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Use of Pistachio Meal and Mono- and Diglyceride in the Production of Low-Fat Pistachio Butter

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ABSTRACT

Background: Pistachio butter is produced from ground roasted pistachio nuts. **Methods:** In this study, different formulas of low-fat pistachio butter with 0, 5 and, 10% of pistachio meal and 0, 1 and, 2% of mono- and diglyceride were examined in terms of physicochemical, sensory, and nutritional characteristics. **Results:** In the fourth month of storage, the highest oil separation (12.4%) from the product was observed in pistachio butter without emulsifier and meal ($P \leq 0.05$). The most value of carbohydrates and the least value of oil content were observed in the pistachio butter containing 10% meal. The lowest anisidine and peroxide value was detected in the formula with higher content of emulsifier (2%). The pistachio butter formulas without or with 5% meal showed a better green color (lower 'a' value). The pistachio butter with higher values of the meal obtained the least spreadability score. **Conclusion**: The formula containing 1% mono- and diglyceride and 5% pistachio meal was selected as the best low-fat pistachio butter.

Keywords: *Emulsifying agents; Food quality; Lipid peroxides; Pistachio*

Introduction

Tree nuts have high nutritional values and are included in people's daily diets. Today, consumers are more inclined to consume low-fat nut butters due to the high risk of consuming high fat products. The qualitative characteristics of plant butters from tree nuts have been studied by many researchers.

Regarding the textural specifications and viscosity of low-fat peanut butter, Singh successfully realized that their sample had a lighter color, better spreadability, and less firmness than the control sample (Singh *et al.* (2000).

Abd-Elsattar *et al.* investigated the quality of soy butter produced from defatted flour and compared it with the commercial peanut butter (Abd-Elsattar and Abdel-Haleem (2016). The results significantly showed that soy butter had the highest protein content and commercial peanut butter had the highest fat and calorie content. They recommended the soy butter with low-fat content

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to consumers who are more concerned about soy products (as a functional food) other than commercial peanut butter.

Shahidi-Noghabi *et al* reported that structural reform of walnut butter occurs at the higher amount of lecithin. They also found that emulsifiers produced a more uniform texture. These results can be helpful in the development of walnut butter process and the design of the packaging system (Shahidi-Noghabi *et al.* (2019).

The pistachio butter is one of the nutritious nuts of the pistachio processing industry, which is provided from ground pistachio nuts with sugar (or other natural sweeteners such as honey and date syrup). The nutritional properties of the pistachio butter are pretty similar to the scorched pistachio kernels, and its sensory specifications depend on the formulation and production method (Shakerardekani and Tavakolipour, 2019) .

Shakerardekani *et al.* explained the pistachio butter production process. They also investigated the oxidative stability of pistachio butter (Shakerardekani and Tavakolipour, 2019). Emadzadeh *et al* used three different gums as a fat replacer and two sweeteners (sucrose and isomalt) in low calorie pistachio butter (Emadzadeh *et al.*, 2011) .

Shakerardekani *et al* investigated whether raising mono- and diglyceride levels affects the specifications of low fat pistachio spread (Shakerardekani *et al.*, 2013c). As a result, they found that the addition of an emulsifier changed the physicochemical and rheological specifications of the pistachio spread.

Using defatted meal can produce low-fat pistachio butter with higher protein and lower price. The method advantage is that both pistachio oil is sold separately and defatted meal is used in the pistachio butter formulation. As a result, it's nutritional value increases and less oil is separated from the butter texture (Emadzadeh *et al.*, 2013, Salinas *et al.*, 2021, Tapsell *et al.*, 2004). Therefore, in this study, pistachio meal and mono- and diglyceride emulsifiers were used for better nutritional value and reducing oil separation from pistachio butter texture. Furthermore, the physicochemical, nutritional, and sensory characteristics of the product were studied after four months of storage.

