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Research Article

Application of Pomegranate Peel Extract, a Waste Agricultural Product, as a Natural Preservative in Tahini

Rayeheh Ghasemi,[1] Fateme Akrami Mohajeri,[1] Ali heydari,[1] Seyed Ali Yasini,[2] Arefeh Dehghani Tafti,[3] and Elham Khalili Sadrabad[1,4]

[1]*Infectious Diseases Research Center, Department of Food Hygiene and Safety, School of Public Health, Shahid Sadoughi University of Medical Sciences, Yazd, Iran*
[2]*Department of Food Science and Technology, Science and Research Branch, Islamic Azad University, Yazd, Iran*
[3]*Department of Biostatistics, School of Public Health, Shahid Sadoughi University of Medical Sciences, Yazd, Iran*
[4]*Nutrition and Food Security Research Center, Shahid Sadoughi University of Medical Sciences, Yazd, Iran*

Correspondence should be addressed to Elham Khalili Sadrabad; khalili.elham@gmail.com

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The pomegranate peel, an agricultural by-product or waste, is a rich source of bioactive compounds. In the current study, the addition of different concentrations of pomegranate peel hydromethanolic extract (PPE) into tahini was investigated. The hydromethanolic extract of pomegranate peel in the ratio of 1 : 1 was prepared, and the PPE yield was evaluated. The HPLC and Folin-Ciocalteu methods were used to determine phenolic compounds and total phenolic content of PPE, respectively. The antioxidant activity of PPE was investigated by DPPH and FRAPS assays. Then, the different concentration of PPE (0, 0.25, 0.5, 1, and 2%) was added to tahini. Thereafter, peroxide value, TBARS, and sensory analyses were determined during 6 months of storage. The PPE yield was reported at 18.90%. Gallic acid, ellagic acid, and punicalagin were identified as the most abundant phenolic compounds in PPE. The total phenolic content, DPPH, and FRAP antioxidant assay of PPE were evaluated as 1577.65 mg/g GAE, 54 μg/ml, and 483.24 mM, respectively. It was shown that by the addition of PPE in tahini, the increase in peroxide value and TBARS was controlled. The concentrations 1 and 2% act better to inhibit lipid peroxidation. Overall, the general acceptance of samples containing 1 and 2% PPE was recorded better than other samples. The PPE showed a good function as a natural antioxidant in tahini to retard oxidation.

1. Introduction

Sesame seed (*Sesamum indicum L.*), an important oil seed crop, is a rich source of nutrition for human consumption [1] which consists of 50% oil and 25% protein [2]. Apart from using sesame seed as a cooking oil, different products have been made including tahini and tahini halva [3]. Tahini or sesame paste (which is called Ardeh in Iran) is a liquid product of the dehulled roasted sesame seeds which are served as breakfast in many Middle East countries such as Iran [1, 4]. Although the presence of sesaminol, sesamin, and tocopherol as natural antioxidants makes sesame paste more resistant to oxidative deterioration, due to the high oil content (65 to 75%) of this product, oxidation is considered a great problem during storage for a long time [4]. The oxidative deterioration of sesame paste could cause rancidity, off-flavor, and reduction of the nutritional value of tahini [5]. Also, despite natural antioxidants, using any synthetic antioxidant in tahini is forbidden according to Iran's national standards [6]. According to our knowledge, there are limited applications of natural antioxidants (raisins and apricot) in tahini [7] to extend its shelf life. Therefore, the use of different natural antioxidants in tahini to retard oxidation could be a good suggestion for the sesame industry.

Pomegranate (*Punica granatum* L.), in the *Punicaceae* plant family, is cultivated extensively in Iran and other

tropical countries [8]. The antioxidant activity of pomegranate is attributed to the presence of phenolic compounds, flavonoids, anthocyanins, tannins, ascorbic acids, and gallic acid [9, 10]. In recent years, the application of agricultural by-products due to their lower costs had been issued by many studies [11]. Pomegranate peel is considered an inedible by-product of the juice industry with high antioxidant activity [12] which consist of more than 50% of the fruit weight [13]. Many functional compounds including ferulic acid, punicalagin, ellagic acid, and gallic acid have been detected in pomegranate peel (PP) [8]. Therefore, the current study was aimed at investigating the composition and antioxidant capacity of hydromethanolic extract of pomegranate peel (PPE). Then, its application in tahini as a natural antioxidant was investigated. Therefore, different concentration of PPE was added to tahini containing PPE, and the oxidation process was evaluated during 6 months of storage.

