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Effect of active edible coating and temperature on quality properties of roasted pistachio nuts during storage

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Abstract

The present study investigated the effect of gelatin coating (GL) containing ascorbic acid (AA:10 g/L) and/or propyl gallate (PG:0.1 g/L) on the chemical (peroxide value (PV); anisidine value (AnV) and free fatty acid (FFA)), instrumental texture (Hardness), and the sensory properties (texture, rancidity, taste, color, and overall acceptability) of roasted pistachio nuts during 3 months of storage at 20, 35, and 50°C. The relationship between PV, AnV, FFA, and rancidity taste beside instrumental hardness and sensory texture were assessed by Pearson's correlation coefficient. Pistachio nuts were treated with five formulations: control, AA + PG, GL + PG, GL + AA, and GL + AA + PG. The antioxidative activity of the GL was more effective at the lower temperature. Instrumental hardness of gelatin-coated samples was significantly ($p < 0.05$) higher than other samples at 20 and 35°C. Instrumental hardness in control samples increased, while samples with gelatin coating showed a decreasing trend. Gelatin-antioxidant coatings didn't affect the total acceptance of samples but provided protection against lipid oxidation. Positive and powerful correlation ($R > 0.9$) was found between sensory and chemical and textural properties.

Practical applications

The use of thin gelatin edible coating containing AA and/or PG, as a natural and economical secondary package, show a good potential for reducing the rate of lipid oxidation and subsequently increasing the shelf life of roasted pistachio nuts, especially at room temperature.

1 | INTRODUCTION

Pistachio (*Pistacia vera* L.) is a tasty nut and a good source of nutrients. During the last decade, the worldwide trades of pistachio has shown an increasing trend, reflecting the increase in consumers demand for these nuts. Based on USDA statistics, the United States (407,000 tons), Turkey (155,000 tons), and Iran (153,000 tons) are the main producers of this nut in 2016/2017 (USDA, 2016). Pistachio has a high content of numerous beneficial nutritive and bioactive compounds such as proteins (23%), carbohydrate (19%), moisture (2%–5%) vitamins (mainly E and B), minerals (Fe, Mg, Ca, K, P), fiber, and other micronutrients. But, oils and fats, especially unsaturated fatty acids (linoleic, linolenic, and oleic acids) are the most important compounds in pistachio nuts (Raei & Jafari, 2011).

In a study carried out on fatty acid compositions of the seven varieties of Iranian pistachio, the results showed that the kernels contained 53%–77.6% Oleic, 15.2%–32.9% Linoleic, and 7.1%–8.6% Palmitic (Mohammadi, Safari, Fatemi, & Hamedi, 2007). Although, the high oil and unsaturated fatty acid contents of pistachio are very important from a nutritional point of view, but it make them, especially roasted nut, more susceptible to oxidation and consequently off-flavored during storage (Haq, Alam, & Hasnain, 2013). Mohammadi et al. (2007) reported 59.8% Oleic- acid and 32.9% Linoleic acid for Ohadi variety of pistachio, which is the highest unsaturated–saturated fatty acids ratio among all other varieties studied by these authors. Therefore, this variety is very sensitive to oxidative rancidity developing.

Using low temperatures and synthetic packaging are some of the solution recommended to control the oxidation level of nuts.

However, the food industry is the main consumer of the synthetic packaging material that plays a significant role in environmental pollution. On the other hand, the control of low temperature during storage and supply chain is difficult and costly. Thus, the storage of nuts at room temperature have great advantage.

The use of edible films and coatings as a new sector in food packaging offer additional protection over the ordinary packaging to conserve food stability and quality. In practice, edible coatings/films exhibit their protective role by providing a semi-permeable barrier against the transfer of molecular components (such as moisture, gases, and flavors) and controlling the adverse reactions that are responsible for undesirable changes in food products (Baldwin, 2004). Edible films/coatings can usually be considered as the secondary packaging system to decrease the amount of synthetic packaging material requirement (Chick & Ustunol, 1998). In the other words, edible polymers can be consumed along with the food products and mitigated environmental concerns about the depletion of natural resources and the waste problems of synthetic, especially petroleum-based plastic, packaging materials. Therefore, edible polymers are considered as eco-friendly and sustainable packaging material (Calva-Estrada, Jiménez-Fernández, & Lugo-Cervantes, 2019). Edible coatings are based on protein and carbohydrate polymer, and some of them are so thick that they change the nutritional value of food (Baldwin, Hagenmaier, & Bai, 2011). Furthermore, an edible coating can serve as a carrier for bioactive component, such as vitamin C and vitamin E, that besides their antioxidative properties, they can enhance the nutritional value of food products (Han, Zhao, Leonard, & Traber, 2004; Rojas-Graü, Soliva-Fortuny, & Martín-Belloso, 2009).

