel, and then the oil was separated from the vegetation water. The oil layer was dried over anhydrous sodium sulfate and then filtered through Whatman No. 1 filter paper and kept in a brown glass bottle (20 mL) at 5°C until analyzed by the method of the AOAC (2000) and Horwitz (2000).

2.5 Analytical examination of sunflower flour

Physical and chemical analyses of the 72% wheat flour, nonirradiated sunflower flour and sunflower flour irradiated at doses of 5 kg and 10 kg were performed before the biscuits were produced.

2.6 Analytical Examination of Oils Extracted from the Biscuits

Physical and chemical analysis was carried out for samples of biscuits that contained 10% sunflower flour (nonirradiated and irradiated with 5 and 10 kGy) and wheat flour. The tests were conducted at the beginning of storage and every 2 months until the end of storage (4 months).

2.7 Physicochemical properties

2.7.1 Refractive index

Objective numerical aperture can be dramatically increased by designing the objective to be used with an immersion medium, such as oil, glycerin, silicone, or water. By using an immersion medium with a refractive index similar to that of the glass coverslip, image degradation due to thickness variations of the cover glass are practically eliminated whereby rays of wide obliquity no longer undergo refraction and are more readily grasped by the objective. The refractive index of the oils was calculated according to the method of the AOAC and Horwitz (2000) using a refractometer (NYRL-3-Poland).

2.7.2 Acid value

The acid value was determined according to the method of the AOAC (2005) and Horwitz (2000). The acid value was reported as mg of KOH required to neutralize 1 g of oil.

2.7.3 Peroxide value

The peroxide value was determined according to the method of the AOAC (2005) and Horwitz (2000) The peroxide value was reported as milliequivalent (ME) peroxide/1 kg fat.

2.7.4 Iodine value

The iodine value was determined with the Hanus method according to the AOAC (2005) and Horwitz (2000). The iodine value was formulated as grams of iodine absorbed by 100 g oil.

2.7.5 Fatty acid composition

The fatty acid composition was determined by a gas-liquid chromatography apparatus according to the method of Aura *et al.* (1995).

2.8 Sensory evaluation

Sensory evaluation is a scientific discipline that is used to measure and analyse people's responses to products as perceived through the five senses - sight, smell, touch, taste and sound. Sunflower biscuit samples were tested by ten panelists for external color and appearance and internal crumb texture, smell and flavor according to Smith (1972).

2.9 Statistical analysis

The data obtained were described as the mean±SD and were statistically analyzed using SPSS Inc. (Chicago, IL, USA). Significant differences were evaluated by Duncan's Multiple Range Test (DMRT), with differences considered significant at $p<0.05$.

3. Results and discussion

3.1 Physicochemical properties of sunflower flour

Table 2 shows the physical and chemical properties of the oil extracted from the sunflower flour. Physical examination of the oil included many tests, the most important of which was the calculation of the refractive index. The refractive index values at 25°C for oil extracted from nonirradiated sunflower flour and the sunflower flour irradiated with 5 and 10 kGy were 1.4677, 1.4657 and 1.4655, respectively, while wheat flour (72%) gave the lowest value for the refractive index at 25°C (1.4616). This may be because the ratio of oil in the flour was low. The refractive index value of oil extracted from nonirradiated sunflower flour was 1.4677, which was slightly lower than the value of 1.475 reported by Mudawi *et al.* (2014) and slightly higher than that value of 1.464 reported by Al-Bachir and Othman (2018) for sunflower oils extracted from other varieties.

Regarding irradiation exposure, the increase in the radiation doses did not have significant ($p>0.05$) effects on the refractive index values of the sunflower seed oil. Our results were in agreement with published reports (Yaqoob *et al.*, 2012), who also did not observe any significant change in refractive indices between control and irradiated sunflower oils.