Materials and Methods

Dried Ohadi pistachio variety was used to produce pistachio butter. After removing the pistachio shell, the kernels were roasted at 110 °C for 15 min (Shakerardekani, 2014, Shakerardekani and Karim, 2018). The samples were formulated with 0, 5 and, 10% pistachio meal and 0, 1 and, 2% mono- and diglyceride emulsifier. The samples were evaluated in terms of physicochemical, sensory, and nutritional characteristics at first and after four months of the storage at 20 °C.

Determination of protein: In order to evaluate protein, Kjeldahl (Gerhardt GMBH & CO. KG; Königswinter, Germany) method was applied. To this end, nitrogen value was calculated. The value of consumed nitrogen was obtained by multiplying the volume of consumed acid by the acid normality by 1.4 divided by the sample weight in grams. The percentage of the protein was obtained by multiplying the percentage of the nitrogen in the protein factor. The protein factor for the pistachios was 5.30 (Wrolstad *et al.*, 2001).

Determination of reducing and non-reducing sugars by the phenol-sulfuric acid method: The reducing and non-reducing sugars of samples concentration was calculated using phenol-sulfuric acid method (Wrolstad *et al.*, 2001). The stoichiometric values of all sugar units in the sample were mixed, and a solution of 1 mg/ml was prepared in distilled water. To prepare the calibration sugar standards, using a pipette, the prepared solution was carefully spilled into 10 laboratory tubes with different sizes and concentration of 5 to 50 µl (first tube 5 µl, second tube 10 µl to tenth tube which was 50 µl). A part of the sample was transferred to a 10 ml laboratory tube. The sample volume or weight was noted and 500 µl of 4% phenol solution and then 2.5 ml of 96% sulfuric acid were added to all tubes. Then, the solutions were transported to the cuvette and were measured by sugar standards of A490 and unknown solutions. To calculate sugar

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concentration in the sample, the calibration curve of A490 was plotted against the weight of sugar (microgram). The A490 intercept of the unknown sample with the calibration line indicates the value (grams) of sugar available in the sample. The unknown sample concentration was calculated using the following equations:

Concentration(mol/g) = x(g)/(Mol.wt(g/mol) × weight(g))

Percentage of sugar (% by weight) = x(g)/weight (g) ×100

Where X is the mass (grams) of the sugar sample and Mol.wt. is the molecular weight of the monosaccharide or polysaccharide available in the sample.

Determination of oil content: Forty grams (± 0.1 g) of pistachio butter samples were mixed with 400 ml hexane followed by homogenization at 8000 rpm using a Polytron homogenizer (PT 3000, Littau, Switzerland) for 3 min. The resulting mixture was filtered with suction through a Whatman No. 4 filter paper using a Buchner funnel. The residue was re-extracted twice. The hexane-oil mixture was then passed through a layer of anhydrous sodium sulfate placed over a filter paper in a funnel and the remaining solvent was removed using a rotary evaporator (Eyela, N-1001, Tokyo, Japan) at 40 °C. The oil was weighed to calculate its concentration in the samples. The oil was stored at -18 °C until further evaluations (Hashemi *et al.*, 2020).

Determination of oil separation: The separated oil from the pistachio butter texture was absorbed by filter paper every month. Oil separation was determined by reducing weight after separating oil (Shakerardekani and Shahedi, 2015).

Determination of peroxide value: First, 0.01 to 0.3 g of oil sample was spilled into a borosilicate glass tube and 9.9 ml of chloroform/methanol solvent (7:3) was added. The sample was mixed with vortex for 2 to 4 seconds. The spectrophotometer was calibrated with a chloroform /methanol solution. Fifty microliters of xylenol orange solution and 50 ml of iron (II) chloride solution were added to the sample. The control sample was prepared without using oil. The solution was deposited at room temperature for 5 min and then the absorbance was read at 560 nm using a spectrophotometer (Biowave, WPA S2100, UK). The peroxide value was determined by the following equation (Wrolstad *et al.*, 2001):

PV = [(AS-AB) × mi] / (W × 55.84 × 2)

AS: absorbance of sample A, AB: absorbance of blank, mi: inverse slope, W: weight (g).