Protein- and carbohydrate-based films/coatings are good barriers to oxygen due to their molecular structure and ordered hydrogen-bonded network (Yang & Paulson, 2000). Additionally, edible films/coatings could be effective carriers for bioactive compounds (No, Lee, Park, & Meyers, 2003). Incorporation of natural antioxidant agents into edible coating solution brings about intensified antioxidant properties because edible coating can control the release of antioxidant agents and thus improve the quality and stability of foods during storage. Gelatin is a protein with a wide range of functional properties and applications, one of this functional properties is film-forming ability (Gómez-Guillén et al., 2002). Gelatin-based films and coatings were shown to be excellent oxygen barriers at low to intermediate relative humidity (Nur Hanani, Beatty, Roos, Morris, & Kerry, 2012). Using gelatin to prepare edible films and coatings was remarkably studied 50 years ago, which resulted in many patents being already published.

However, the use of gelatin as a polymer for the production edible films and coatings have attracted wide attention due to its biodegradability, low cost, availability, and its potential to form edible films and coating (Nur Hanani et al., 2012).

In the last decade, many studies have dealt with application of various edible coatings and films on nut kernels. Whey protein isolate (Gounga, Omar, Amadou, & Xu, 2017; Gounga, Xu, Wang, & Yang, 2008; Javanmard, 2008; Lee & Krochta, 2002; Mehyar, Al-Ismail, Han, & Chee, 2012), Pullulan (Gounga et al., 2017), soy protein (Chinma, Ariahu, & Abu, 2014; Kang, Kim, You, Lacroix, & Han, 2013), cordia gum, carboxyl methyl cellulous (Haq et al., 2013; Sedaghat & Khoshnoudi-nia, 2015), methylcellulose (Suppakul, Boonlert, Buaphet, Sonkaew, & Luckanatinvong, 2016), hydroxyl propyl methylcellulose (Atarés, Pérez-Masiá, & Chiralt, 2011), hydroxyl propyl methylcellulose (Baldwin & Wood, 2006), chitosan (Bonilla, Poloni, & Sobral, 2018; Zhang, Hao, Li, & Wang, 2017), starch cashew tree gum nanocomposite film (Pinto et al., 2015), Indian gooseberry puree (IGP) (Suppakul et al., 2016), and sodium caseinate (Bonilla et al., 2018) have been used to protect nut kernels against oxidation and increase the shelf life of them. In previous studies, gelatin coating containing ascorbic acid (AA) had not been applied to nuts. Furthermore, few studies have been focused on texture properties of nuts after coating treatment. Therefore, the aim of this research was to evaluate the effect of gelatin and antioxidant agents to extend shelf life of roasted pistachio nuts at various storage conditions.

2 | MATERIALS AND METHODS

2.1 | Materials

Roasted pistachio nuts (Ohadi variety) were obtained from Pisteej. Ltd. (Yazd, Iran). Bovine gelatin powder type B (medium Bloom 180/220) donated by Arya Gelatin CO. (Mashhad, Iran). Glycerol, as plasticizer of the edible coating solutions, and all of chemical materials were obtained from Merck Chemicals Co. (Germany). AA 99% and propyl gallate (PG) 99%, as antioxidant standard, were perched from Sigma-Aldrich CO. (Switzerland).

2.2 | Coating solution preparation

Four coating formulations investigated in this study are shown in Table 1. Gelatin powder (40 g/L of water) and glycerol (12 g/L of water or 30% gelatin powder) were added to deionized water and stirred by magnetic stirrer and heated to 80°C for 30 min to obtain a good blend (Nur Hanani et al., 2012). Coating solution was cooled down to room temperature, after which concentrations of 10 g/L, L-ascorbic acid and 0.1 g/L PG was slowly incorporated into the coating solution and all solution were degassed by stirring under vacuum for 1 hr.

TABLE 1 Coating formulations used in the study

Treatment code	Gelatin (g/L)[a]	Propyl gallate (g/L)	Ascorbic acid (g/L)
T_{CO} (control)	0	0	0
T_{PA}	0	0.1	10
T_{GP}	40	0.1	0
T_{GA}	40	0	10
T_{GAP}	40	0.1	10

[a]Concentration based on solution.

2.3 | Coating of pistachio nuts

Coating procedure was followed by Kang et al. (2013) method. Roasted pistachio nuts were coated by dipping the nuts in the coating solutions for 15 s. Afterward, the samples were dried in controlled environmental chamber at 35°C (Lab Tech Model LCT1075C, Korea) for 12 hr (Kang et al., 2013).