2. Material and Method

2.1. Preparation of Pomegranate Peel Extract. The healthy ripened pomegranate fruit was purchased from the local market of Yazd, Iran. The fruit was rinsed, and the peel was manually separated. The peels were air-dried and powdered by a grinder. The peel powder (100 g) was extracted with methanol-water (50 : 50 v/v) for 48 hours. To remove peel particles, the extract was filtered through a Whatman filter and then centrifuged. The supernatant extract was concentrated at 45°C and stored at 4°C for further analysis [14].

2.2. Pomegranate Peel Yield. The dried PPE yield was evaluated according to the following equation:

$$\text{Yield}(\%) = () \times 100. \quad (1)$$

W_1 and W_2 are considered as the weight of dried pomegranate peel powder and extraction, respectively [15].

2.3. HPLC Analysis. The HPLC (Knauer, Germany), a Pump K-1000 and UV-visible detector and C18-SEC column (250 mM length, i.d. 4.8 mM), was used. Before injection, 1 g of PPE was dissolved in 10 ml distilled water and then centrifuged for 4 min at 4500 rpm. The supernatant of centrifuged PPE was passed through a 0.45 μm filter. Then, 20 μl of filtered PPE was injected into the HPLC. The column temperature was maintained at 25°C. The chromatographic separation was done by acetonitrile/distilled water/acetic acid as a mobile phase at a flow rate of 0.5 ml/min. The wavelength was monitored from 190 to 750 nm for the detection of phenolic compounds. The wavelength of 270 nm was used to monitor the chromatogram. Prior to sample injection, a standard solution of gallic acid, punicalagin, and ellagic acid was prepared [16, 17].

2.4. Total Phenolic Content. The Folin-Ciocalteu method was used for the determination of total phenolic compounds in pomegranate peel extract. The total phenolic content was determined as gallic acid equivalent (mg GAE/g) [18].

2.5. Evaluation of Antioxidant Capacity

2.5.1. DPPH Radical Scavenging Activity. The DPPH assay was done according to Ahmed et al. with some modifications [19]. Approximately 2.5 ml of DPPH working solution was added to 500 μl diluted PPE. After 30 min incubation in a dark room, the absorbance was read at 517 nm. The radical scavenging activity (RSD) was measured by the following equation:

$$\%\text{RSD} = \left[\frac{(A_c - A_s)}{A_c}\right] \times 100, \quad (2)$$

where the A_c and A_s are the absorbance of the control (contains 500 μl methanol instead of the sample) and sample, respectively.

2.5.2. FRAP Radical Scavenging Assay. The FRAP reagent containing acetate buffer (300 mM, pH: 3.6), 2,4,6-tripyridyl-s-triazine (TPTZ 10 mM solution in 40 mMHCl), and $FeCl_3$ $6H_2O$ (20 mM) in the ratio of 10 : 1 : 1 was prepared. Aliquots of 500 μl diluted PPE were mixed with 3 ml FRAP reagent, and after incubation for 6 min, the absorbance was measured at 593 nm. The results were expressed by $FeSO_4$ as a standard curve [20].

2.6. Addition of PPE to Tahini. The tahini was bought from the local market of Yazd, Iran. The different concentration of PPE (0, 0.25, 0.5, 1, and 2%) was added to tahini. The peroxide value and thiobarbituric acid reactive substances (TBARs) were evaluated at an interval of 1 month during 6 months of storage.

2.7. Peroxide Value. For determination of the peroxide value, 30 ml n-hexane (Merck, Germany) was added to 20 g of tahini to extract the oil. The extracted oil sample (5 g) was dissolved in glacial acetic acid and chloroform in a ratio of 3 : 2. After adding the saturated KI (0.5 ml), the solution was kept in the dark. Then, the distilled water (30 ml) was added, and titration by sodium thiosulfate (0.1 N) in the presence of starch as an indicator was done. The peroxide value was evaluated by the following equation:

$$\text{PV} = (V - V_b) \times N \times \frac{1000}{W}. \quad (3)$$

The V and V_b are the volume of used sodium thiosulfate by sample and blank (ml), N is the concentration of sodium thiosulfate, and W is the oil weight (g) [21].