Determination of anisidine value (AnV): AnV is equal to 100 times the optical density measured at a wavelength of 350 nm in a cell containing one gram of oil per 100 ml of isooctane and the p-anisidine reagent (AOCS, 2004). Oil samples (0.5 ± 0.01 g) were weighed in a 25 ml volumetric flask and satiated with isooctane. Solution adsorption was measured at 350 nm. As much as 5 ml of the solution and one ml of the p-anisidine reagent were spilled into a laboratory tube. The reagent contained 0.25 g of p- anisidine per 100 ml of glacial acetic acid. The solution adsorption was read after 10 min at 350nm. The solution with 5 ml of the isooctane and 1 ml of p-anisidine was used as a blank (control). The AnV was calculated based on the following formula (Shakerardekani *et al.*, 2015):

AnV = [25 × (1.2 As - Ab)] / W

In this formula, AS refers to the absorbance of samples containing reagents after 10 min, Ab is the absorbance of blank samples after 10 min and W is the samples weight in grams.

Determination of color: The pistachio butter color was measured by Hunter Lab (Model A60-1012-402 Model, made in USA) and values of L, a, and b parameters were determined.

Sensory evaluation: The evaluation was performed by 10 trained assessors. The necessary training in relation with the samples and sensory test was provided for them. The quantitative descriptive analysis (QDA) method using 15 cm line scale was applied for sensory evaluation. The quality resulting from the assessors' opinions in relation to the special specifications of the product was collected in a special form and converted into quantity. In the evaluation, the specifications such as flavor, smell (aroma), spreadability, green color, and aftertaste were evaluated. All treatments received a code and the assessors were also

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received an evaluation form, a glass of water, and a spoon (Shakerardekani, 2017).

Data analysis: The experiment was conducted using a completely randomized design (CRD) with factorial arrangement consisting of different formulation of pistachio butter containing pistachio meal (0-10%) and mono- and diglyceride (0-2%). The data analysis was performed using Minitab 19.1 statistical software. A one-way ANOVA test was used to compare the quantitative and qualitative specifications and Tukey's test was performed to compare the average.

Results

Protein: The results (**Table 1**) showed that treatments with different values of meal and emulsifier had a significant difference in the protein value. Meal-free treatments had lower protein values ($P\leq$ 0.05). In the fourth month of storage, there was a significant difference in the treatments with different amounts of meal and the emulsifier in terms of protein content ($P\leq$ 0.05). Treatments containing 10% meal showed more protein than meal-free treatments.

Carbohydrate: According to **Table 1**, at zero time, there was a significant difference between treatments in terms of carbohydrate content ($P\leq$ 0.05). The highest value of the carbohydrate was observed in treatments containing 10% meal. These treatments had no significant difference with treatments containing 5% meal. The lowest value of carbohydrate was detected in meal-free treatments, although there was no significant difference between this formula and pistachio butter containing 5% meal. In the fourth month, there was a significant difference between treatments in terms of carbohydrate content ($P\leq$ 0.05). The highest value of carbohydrates was detected in pistachio butter containing 10% meal, which was not significantly different from other treatments containing meal. The lowest value of the carbohydrate was detected in meal-free treatments, which was not significantly different from other treatments except for the treatment containing 10% meal and 1% emulsifier.

Oil content: At zero time, there was a significant difference between pistachio butter treatments in terms of the oil content ($P\leq$ 0.05, **Table 1**). The highest oil value was observed in the meal-free treatment and the lowest in treatment with 10% meal, which was not significantly different from treatments of 5% and 10% meal. In the fourth month of storage, there was a significant difference between the treatments with different values of emulsifier and meal in terms of oil content. The highest oil content was in meal-free treatments. The lowest oil value was observed in treatments with 10 % of meal, which was not significantly different from treatments containing 5% meal.

Oil separation: **Table 2** shows that at the beginning, the value of oil separation in treatments was equal to zero. Therefore, there was no significant difference between them (P>0.05). In the fourth month of storage, there was a significant difference in terms of oil separation in treatments with different values of meal and emulsifier ($P\leq$ 0.05). The highest value of oil separation was observed in treatments without emulsifier and meal. The value of separated oil was lower in treatments that contained meal and emulsifier and there was no significant difference between them (P>0.05).