2.4 | Storage conditions and sampling

For each treatment, 100 g of pistachio nuts was packaged (Polyethylene/polyamide 75-micron plastic bags). Samples of each treatment were stored in incubators at 20°C (normal condition); 35 and 50°C (accelerated condition) (Crop-Life-International, 2009). All the samples were kept away from light. The nuts were sampled on the zero, first, second, and third months of storage.

2.5 | Chemical methods

The oil was extracted by following the modified method of (Kang et al., 2013). Pistachio kernels (40 g) were smashed by a mortar. Then, smashed pistachio was macerated with n-hexane at a volume double of grounded pistachio. Lipids were extracted in a shaking incubator at ambient temperature for 12 hr. The pistachio powder and pieces were completely separated from aqueous media using a vacuum pump filtration and filter paper (Whatman no. 1). The hexane was evaporated under vacuum at ambient temperature.

Para-anisidine value (AnV) and peroxide value (PV) of the extracted oil were determined by the colorimetric procedure (spectrophotometer model 2100 UV, Cole Parmer Instruments Company 625 East Bunker Court Vernon Hills, USA) (Semb, 2012). Free fatty acids (FFA), as oleic acid percentages in oil samples, were measured using the titration method according to AOAC method (AOAC, 1995).

2.6 | Texture measurements

Texture profile analysis (TPA) was performed by an Instron Universal Texture Analyzer (model 1122, Instron Ltd., Buckinghamshire, England). The pistachio kernels were placed individually on the plate and compression test was applied using cylinder probe (diameter: 20 mm) at a test speed of 50 mm/min, and readings were taken after 50% compression. The test was performed in 15 replications for each sample. Hardness (Newton: N) was defined as the first force peak on the TPA curve (Kita, Figiel, Carbonell-Barrachina, & Gwozdziowska, 2009; Nikzadeh & Sedaghat, 2008).

2.7 | Sensory analysis

Initially, and after every month of storage, the coated and uncoated pistachio nuts were provided to 20 semi-trained panels (10 female and 10 male) from students of the Food Science and Technology Department, Faculty of Agriculture, Ferdowsi University of Mashhad, Iran, to evaluate color, hardness, taste, rancidity, and overall acceptance on a 5-point hedonic scale, where 1 represented "dislike extremely" and 5 represented "like extremely." Also, for evaluation of hardness and rancidity, 5 delineated "very high" and 1 delineated "very low". Sensory attributes of pistachio were selected from peanut lexicon (Lee, Trezza, Guinard, & Krochta, 2002; Nepote, Mestrallet, & Grosso, 2006). The sensory analysis was conducted in an odorless and quiet laboratory condition under fluorescent light at room temperature. Roasted pistachio nuts were considered acceptable if their mean value for overall acceptance scores was above 3 (neither like nor dislike).

2.8 | Statistical analysis

All analyses were carried out in three replications. Data were analyzed using Minitab 16 (Minitab, Inc., State College, PA). Data analysis of variance (ANOVA) and general linear models (GLM) were used to compare the mean values of each treatment and significant differences between the means of parameters were determined by using the Tukey's multiple range test ($p < 0.05$). In addition, Pearson's correlation coefficient was used to determine the correlation between sensory and instrumental parameters.

3 | RESULTS

3.1 | Peroxide value

Lipid oxidation includes the continuous formation of hydroperoxides as primary oxidation products that may disintegrate to a variety of nonvolatile and volatile secondary products. The PV is one of the most widely used test for detection of the initial stages of oxidative rancidity in oils and fatty foods (Shahidi & Zhong, 2005). The changes in the PV of samples during storage at various temperatures are shown in Figure 1a–c. The results showed that the PV increased with time in coated and uncoated samples due to the relatively high unsaturated fatty acids in pistachio nuts (Suppakul et al., 2016). The increase in PV of samples showed a strong increasing trend at higher storage temperature. Tavakolipour, Mokhtarian, and Kalbasi-Ashtari (2017) also reported the increasing trend of PV in pistachio powder during storage at different RH and temperature (15, 25, 35, and 40°C) and related the reason to equilibrate the moisture content of pistachio at monolayer level in lower RHs (33%–73%) and temperature (15°C). Therefore, with limited availability and mobility of free radicals, the lipid oxidation occurred more slowly (Tavakolipour et al., 2017). However, PV in gelatin-coated samples (T_{GA}, $T_{GP,}$ and T_{GAP}) was significantly ($p < 0.05$) lower than the control sample (T_{CO}), which may be due to oxygen barrier function of gelatin coatings. Moreover, some researches were shown that several amino acids in gelatin, such as prolin, glycine, phenylalanine, and leucine, have potent antioxidative activity (Kim, Byun, & Ito, 2001; Kim, Kim, et al., 2001; Mendis, Rajapakse, & Kim, 2005; Pihlanto, 2006). It was observed that all the gelatin coatings were effective in retarding oxidation at all of temperatures. If the acceptance threshold value of PV is supposed to be 2 meq·O_2kg^{-1} (Kanner, 2007), the PV showed