The table also shows the acid value of oils extracted from wheat flour, nonirradiated and irradiated sunflower flour. The wheat flour samples showed (0.2871 mg KOH/g oil) the lowest value compared to the

Table 2. Physical and chemical properties of sunflower flour and wheat flour samples

Properties	Wheat Flour, 72% extract	Nonirradiated sunflower flour	Irradiated sunflower flour	
			5 kGy	10 kGy
Refractive index at 25°C	1.4616^{b}	1.4677^{a}	1.4657^{a}	1.4655^{a}
* Acid value	0.2871^{a}	0.3936^{ab}	0.3167^{bc}	0.3124^{ab}
Acid value as KOH%	0.5710^{c}	0.7820^{a}	0.6290^{b}	0.6210^{ab}
** Peroxide value O_2/kg oil	2.0000^{b}	2.5000^{a}	2.0300^{b}	2.0000^{b}
*** Iodine value	104.0000^{a}	124.0000^{a}	128.0000^{b}	129.0000^{b}

Values with different superscripts indicate significant difference ($p<0.05$) between samples.
* Acid value is expressed as % oleic acid
** Peroxide value is reported as milliequiv peroxide/kg oil
*** Iodine value was determined by the Hanus method and is expressed as g iodine absorbed/100 g oil

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nonirradiated sunflower flour and the 5 and 10 kGy irradiated-sunflower flours. This may be because the ratio of oil was low in the flour. These results agree with published reports (Farkas 2006; Basmacioğlu-Malayoğlu *et al.*, 2011; Yaqoob *et al.*, 2012).

The acid value of the oil extracted from the nonirradiated sunflower flour was 0.3936 mg KOH/g oil. This value was in the range of 0.11 - 0.51 mg KOH/g oil, which is consistent with studies of sunflower seed oil (Hoseini *et al.*, 2011; Samarth and Mahanwar, 2015).

The radiation doses did not have significant ($p>0.05$) effects on the acid value (0.3167 - 0.3124 mg KOH/g oil), which is affected by the conversion of triglycerides (Lutfullah *et al.*, 2003). Similar findings were reported for the acid values of sunflower and soybean oils (Zeb and Ahmad, 2004) and pumpkin seed (EI-Aziz *et al.*, 2011).

The peroxide value of the oil extracted from the nonirradiated sunflower flour was 2.500 meq O_2/kg oil. This value agrees with the study by Al-Bachir and Othman (2018) for oil extracted from gamma-irradiated sunflower seeds (2.45 meq O_2/kg oil).

However, the peroxide value of sunflower seed oil found in this study (2.500 meq O_2/kg oil) was below the maximum acceptable value of 10 meq O_2/kg oil set by the Codex Alimentarius Commission for seed oils (Mohammed and Hamza, 2008).

While the peroxide value of oils extracted from wheat flour was 2.000 meq O_2/kg oil, similar to that of oils extracted from irradiated sunflower flour (2.030-2.000 meq O_2/kg oil), the low peroxide value of sunflower oil found in the present study suggests that this oil may be less susceptible to rancidity than other vegetable oils (Al-Bachir and Othman, 2018).

The iodine values of oil extracted from nonirradiated sunflower flour and the sunflower flour irradiated with 5 and 10 kGy were 124.00, 128.00 and 129.00 g of I_2 100/g oil, respectively, while wheat flour (72%) gave the lowest iodine value (104.00 g of I_2 100/g oil). The irradiation doses (5 and 10 kGy) had no significant ($p>0.05$) effect on the iodine values of sunflower flour.

The results indicate a low degree of saturation. The iodine value gives a proximate amount of the unsaturated fatty acids in any oil sample, thereby providing a comparison of the saturated fatty acid components (Ogungbenle, 2003).

Contrasting findings were reported (Zeb and Ahmad, 2004) for the iodine value of sunflower and soybean oil, which decreased significantly with high gamma radiation (1, 5 and 20 kGy). Similar results were reported (EI-Aziz *et al.*, 2011) for the iodine value of pumpkin oil, which decreased significantly with 1, 3, 6 and 10 kGy of gamma radiation.

The data for the refractive index and the iodine value indicate that the oil extracted from sunflower flour is a semi-drying oil. conclude that oils are classified into drying, semi-drying and non-drying categories according to their iodine values (Akinhanmi *et al.*, 2008).

The acid and peroxide values demonstrate that no hydrolytic and oxidative rancidity occurred in the extracted oils. The acid value is a measure of the amount of free fatty acids present in the oil due to the hydrolysis of its triglycerides (Tan *et al.*, 2001; Smith *et al.*, 2007).

Figure 2 shows that the oil extracted from nonirradiated sunflower flour contained saturated and unsaturated fatty acids in different amounts, including (55.92%) linoleic acid, (26.75%) oleic acid, (11.77%) palmitic acid, and (3.05%) stearic acid, which comprised 100% of the total fatty acids.