Peroxide value: The results of peroxide value measurement (**Table 2**) indicate that there was no significant difference between the treatments with different values of meal and emulsifier at the storage time of zero. In the fourth month of the storage, the peroxide value had a significant difference between the pistachio butter samples with a different amount of meal and emulsifier ($P\leq$ 0.05). The highest peroxide value (2.58 Meq/kg) was observed in pistachio butter with 5% meal and without emulsifier. The lowest peroxide value was observed in treatments containing 1% or 2% emulsifier (with or without meal).

Anisidine value: **Table 2** indicates that there was no significant difference between treatments with different amounts of meal and emulsifier at zero times. In the fourth month of the storage, there was a significant difference between treatments with different values of the meal and emulsifier in pistachio butter samples ($P\leq$0.05). The highest

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AnV was observed in treatments without emulsifier. The lowest AnV was observed in treatments containing both emulsifier and meal.

Color

'L' index: **Table 3** reveals that there was no significant difference between treatments with different values of meal and emulsifier at zero times. In the fourth month of storage, the lowest L value was observed in treatments without meal and emulsifier (control). There was no significant difference among other treatments.

'a' index: According to the results (**Table 3**), at zero times, there was a significant difference between treatments in terms of 'a' index and meal-free treatments had a lower 'a' index. Therefore, they had more green color. In the fourth month of storage, there was a significant difference between treatments in terms of 'a' index ($P \leq 0.05$). The highest 'a' index value was related to treatment of 10% meal, which had less green color than other treatments. The lowest 'a' value was related to meal-free treatments, which had more green color. the 'a' index showed green color of pistachio kernels.

'b' index: **Table 3** shows that there was no significant difference between treatments with different amounts of meal and emulsifier in terms of 'b' index at zero times. In the fourth month of storage, the highest 'b' value was related to treatments with higher values of meal (10%). The lowest 'b' value was related to meal-free treatments. However, 'b' values were close, and the difference was not significant compared to other treatments.

Sensory evaluation

Flavor: According to the results (**Table 4**), at zero times, there was a significant difference between treatments with different amounts of meal and emulsifier in terms of flavor ($P \leq 0.05$). Treatments with emulsifier and meal obtained the highest score and there was no significant difference with control treatment. In the fourth month of the storage, there was a significant difference between treatments with different amounts of meal and emulsifier.

Aroma

At zero times, there was a significant difference between treatments with different amounts of meal and emulsifier (**Table 4**, $P \leq 0.05$). Treatments containing 2% emulsifier and without meal obtained higher score and there was no significant difference with control treatment. In the fourth month of storage, there was a significant difference among the treatments. Higher amounts of meal in the formula caused lower aroma scores.

Spreadability

Table 4 indicates that the spreadability (ability to spread the pistachio butter on bread) in different treatments of emulsifier and meal had a significant difference at zero times ($P \leq 0.05$). As might be expected, spreadability is higher in the treatments with emulsifier and without meal. The lowest scores were obtained by treatments with the higher amount of meal that were without emulsifier or had lower values of emulsifier .In the fourth month of storage, there was a significant difference between treatments in terms of spreadability. Treatments without meal and with 1 or 2% emulsifier showed more spreadability. Lower scores were related to treatments with 10 % of meal.

Green color

There was a significant difference between treatments with different amounts of meal and emulsifier in terms of color at zero times ($P \leq 0.05$) (**Table 4**). Meal-free treatments or with 5% meal had a higher score in terms of green color. The lowest score (10.1) was related to treatments with 10 % of meal. In the fourth month of the storage, there was a significant difference between treatments. Meal-free treatments had more green color.

Aftertaste

There was no significant difference in treatments with different values of meal and emulsifier in terms of aftertaste at time zero and after forth months of storage (**Table 4**). The results indicate that the addition of different amounts of meal and emulsifier did not increase the aftertaste (which is the product desirability indicator). Therefore, aftertaste was not considered as a main indicator in sensory evaluation.