2.8. TBARS. Thiobarbituric acid reactive substances (TBARS) were determined according to the study of Kamkar et al. with some modifications. The TBA reagent was prepared by a mixture of trichloroacetic acid (15 g), thiobarbituric acid (0.375 g), HCl (2 ml), and distilled water (82.9 ml). The total of 200 μl extracted oil sample was added to 800 μl distilled water and 2 ml TBA reagent and placed in the water bath (95-100°C) for 30 minutes. The samples were cooled and centrifuged at 4500 g for 15 min. The absorbance of samples was recorded at 532 nm, and the results were

Table 1: Chemical analysis (yield, phenolic content, and antioxidant activity) of PPE.

PPE characteristics	Yield (%)	Total phenolic content (mg/g GAE)	FRAP (mM)	DPPH (mg/ml)
Mean ± SD	18.90 ± 1.05	1577.65 ± 503.05	483.24 ± 56.56	0.054 ± 0.0085

Table 2: Peroxide values (meq O_2/kg) of tahini samples supplemented with different PPE concentration during 6-month storage.

Treatment (%)	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
0	$0.98 \pm 0.03^{A\text{-}a}$	$1.12 \pm 0.1^{A\text{-}a}$	$2.27 \pm 0.04^{A\text{-}ae}$	$4.23 \pm 0.1^{A\text{-}be}$	$7.90 \pm 1.44^{A\text{-}cf}$	$8.80 \pm 1.93^{A\text{-}df}$
0.25	$0.98 \pm 0.01^{A\text{-}a}$	$0.98 \pm 0.04^{A\text{-}a}$	$1.26 \pm 0.26^{B\text{-}a}$	$4.38 \pm 0.48^{A\text{-}b}$	$8.30 \pm 0.58A^{\text{-}ce}$	$8.41 \pm 0.55^{A\text{-}de}$
0.5	$1.01 \pm 0.04^{A\text{-}a}$	$1.02 \pm 0.04^{A\text{-}a}$	$1.16 \pm 0.01^{B\text{-}a}$	$3.92 \pm 0.19^{AC\text{-}b}$	$8.15 \pm 0.68^{A\text{-}ce}$	$7.93 \pm 0.76^{A\text{-}de}$
1	$0.99 \pm 0.005^{A\text{-}a}$	$1.02 \pm 0.02^{A\text{-}a}$	$1.04 \pm 0.04^{B\text{-}a}$	$3.31 \pm 0.65^{AC\text{-}b}$	$5.82 \pm 0.23^{B\text{-}ce}$	$7.05 \pm 0.83^{B\text{-}de}$
2	$0.98 \pm 0.02^{A\text{-}a}$	$1.03 \pm 0.05^{A\text{-}a}$	$1.05 \pm 0.05^{B\text{-}a}$	$2.88 \pm 0.48^{BC\text{-}b}$	$4.49 \pm 0.57^{B\text{-}ce}$	$6.41 \pm 0.74^{B\text{-}de}$

Values are mean ± SD of three measurements. Different small letters in the same row show significant difference at a level of 0.05. Different capital letters in the same column show significant difference at a level of 0.05.

Table 3: TBARS values (mg MDA/kg) of tahini samples supplemented with different PPE concentration during 6 months of storage.