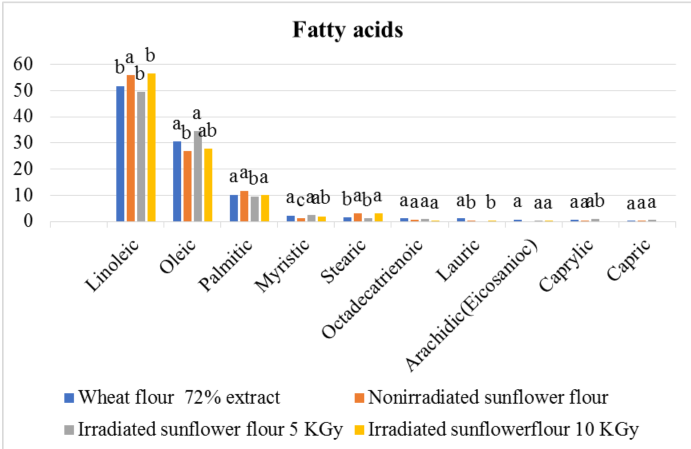

Figure 2. The fatty acid composition of sunflower flour and wheat flour samples (calculated as % of the total fatty acids). Values with different superscripts indicate significant difference ($p<0.05$) between samples.

The composition of fatty acids in oils extracted from sunflower flour changes with climatic conditions during the growing season and with planting location. The fatty acid content of sunflower oils presented in this study was similar to that of reports (Makhoul *et al.,* 2006; Hoseini *et al.*, 2011; Samarth and Mahanwar, 2015), who reported that sunflower oil contained palmitic (5.81-8.0%) stearic (3.35-6.3%) oleic (23.81-42.6%) and linoleic (46-65.73%) acids.

Gamma irradiation caused a noticeable alteration in the unsaturated and saturated fatty acid composition of sunflower flour, which showed a decrease ($p<0.05$) in the relative amounts of palmitic acid at 5 and 10 kGy and an increase ($p<0.05$) in the linoleic acid ($p<0.05$).

The present findings agree with previous studies; the fatty acid linoleic C18:2 is considered to be the most affected by gamma radiation, which was decreased by over 2% when irradiated at 7.5 kGy, followed by oleic C18:1 (Afify *et al.*, 2013).

Al-Bachir (2014) indicated that the SFAs and USFAs of almond were not affected by irradiation with an irradiation dose of 3 kGy. There was a significant increase ($p<0.05$) in the concentration of total unsaturated fatty acids in sunflower seed oil, while the total saturated fatty acids were significantly ($p<0.05$) reduced as a result of the irradiation process.

3.2 Physicochemical properties of biscuits

The data in Table 3 show that the addition of sunflower flour improves the physical and chemical properties of biscuits compared to those of the control.

The values of various parameters of biscuits with 10% nonirradiated sunflower flour, sunflower flour irradiated at 5 and 10 kGy and control biscuits during the storage periods are shown in Table 3.

The refractive index values at 25°C were highest for the oil extracted from the biscuits with the irradiated sunflower flour (1.4729, 1.4595 and 1.4579) during the storage periods.

Regarding irradiation exposure, the refractive index values decreased with increasing radiation doses and storage periods (1.4749, 1.4545 and 1.4519) at 5 kGy (1.4797, 1.4404 and 1.4356) at 10 kGy. Overall, the refractive index decreased with increasing storage periods for all samples.

Lutfullah *et al.* (2003) indicated that 1, 5, 10, 15 and 20 kGy of gamma irradiation doses did not have significant effects on the refractive index of sunflower and soybean oils.

These results agree with those of Yaqoob *et al.* (2010), who did not observe any significant change in refractive indices between the control and irradiated sunflower oils. Additionally, the results indicated that storage periods had an effect on the refractive index of sunflower seed oil (Ogungbenle, 2003). Conversely, the acid value increased with increasing storage period and irradiation dose. Additionally, the peroxide value and iodine value decreased with increasing storage periods for all samples.

The data indicated that oils extracted from biscuit samples are less stable with radiation and storage, resulting in high rancidity. The acid value of the oil extracted from nonirradiated sunflower biscuits increased ($p<0.01$) during storage. After 4 months of storage, the acid value of the oil extracted from irradiated sunflower flour was lower ($p<0.05$) than that from nonirradiated sunflower flour.