Table 1. Protein, carbohydrate, and oil content (%) of pistachio butter with different formulation.

MD	Meal	Storage time (month)					
		Protein		Carbohydrate		Oil	
		0	4	0	4	0	4
0	0	17.5 ± 1.0 b	17.5 ± 1.2 b	37.0 ± 1.5 bc	37.0 ± 1.7 ab	40.0 ± 2.0 ab	40.0 ± 2.2 a
0	5	20.0 ± 1.4 ab	20.0 ± 1.5 ab	39.5 ± 1.9 abc	39.5 ± 2.1 ab	35.0 ± 2.4 bc	35.0 ± 2.6 ab
0	10	22.5± 1.6 a	21.9 ± 0.9 a	42.0 ± 2.1 ab	41.7 ± 2.7 ab	30.0 ± 2.6 cd	30.0 ± 2.7 b
1	0	17.0 ± 1.3 b	17.0 ± 1.4 b	36.5 ± 1.8 c	36.5 ± 1.9 b	41.0 ± 2.3 ab	41.0 ± 2.5 a
1	5	20.0 ± 1.3 a	20.0 ± 1.5 ab	39.5 ± 1.8 abc	39.5 ± 2.0 ab	35.0 ± 2.3 bc	35.0 ± 2.5 ab
1	10	23.5 ± 1.6 a	23.5 ± 1.7 a	43.0 ± 2.1 a	43.0 ± 2.3 a	28.0 ± 2.7 cd	28.0 ± 2.8 b
2	0	16.5 ± 1.3 b	16.5 ± 1.4 b	36.0 ± 1.8 c	36.0 ± 1.9 b	42.0 ± 2.3 a	42.0 ± 2.4 a
2	5	20.0 ± 1.3 ab	20.0 ± 1.5 ab	39.5 ± 1.8 abc	39.5 ± 2.0 ab	35.0 ± 2.3 bc	35.0 ± 2.5 ab
2	10	22.5 ± 1.5 a	22.5 ± 1.6 a	42.0 ± 2.0 ab	42.0 ±2.1 ab	30.0 ± 2.5 cd	30.0 ± 2.6 b
2	5	20.0 ± 1.3 ab	20.0 ± 1.5 ab	39.5 ± 1.8 abc	39.5 ±2.0 ab	35.0 ± 2.3 bc	35.0 ± 2.5 ab

MD: mono- and diglyceride; Means of triple determinations ± SD with different, letters on the same column are significantly different at $P \leq 0.05$

Table 2. Oil separation, peroxide value, and anisidine value (AnV) of pistachio butter with different formulation.

MD	Meal	Storage time (month)					
		Oil separation (%)		Peroxide value (Meq/kg)		Anisidine value	
		0	4	0	4	0	4
0	0	0.0 ± 0.0 a	12.4 ± 0.4 a	0.12 ± 0.02 a	1.58 ± 0.14 c	0.79 ± 0.03 a	1.76 ± 0.08 abc
0	5	0.0 ± 0.0 a	0.3 ± 0.0 b	0.12 ± 0.02 a	2.58 ± 0.14 a	0.79 ± 0.03 a	1.90 ± 0.10 a
0	10	0.0 ± 0.0 a	0.3 ± 0.0 b	0.13 ± 0.01 a	2.07 ± 0.37 b	0.78 ± 0.02 a	1.83 ± 0.09 ab
1	0	0.0 ± 0.0 a	0.3 ± 0.0 b	0.12 ± 0.02 a	0.69 ± 0.09 d	0.77 ± 0.02 a	1.23 ± 0.05 e
1	5	0.0 ± 0.0 a	0.3 ± 0.0 b	0.14 ± 0.02 a	0.67 ± 0.07 d	0.79 ± 0.03 a	1.24 ± 0.06 e
1	10	0.0 ± 0.0 a	0.0 ± 0.0 c	0.12 ± 0.02 a	0.60 ± 0.08 d	0.79 ± 0.03 a	1.20 ± 0.04 e
2	0	0.0 ± 0.0 a	0.0 ± 0.0 c	0.12 ± 0.02 a	0.55 ± 0.05 d	0.77 ± 0.02 a	1.15 ± 0.04 e
2	5	0.0 ± 0.0 a	0.0 ± 0.0 c	0.14 ± 0.02 a	0.56 ± 0.04 d	0.76 ± 0.03 a	1.12 ± 0.07 e
2	10	0.0 ± 0.0 a	0.0 ± 0.0 c	0.12 ± 0.02 a	0.54 ± 0.06 d	0.78 ± 0.02 a	1.14 ± 0.06 e