Treatment (%)	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
0	$0.36 \pm 0.01^{ABC\text{-}a}$	$0.52 \pm 0.02^{A\text{-}a}$	$1.21 \pm 0.04^{A\text{-}b}$	$3.71 \pm 0.17^{A\text{-}c}$	$6.30 \pm 0.34^{A\text{-}d}$	$8.49 \pm 0.14^{A\text{-}f}$
0.25	$0.37 \pm 0.03^{AB\text{-}a}$	$0.49 \pm 0.02^{AB\text{-}a}$	$1.21 \pm 0.04^{A\text{-}a}$	$3.82 \pm 0.62^{A\text{-}b}$	$6.38 \pm 0.62^{A\text{-}c}$	$8.39 \pm 0.1^{A\text{-}d}$
0.5	$0.38 \pm 0.09^{A\text{-}a}$	$0.48 \pm 0.06^{AB\text{-}a}$	$1.08 \pm 0.14^{A\text{-}a}$	$3.34 \pm 0.09^{AC\text{-}b}$	$5.01 \pm 0.57^{A\text{-}ce}$	$6.82 \pm 0.53^{AC\text{-}de}$
1	$0.30 \pm 0.03^{AC\text{-}a}$	$0.40 \pm 0.01^{BC\text{-}a}$	$0.96 \pm 0.08^{A\text{-}a}$	$2.25 \pm 0.18^{AC\text{-}b}$	$2.87 \pm 0.78^{B\text{-}c}$	$3.19 \pm 0.06^{BC\text{-}d}$
2	$0.22 \pm 0.04^{C\text{-}a}$	$0.38 \pm 0.03^{C\text{-}a}$	$0.50 \pm 0.03^{B\text{-}a}$	$1.43 \pm 0.63^{BC\text{-}be}$	$2.36 \pm 0.08^{B\text{-}cef}$	$3.05 \pm 1.21^{B\text{-}df}$

Values are mean ± SD of three measurements. Different small letters in the same row show significant difference at a level of 0.05. Different capital letters in the same column show significant difference at a level of 0.05.

expressed as mg MDA/kg tahini according to the standard curve of 1,1,3,3-tetraethoxypropane [22].

2.9. Sensory Evaluation. The 20 trained panelists (10 male and 10 female) who were familiar with tahini characteristics were chosen. The sensory characteristics of tahini such as taste, color, texture, odor, and overall acceptance were evaluated by a 9-point hedonic scale. The judges of 20 trained sensory panelists were recorded on a questionnaire [23].

2.10. Statistical Analysis. All data were tested using analysis of variance (ANOVA) followed by repeated measure tests using SPSS 9.0. The differences in results at the $P < 0.05$ level were considered significant.

3. Results

3.1. The Pomegranate Peel Characteristics. According to Table 1, the yield of PPE was determined at 18.90%. The total phenolic content, FRAP, and DPPH were evaluated at 1577.65 mg/g GAE, 483.24 mM, and 0.054 mg/ml, respectively.

Gallic acid, ellagic acid, and punicalagin were determined as the most predominant polyphenol compounds in PPE by HPLC.

3.2. PPE Addition in Tahini. During 4-month of storage, the peroxide values of all samples were lower than Iran's standard limit (5 meq O_2/kg). Although in the last two months, the peroxide value of treatments containing 1 and 2% PPE was significantly lower than other treated samples (Table 2).

The high amounts of TBARS in samples indicate the oxidative damage in Tahini (Table 3). The results showed that an increase in PPE concentration had been effective in decreasing the TBARS and peroxide values, while promoting the organoleptic and sensory characteristics. The lowest TBARS value was reported in tahini with 2% PPE. According to the achieved results, the addition of PPE reduced the TBARS value during 6 months of storage. The highest TBARS value was reported in the control (sample without PPE) with 8.49 mg MDA/kg after 6 months of storage. In the current study, the sensory evaluation showed a significant effect of PPE in tahini in contrast to the control (Table 4).

4. Discussion

4.1. The PPE Yield. The yield of dried hydromethanolic PPE was evaluated as 18.90 ± 1.05%. The yield of methanolic extract of pomegranate peel in Padmaja and Prasad's study was evaluated at 23.56% [15]. According to Kennas and Amellal-Chibane and Sultana et al.'s studies, PPE yield was provided at 27.21% and 29.9%, respectively [24, 25] which were higher than the current study. Ultrasonic extraction of bioactive compounds of PP showed a maximum yield of 13.1% which is lower than our result [26]. According to Singh et al., the use of methanol in extraction could maximize the phenolic yield due to polarity differences among

Table 4: Sensory analysis of tahini supplemented with PPE using a 9-point hedonic scale during 6 months of storage (mean ± SD).