These results agree with Studies (Al-Bachir, 2004; Al-Bachir, 2015), who found that the acid values increased with irradiation dose and storage time in walnut and peanut. The increasing acidity in oil after irradiation may be attributed to the production of small

Table 3. Physical and chemical properties of biscuits during the storage periods

	Wheat Flour, 72% extract	Nonirradiated sunflower flour	Irradiated sunflower flour 5 kGy	Irradiated sunflower flour 10 kGy
Property		Baseline		
Refractive index at 25°C	1.4652^{b}	1.4729^{a}	1.4749^{a}	1.4797^{a}
Acid value	0.2016^{c}	0.2321^{d}	0.2931^{c}	0.2145^{c}
Acid value as KOH%	0.5008^{d}	0.5510^{e}	0.4510^{c}	0.4020^{c}
Peroxide value O_2/kg oil	2.0000^{b}	2.5000^{a}	1.8000^{a}	1.6600^{a}
Iodine value	108.0000^{a}	113.0000^{a}	127.000^{a}	128.0000^{a}
Property		After 2 months		
Refractive index at 25°C	1.4585^{b}	1.459^{a}	1.4545^{ab}	1.4404^{b}
Acid value	0.7200^{bc}	1.1000^{b}	1.0300^{a}	0.7900^{bc}
Acid value as KOH%	1.4300^{a}	2.3000^{a}	1.7200^{a}	1.5900^{ab}
Peroxide value O_2/kg oil	1.5500^{a}	1.7200^{a}	1.6200^{a}	1.2500^{a}
Iodine value	100.0000^{a}	110.0000^{a}	123.0000^{a}	120.000a
Property		After 4 months		
Refractive index at 25°C	1.4519^{c}	1.4579^{a}	1.4519^{a}	1.4356^{bc}
Acid value	0.8300^{b}	2.0000^{a}	1.1800^{a}	1.1100^{a}
Acid value as KOH%	1.6600^{a}	4.0200^{a}	2.3800^{a}	2.2500^{a}
Peroxide value O_2/kg oil	0.6300^{c}	0.6800^{d}	0.5200^{c}	0.5000^{ab}
Iodine value	96.0000^{ab}	107.0000^{a}	118.000^{a}	112.000^{a}

Values with different superscripts indicate significant difference ($p<0.05$) between samples.

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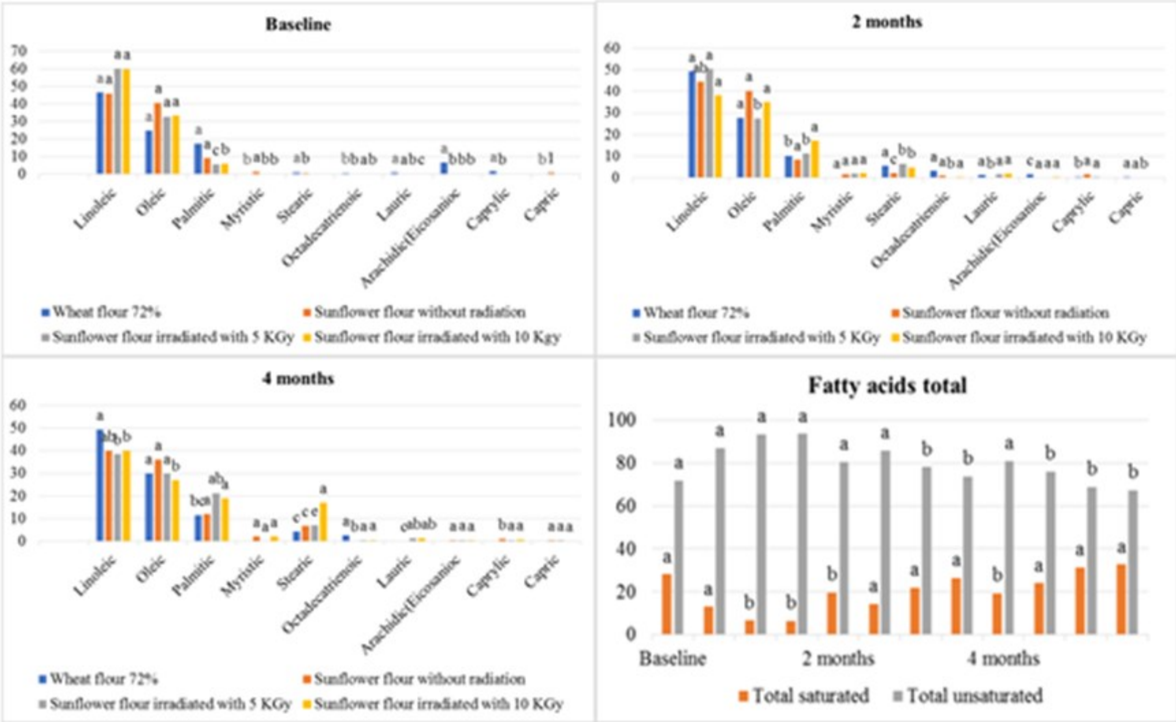