MD: mono- and diglyceride; Means of triple determinations ± S.D with different letters on the same column are significantly different at $P \leq 0.05$.

Table 3. Color index of pistachio butter with different formulation.

MD	Meal	L		a		b	
		Storage time (month)					
		0	4	0	4	0	4
0	0	36.5 ± 0.8 a	33.0 ± 0.4 b	-2.9 ± 0.2 b	1.3 ± 0.2 c	14.2 ± 0.8 a	15.0 ± 0.4 ab
0	5	36.9 ± 0.6 a	34.6 ± 0.7 ab	-2.0 ± 0.0 a	2.1 ± 0.2 bc	15.5 ± 0.3 a	14.8 ± 1.8 ab
0	10	37.4 ± 0.5 a	36.2 ± 0.5 ab	-2.4 ± 0.2 a	2.5 ± 0.2 ab	15.1 ± 0.5 a	16.7 ± 0.8 a
1	0	36.5 ± 0.8 a	33.1 ± 1.3 ab	-2.9 ± 0.2 b	1.2 ± 0.1 e	14.2 ± 0.7 a	11.8 ± 2.0 b
1	5	36.9 ± 0.6 a	34.3 ± 0.7 ab	-2.0 ± 0.0 a	2.1 ± 0.2 c	15.5 ± 0.3 a	14.7 ± 1.0 ab
1	10	36.0 ± 0.5 a	35.5 ± 0.5 ab	-2.3 ± 0.2 a	2.6 ± 0.2 a	15.1 ± 0.5 a	17.2 ± 1.6 a
2	0	36.5 ± 0.8 a	33.6 ± 1.2 ab	-2.9 ± 0.2 b	1.1 ± 0.1 e	14.2 ± 0.8 a	12.6 ± 1.3 ab
2	5	37.1 ± 0.6 a	35.6 ± 2.1 ab	-2.0 ± 0.0 a	1.7 ± 0.2 cd	15.5 ± 0.3 a	15.4 ± 3.3 ab
2	10	37.4 ± 0.5 a	35.4 ± 1.2 ab	-2.4 ± 0.2 a	2.5 ± 0.2 ab	15.1 ± 0.5 a	16.0 ± 1.4 ab

MD: mono- and diglyceride; Means of triple determinations ± S.D with different letters on the same column are significantly different at $P \leq 0.05$.

Table 4. Sensory evaluation of pistachio butter containing different amounts of meal and emulsifier