Parameters	Treatments (%)	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
Color	0	7.56 ± 0.61	7.56 ± 0.36	7.56 ± 0.36	7.2 ± 0.55	5.76 ± 0.36	4.68 ± 0.72
	0.25	7.92 ± 0.43	7.56 ± 0.36	7.2 ± 0.55	7.2 ± 0.55	5.76 ± 0.36	3.96 ± 0.36
	0.5	7.2 ± 0.55	7.92 ± 0.43	7.2 ± 0.79	6.84 ± 0.88	6.12 ± 0.43	4.68 ± 0.91
	1	7.92 ± 0.43	8.28 ± 0.43	7.56 ± 0.66	7.2 ± 0.55	6.12 ± 0.43	7.2 ± 0.55
	2	7.92 ± 0.43	8.28 ± 0.43	7.92 ± 0.72	7.2 ± 0.55	6.48 ± 0.43	6.48 ± 0.43
Odor	0	7.56 ± 0.66	6.12 ± 0.43	7.56 ± 0.66	6.48 ± 0.43	5.76 ± 0.66	2.88 ± 0.43
	0.25	7.2 ± 0.55	7.2 ± 0.79	6.84 ± 0.66	5.76 ± 0.66	6.12 ± 0.43	3.6 ± 1.0
	0.5	7.56 ± 0.36	7.2 ± 0.10	6.84 ± 0.66	6.48 ± 0.43	5.4 ± 0.55	5.04 ± 0.88
	1	7.92 ± 0.43	7.56 ± 0.36	7.56 ± 0.36	6.12 ± 0.72	6.12 ± 0.72	6.84 ± 0.66
	2	7.56 ± 0.36	7.56 ± 0.36	7.2 ± 0.12	6.48 ± 0.43	6.12 ± 0.43	5.76 ± 0.36
Taste	0	7.2 ± 0.55	6.84 ± 0.43	7.2 ± 0.55	6.84 ± 0.66	—	—
	0.25	7.56 ± 0.88	7.2 ± 0.79	7.56 ± 0.43	5.76 ± 0.66	—	—
	0.5	7.2 ± 0.55	7.56 ± 0.36	6.48 ± 0.43	5.76 ± 0.36	—	—
	1	7.2 ± 0.79	7.56 ± 0.36	7.92 ± 0.55	6.48 ± 0.72	—	—
	2	8.28 ± 0.43	7.56 ± 0.36	7.2 ± 0.55	6.84 ± 0.43	—	—
Texture	0	6.84 ± 0.66	7.56 ± 0.36	7.2 ± 0.79	6.84 ± 0.36	4.68 ± 0.43	3.96 ± 0.66
	0.25	7.2 ± 0.55	6.48 ± 0.72	6.84 ± 0.66	6.12 ± 0.43	5.76 ± 0.66	3.96 ± 0.88
	0.5	8.28 ± 0.43	7.56 ± 0.66	6.84 ± 0.66	6.84 ± 0.36	5.76 ± 0.36	4.68 ± 0.72
	1	8.28 ± 0.72	7.92 ± 0.43	6.84 ± 0.88	6.84 ± 0.36	7.2 ± 0.15	5.4 ± 0.55
	2	8.28 ± 0.43	7.56 ± 0.36	7.2 ± 0.55	6.84 ± 0.36	6.12 ± 0.43	6.12 ± 0.72
Overall acceptance	0	6.84 ± 0.66	7.2 ± 0.1	7.56 ± 0.43	6.48 ± 0.43	5.04 ± 0.36	3.6 ± 0.79
	0.25	7.92 ± 0.72	7.2 ± 0.55	7.56 ± 0.36	6.48 ± 0.43	6.48 ± 0.1	3.6 ± 0.55
	0.5	7.56 ± 0.36	7.2 ± 0.23	7.2 ± 0.55	6.48 ± 0.43	6.48 ± 0.43	5.04 ± 1.04
	1	7.92 ± 0.43	7.92 ± 0.43	7.2 ± 0.79	6.84 ± 0.66	7.2 ± 0.54	5.1 ± 0.43
	2	7.92 ± 0.43	7.56 ± 0.36	7.56 ± 0.66	6.48 ± 0.72	6.48 ± 0.43	6.48 ± 0.43

Due to an increase in chemical indexes, the taste was not evaluated at months 5 and 6 by panelists.

the solvent and the nature of polyphenol compounds [27]. In the current study, PPE yield was evaluated as lower than mentioned studies which may be due to the use of 50% water in pomegranate extraction. Kennas and Amellal-Chibane showed a yield of 37.33% in the extraction method by the mixture of methanol/water (50 : 50) [24] which is not consistent with the result of the present study. Some studies indicated that the use of different solvents in extraction could increase the yield and total phenolic compound. Therefore, these variations in extract yield could be explained by the different solubility of phenols in solvents [24].