Figure 3. The fatty acid composition of biscuits during the storage periods. Values with different superscripts indicate significant difference (p<0.05) between samples.

molecules, including free fatty acids, by the degradation of large lipid molecules (Al-Bachir, 2004; Ghosh *et al.*, 2019).

The data in Figure 3 show that levels of saturated and unsaturated fatty acids from oils extracted from biscuit samples change with radiation and storage. Changes in the composition and concentration of fatty acids in irradiated products are related to essential fatty acids, irradiation dose, temperature and storage conditions (Al-Bachir, 2017).

Unsaturated fatty acid levels were low in the control biscuits at 71.90% at the beginning of storage, in comparison with biscuits with 10% sunflower flour without radiation and sunflower flour irradiated with 5 and 10 KGy, which showed high unsaturated fatty acids (87.05, 93.50 and 93.60%, respectively). On the other hand, the saturated fatty acid content was lower than the unsaturated fatty acid content.

After storage, it could be observed that unsaturated fatty acid levels were high in the control biscuits (80.39%) and the biscuits made with 10% nonirradiated sunflower flour (85.70%). In contrast, decreased levels of unsaturated fatty acids from 93.5% to 73.11% and 68.79% and 93.60% to 73.61% and 64.70% were observed in biscuits made with 10% sunflower flour irradiated with 5 and 10 KGy from the initial time of storage to timepoints two and four months after the initial storage, respectively.

This may be because, with radiation, some unsaturated fatty acids were degraded, and new saturated fatty acids may have been formed. Irradiation affects the fat fraction structure, and free radicals increase the recombination activity to form substances that can react with other components (Biswas *et al.*, 2007). Lipids in fatty acids can form stable complexes with sugar and protein compounds. These complexes can be found in the crude fat fraction, which may suggest that no such changes occur in raw fat (Kiczorowska *et al.*, 2015; Kiczorowska *et al.*, 2016).

The fatty acid profile of oil seeds subjected to the culinary treatments showed saturation of acids accompanied by an increase in the saturated fatty acid content at the expense of the unsaturated fatty acid fraction is processed camelina, sunflower, and flax seeds (Kiczorowska *et al.*, 2019).

Another study reported that irradiation of hazelnuts at a dose of 7 kGy resulted in an increase in saturated fatty acids and a parallel decrease in unsaturated fatty acids (Mexis and Kontominas, 2009). Irradiation of pine nuts (*Pinus pinae*), fenugreek and turmeric had no effect on their fatty acid compositions (Gölge and Ova, 2008; Chatterjee *et al.*, 2009). investigated the effect of irradiation on the fatty acid composition of black cumin and reported that irradiation affected the stearic and oleic acid contents of the samples (Arici *et al.*, 2007).

3.3 Sensory evaluation

The sensory tests (external color and appearance, internal color, sensory and overall acceptability) of biscuits samples were scored by trained panelists. The hedonic scale test scores were subjected to analysis of variance as shown in Table 4.

The sensory scores of all desirable attributes decreased slightly in both control biscuits and biscuits containing 10% 5 and 10 KGy-irradiated or nonirradiated sunflower at the end of 4 months when compared to the initial values (Table 4). However, the sensory scores were still acceptable.

The data showed that the overall acceptability of sunflower flour biscuits irradiated at a dose of 10 KGy was highest, while the control biscuits had the lowest acceptability after 4 months of storage.

There were no statistically significant differences in the scores for the different durations of storage. The increase in overall acceptability was due to the fat content of the sunflower flour in addition to the effect of the irradiation dose, which significantly improved the sensory and overall acceptability of the biscuits. According to Simona *et al.* (2017). the overall acceptability, texture and aroma were significantly improved in cracker biscuits made with sunflower seed flour.