MD	Meal	Storage time (month)									
		Flavor		Aroma		Spreadability		Green color		Aftertaste	
		0	4	0	4	0	4	0	4	0	4
0	0	13.9 ± 0.3^{ab}	15.0 ± 0.4^{ab}	12.3 ± 0.3^{a}	12.0 ± 0.3^{a}	11.7 ± 0.3^{abc}	11.5 ± 0.3^{bcd}	12.7 ± 0.7^{a}	11.1 ± 0.6^{a}	2.4 ± 0.3^{a}	2.5 ± 0.3^{a}
0	5	10.9 ± 0.3^{d}	14.8 ± 1.8^{ab}	11.3 ± 0.3^{b}	11.0 ± 0.3^{b}	10.9 ± 0.3^{c}	10.8 ± 0.3^{d}	10.3 ± 0.3^{b}	10.0 ± 0.3^{b}	2.6 ± 0.1^{a}	2.6 ± 0.1^{a}
0	10	10.5 ± 0.3^{d}	16.7 ± 0.8^{a}	10.3 ± 0.4^{c}	10.0 ± 0.4^{c}	10.8 ± 0.3^{c}	10.6 ± 0.6^{d}	10.4 ± 0.3^{b}	10.0 ± 0.3^{b}	2.5 ± 0.1^{a}	2.6 ± 0.1^{a}
1	0	14.0 ± 0.4^{a}	11.8 ± 2.0^{b}	12.1 ± 0.3^{ab}	11.8 ± 0.3^{ab}	12.4 ± 0.4^{a}	12.3 ± 0.4^{ab}	12.6 ± 0.3^{a}	12.2 ± 0.3^{a}	2.4 ± 0.1^{a}	2.6 ± 0.1^{a}
1	5	13.0 ± 0.4^{bc}	14.7 ± 1.0^{ab}	11.8 ± 0.3^{ab}	11.5 ± 0.3^{ab}	11.8 ± 0.2^{ab}	11.8 ± 0.3^{abc}	12.3 ± 0.4^{a}	11.2 ± 0.4^{a}	2.4 ± 0.3^{a}	2.4 ± 0.3^{a}
1	10	10.8 ± 0.3d	17.2 ± 1.6^{a}	9.9 ± 0.3^{d}	9.6 ± 0.4^{d}	10.8 ± 0.3^{c}	10.6 ± 0.3^{d}	10.1 ± 0.3^{b}	9.8 ± 0.3^{b}	2.6 ± 0.1^{a}	2.7 ± 0.1^{a}
2	0	14.3 ± 0.4^{a}	12.6 ± 1.3^{ab}	12.4 ± 0.3^{a}	12.1 ± 0.3^{a}	12.5 ± 0.4^{a}	12.5 ± 0.3^{a}	12.6 ± 0.4^{a}	12.4 ± 0.3^{a}	2.5 ± 0.1^{a}	2.5 ± 0.1^{a}
2	5	12.9 ± 0.4^{c}	15.4 ± 1.3^{ab}	11.9 ± 0.3^{ab}	11.6 ± 0.3^{ab}	12.0 ± 0.4^{ab}	12.0 ± 0.4^{ab}	10.7 ± 0.4^{b}	10.5 ± 0.3^{b}	2.4 ± 0.2^{a}	2.4 ± 0.1^{a}
2	10	10.9 ± 0.3^{d}	16.0 ± 1.4^{ab}	10.5 ± 0.2^{c}	10.2 ± 0.2^{c}	11.3 ± 0.3^{bc}	11.0 ± 0.4^{cd}	10.6 ± 0.3^{b}	10.4 ± 0.3^{b}	2.4 ± 0.1^{a}	2.4 ± 0.1^{a}

MD: mono- and diglyceride; Means of triple determinations ± SD with different letters on the same column are significantly different at $P \leq 0.05$.

Discussion

Protein: Most nut spreads and nut butters contain protein that helps to improve stability and nutritional values of the products. The amount of total protein in most spreads are in the range of 20-28% (Shakerardekani *et al.*, 2013a). The pistachio meal has 38% of the protein used to produce low-fat pistachio butter in the research (Pardo-Giménez *et al.*, 2016).

Carbohydrate: One of the main combinations of oil-free pistachio meal is carbohydrates added to low-fat pistachio butter in the research. A study reported that the pistachio meal contained 32.4% carbohydrates (Pardo- Giménez *et al.*, 2016). The highest value of carbohydrates in low-fat pistachio butter was observed in the formula with 10% meal (in time zero and the fourth months of storage). Other samples of pistachio butter also had more or less carbohydrates by the amount of meals used. Similarly, it was reported that addition of nut meal increases the carbohydrate of nut spreads (Shakerardekani *et al.*, 2013c).

Oil content: Since the nut meal used in the production of low-fat pistachio butter has much less oil, the oil content in pistachio butter varies based on the amount of meal used (Moharana *et al.*, 2020). The emulsifier used in pistachio butter is a type of oil and depending on the amount used in the formula, the amount of oil in the final formula is added. Mono-diglyceride application in nut butter formulation reduces the need to use high amount of oil in the formula (Shahidi-Noghabi *et al.*, 2019).