4.2. HPLC Analysis. There were three sharp peaks in the HPLC chromatogram, which were identified with the retention time of 2.517 min, 6.783 min, and 11.383 min as gallic acid, punicalagin, and ellagic acid, respectively. In the current study, the major phenolic compounds in PPE were gallic acid, ellagic acid, and punicalagin with 9.01, 1.73, and 0.28 mg/100 g, respectively. Li et al. showed that punicalagin, catechin, ellagic acid, and gallic acid account for 76.7%, 14.9%, 3.3%, and 3.1% of the eight monophenols recognized in pomegranate peel, respectively [16]. In the current study, gallic acid, ellagic acid, and punicalagin account for 59.3%, 19.9%, and 4% of polyphenols, respectively. Middha et al. reported quercetin, rutin, gallic acid, ellagic acid, and punicalagin as major phenolic compounds in PPE [28]. In contrast to the present study, Ali et al. revealed the presence of catechin, chlorogenic acid, rutin, coumaric acid, and pyrogallol as the major phenolic compounds of the methanolic extract of pomegranate peel [29]. Padmaja and Prasad showed gallic acid (133.2 mg/g), rutin (18.96 mg/g), and kaempferol (10.8 mg/g) as the abundant phenolic compounds in PPE [15]. Due to the variations in the phenolic compounds of different geographical areas, comparisons with other published studies are difficult. The presence of phenolic compounds in PPE is the key factor in reducing oxidative stress and lipid peroxidation [29].

4.3. Total Phenolic Content. As shown in Table 1, the total phenolic content was evaluated as 1577.65 mg/g GAE. The total phenolic contents in Turgut et al. (165.4 mg/g GAE) [30], Kanatt et al. (161.3 m/g CA) [31], Negi et al. (140 mg/g

CA) [32], Ozdemir et al. (158.5 mg/g GAE) [33], Ali et al. (103.2 mg/g GAE) [29], Padmaja and Prasad (78.92 mg/g GAE) [15], Sultana et al. (364 mg/g GAE) [25], Sharayei et al. (42.2 mg/g GAE) [26], Pal et al.'s (139.40 mg/g GAE) [34] studies were lower than the current study. In Kennas and Amellal-Chibane's research, total phenolic content of pomegranate peel extracted with the same amount of water and methanol was reported as 625.525 mg/g GAE [24] which is lower than the present study. The free radical scavenging capacity and their antioxidant activities are related to phenolic structural properties and the number of present hydroxyl groups (-OH) [27]. Also, it was reported that the Folin-Ciocalteu reagent would be able to react with all phenolic groups including extractable protein, organic acids, and sugars which could interfere with results [18]. Also, the varieties in total phenolic content of different studies may be due to the affinity of polyphenols toward different solvents, which could be affected by sunlight, environmental factors, abiotic stress, and contact with pests and pathogens [9, 35].

4.4. Antioxidant Activity by DPPH and FRAP. The antioxidant capacity of PPE was evaluated by DPPH and FRAPS methods. The antioxidant compounds of PPE in the FRAP test act as reducing agents by donating a hydrogen atom to a ferric complex [29]. The DPPH and FRAP of PPE were determined as 0.054 mg/ml and 483.24 mM. Ali et al. reported the ferric-reducing power of the methanolic extract of pomegranate peel at 166.9 mg/g [29] which is lower than the present research. The DPPH scavenging activity of the mixture of water/methanol in Kennas and Amellal-Chibane's study was 85.37 μg/ml [24] which is higher than the current results (54 μg/ml). Sharayei et al. showed the FRAP and IC_{50} of 1824.6 μmol Fe^{2+}/g and 0.51 mg/ml for PPE, respectively, [26]. The IC_{50} of PPE in Ali et al. [29] and Kanatt et al's [31] researches were evaluated as 14.75 μg/ml and 4.9 μg/ml, respectively, which showed higher antioxidant activity than the current study.