After 4 months, the biscuit samples lost their crisp texture and the crumb color changed but remained acceptable.

Chetana and Sunkireddy (2011) evaluated the sensory characteristics of peanut chikki and observed a crisp texture up to 45 days under accelerated conditions and up to 60 days under ambient conditions.

Slight off-flavor was evident in irradiated sunflower flour biscuits at the end of 4 months of storage compared

Table 4. Sensory scores of biscuits during storage periods

	Wheat Flour, 72% extract	Nonirradiated sunflower flour	Irradiated sunflower flour	
			5 kGy	10 kGy
Factors	Baseline			
External color and appearance:				
Top (10)	10[a]	9.8[ab]	9.8[ab]	9.8[a]
Bottom (10)	10[a]	10[a]	9.9[a]	9.9[a]
Internal: Crumb Color (20)	20[a]	19.5[a]	19.3[ab]	19.0[a]
Crumb Texture (20)	20[a]	19.5[ab]	19.5[ab]	19.5[a]
Sensory:				
Small (15)	15[a]	14.7[ab]	13.5[ab]	13.0[b]
Flavor (15)	15[a]	14.1[ab]	13.0[b]	12.5[b]
Bite (10)	15[a]	9.7[ab]	9.5[ab]	9.5[a]
*Overall: Acceptability	100[a]	97.3[a]	94.5[a]	92.7[a]
Factors	After 2 months			
External color and appearance:				
Top (10)	8.5[ab]	8.3[ab]	8.9[b]	8.9[ab]
Bottom (10)	8.4[ab]	8.8[ab]	8.6[b]	8.5[b]
Internal: Crumb Color (20)	18.0[ab]	17.5[b]	17.3[b]	18.0[b]
Crumb Texture (20)	17.5[b]	18.0[bc]	19.0[b]	19.0[b]
Sensory:				
Small (15)	12.5[b]	12.5[b]	12.5[b]	13.0[ab]
Flavor (15)	12.5[ab]	12.0[b]	12.5[ab]	12.0[ab]
Bite (10)	7.5[b]	8.3[b]	8.5[ab]	9.0[ab]
*Overall: Acceptability	84.9[b]	85.4[ab]	87.3[ab]	88.4[a]
Factors	After 4 months			
External color and appearance:				
Top (10)	8.0[b]	6.8[c]	7.0[bc]	8.5[b]
Bottom (10)	7.9[b]	7.5[b]	8.0[b]	8.3[b]
Internal: Crumb Color (20)	17.5[b]	17.0[bc]	16.5[bc]	17.5[b]
Crumb Texture (20)	15.5[c]	15.0[c]	18.0[bc]	18.5[b]
Sensory:				
Small (15)	10.0[c]	13.0[c]	12.0[bc]	13.0[b]
Flavor (15)	11.0[c]	12.0[c]	11.0[bc]	11.5[b]
Bite (10)	5.5[b]	7.5[c]	8.0[b]	8.5[b]
*Overall: Acceptability	75.4[c]	79.0[bc]	80.5[ab]	81.0[ab]

* 100-90: Excellent, 89-80: Very good, 79-70: Good, 69-60: Acceptable, <59: Not acceptable. Values with different superscripts indicate significant difference ($p<0.05$) between samples.

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to that of the control biscuits, thus increasing the shelf life of the product. In the present study, the biscuits remained viable for a longer period.

According to Škrbić and Filipčev (2008), Muttagi *et al*. (2014) and de Lamo and Gomez (2018), the incorporation of oilseeds modifies the rheology of the doughs and the volume and texture of the products, affecting their organoleptic characteristics and their acceptability.

4. Conclusion

This study showed that incorporation of sunflower flour irradiated at a dose of 10 kGy at a rate of 10% in biscuits made of wheat flour resulted in the highest scores for all quality traits and good physical and chemical properties of oils extracted from the biscuits during four months of storage. Overall, the substitution of 10% of the wheat flour with sunflower flour in the biscuit formulation enhanced the nutritional value of the biscuits.

Sunflower flour is a good source for bakery product development due to its ability to improve the nutritional value and total acceptability of biscuits.

Conflict of interest

The author declares that there is no conflict of interest regarding the publication of this article.

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