Oil separation: Oil separation of pistachio butter texture is one of the negative features that create an improper appearance in the product and decrease the product shelf life due to exposure to air, and consequently oxidation (Shakerardekani and Shahedi, 2015). In the current pistachio formulas, during the storage period, the amount of separated oil increases in the product texture (Ereifej *et al.*, 2005, Shakerardekani and Shahedi, 2015). One application of emulsifiers is to prevent oil leakage from the product (Hasenhuettl and Hartel, 2008, Shahidi-Noghabi *et al.*, 2019). Pistachio paste products are no exception from the regular (Shakerardekani *et al.*, 2013d). In a similar research, reported that the application of soy protein isolate and mono- and diglyceride emulsifier reduced oil separation from pistachio spread (Shakerardekani, 2017).

Peroxide value: Emulsifiers are able to stabilize and protect lipid compounds from oxidation. Pistachio meal absorbs oil, then oil is less exposed to air and less oxidized, and as a result, the peroxide value decreases. Shakerardekani in a similar research, reported that pistachio spread with different values of emulsifier and soy protein isolate has a lower peroxide value than treatments without emulsifier and soy protein isolate (Shakerardekani *et al.*, 2015).

Anisidine value: The same conditions as for the peroxide value were applied to the AnV. Shakerardekani reported that pistachio breakfast cream with different values of emulsifier and soy protein isolate has a lower AnV than treatments without emulsifier and soy protein isolate (Shakerardekani *et al.*, 2015).

Color: Ling *et al.* reported that the use of pistachio meal causes changes in lightness of the final product (Ling *et al.*, 2016). Based on the results, in the fourth month of storage, there was a significant difference between control sample and other pistachio butter samples with different values of meal. Ling *et al.* reported that the utilization of the pistachio meal is effective on 'b' index (Ling *et al.*, 2016). The color green is due to its chlorophyll (Bellomo *et al.*, 2009). Meal-free samples prepared from roasted pistachios have a lower 'a' index and have more green color. In other words, part of the color and oil are removed during roasting process. Similarly, Gamli reported that during the period of storage, the green color of pistachio paste products gradually decreases (Gamli *et al.*, 2009).

Sensory evaluation: Although consumers commonly prefer high-fat products, it is required to produce low-fat products due to the obesity and high-calorie products disadvantages (Crowe and White, 2003, Rolland-Cachera *et al.*, 2016). Reduced-calorie nut butters are desirable to consumers, but it is difficult to maintain the organoleptic character of full-calorie nut butter products (Strecker *et al.*, 2019). Shakerardekani reported that the addition of soy protein isolate (as a protein source) to pistachio breakfast cream reduces its aroma score (Shakerardekani, 2017). The addition of mono- and diglyceride increase the spreadability of nut butter products. Similar cases have been reported in products such as pistachio breakfast cream (Shakerardekani *et al.*, 2013b), hazelnut butter (Pourfarzad and Kisomi, 2020), and walnut butter (Shahidi-Noghabi *et al.*, 2019). The green color of the product gradually reduces in pistachio paste during the storage period (Gamli *et al.*, 2009). The results of sensory evaluation in this research also agree with this reduction.

Conclusion

In this study, the most important effective parameters on the quality of low-fat pistachio butter were considered oil separation, oil content, protein value, peroxide value, AnV, 'a' index color, flavor (taste), aroma, spreadability, and green color. Pistachio butter formula containing 1% mono- and diglyceride and 5% pistachio meal showed the lowest oil separation, oil content, peroxide value, AnV, ‘a' index, and the highest protein content, flavor (taste), aroma, spreadability, and green color. Therefore, this formula is introduced as the best formula for the production of low-fat pistachio butter.

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Authors' contributions

Shakerardekani A contributed to the design of the research, to the analysis of the results and to the writing of the manuscript. Kavoosi M contributed to the implementation of the research.

Conflict of interest

The authors declare that there is no conflict of interest.

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