Therefore, the differences in the antioxidant capacity of extracts are due to varieties of phenolic contents which are attributed to solvents used for extraction, geographical conditions, pomegranate varieties, and harvest date [32, 36]. The suitable extraction method is considered important in preparing extracts which is rich in natural antioxidants [37]. The presence of reduction agents to break free radicals by donating hydrogen indicated the reducing power and antioxidant activity of the extract [37]. The studies indicated that the use of solvent mixture for peel extraction could increase the recovery of antioxidants [20]. According to different studies, plant phenolic content is related to antioxidant activity, redox prosperities, and metal-chelating ability [38].

The antioxidant activity of extracts can be attributed to the presence of polyphenols such as gallic acid, ellagic acid, and punicalagin. In the current study, the PPE showed good antioxidant activity. A positive and significant correlation was reported between total phenolic content and radical scavenging activity (DPPH) of PPE which is in agreement with Negi et al. [32], Singh et al. [27], Kennas and Amellal-Chibane [24], and He et al. [39]. The achieved results are compatible with the fact that using high polar solvents in extraction could be more effective in radical scavenging activity than less polar solvents [29]. The varieties in the results of the two methods of antioxidant activity are attributed to differences in their mechanisms [40].

4.5. Quality Characteristics of Tahini Supplemented with PPE. The oxidation properties of tahini supplemented with different concentration of PPE were evaluated during six months of storage at room temperature. Overall, in all samples, the peroxide and TBARS values were increased during 6 months of storage. Although, it was shown that by increasing the PPE extract in tahini, the radical scavenging activity had been sharply increased.

The increase in TBARS value was more rapid in control (0.25, 0.5% PPE) than that in 1 and 2% concentrations. The antioxidant activity of PPE in tahini was dose-dependent, which decrease the oxidation by increasing the PPE. The results are in agreement with Kanatt et al. who showed an increase in TBARS of chicken during chilling storage. They also indicate lower oxidative rancidity in samples containing PPE in comparison to untreated samples [31]. Yasoubi et al. reported a lower peroxide value and TBARS in soybean oils supplemented by 0.01 to 0.05% concentration of PPE compared to the control [11].

The overall acceptance of samples containing 1 and 2% PPE was evaluated better than other samples. El-Said showed that the addition of PPE into stirred yogurt had no significant effects on appearance, texture, and flavor in comparison to the control [38]. Ismail et al. showed that the addition of pomegranate peel in cookies did not show any undesirable organoleptic changes in samples containing 7.5% and remained acceptable. They reported the extension of shelf life in cookies supplemented with pomegranate peel [41]. Kanatt et al. reported that chicken samples treated with PPE had no changes in color, flavor, taste, and texture in comparison to the control [31]. In Naveena et al.'s study, the addition of pomegranate rind powder extract in cooked chicken patties did not affect the sensory characteristics [42]. Berizi et al. used methanolic PPE on rainbow trout during frozen storage with the highest general acceptability shown in the 1% concentration. The greatest hardness and chewiness were reported in a 4% concentration of PPE [12].

The results indicated the effectiveness of PPE in preventing lipid oxidation in tahini. Therefore, it was shown that the addition of PPE has stabilized the tahini against lipid oxidation changes. The presence of phenolic compounds such as gallic acid, ellagic acid, and punicalagin could have a direct effect on increasing the free radical scavenging properties and decreasing lipid oxidation in supplemented foods. It was mentioned by previous researchers that bioactive compounds in PPE can inhibit free radicals, lipid peroxidation, and lipoxygenase as well as metal-chelating properties [43]. In the presence of a low concentration of hydroperoxides due to monomolecular mechanism, the formation of hydroperoxides is faster than its breakdown. By increasing the hydroperoxide concentrations, their decomposition followed by a bimolecular mechanism would increase [44].

5. Conclusion

It was shown that pomegranate peel, an agricultural by-product, is a good source of natural phenolic compounds. Also, the high antioxidant capacity of PPE by two methods of FRAP and DPPH was shown. According to the results, the PPE contained gallic acid, ellagic acid, and punicalagin which could be related to high antioxidant activity and radical scavenging power. The antioxidant activity of PPE in tahini was dose-dependent, which decrease the oxidation by increasing the concentration of PPE. The use of PPE in tahini would increase consumer acceptability due to its health-promoting effects and also decrease lipid oxidation in food.

Data Availability

The data are available by request on authors.

Conflicts of Interest

There is no conflict of interest.

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