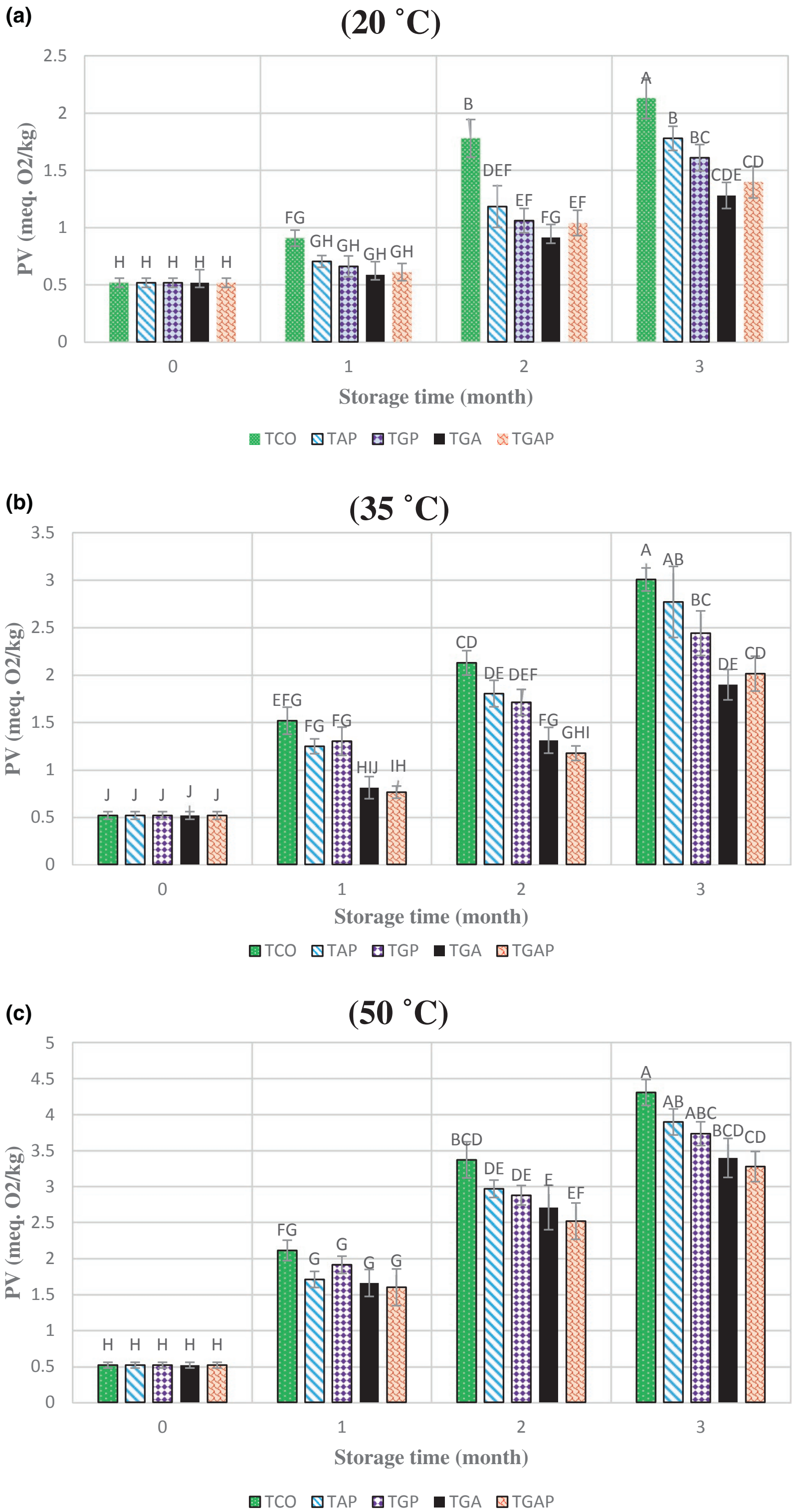

FIGURE 1 Peroxide values ($meq{\cdot}O_2kg^{-1}$) changes of roasted pistachio nuts during storage at (a) 20°C, (b) 35°C and (c) 50°C

that samples were in good condition during 3 months of storage at 20°C. Furthermore, the lowest PV at the end of third month storage was obtained for T_{GAP} samples (1.4 $meq{\cdot}O_2kg^{-1}$) and the highest one was acquired in T_{CO} (2.1 $meq{\cdot}O^2kg^{-1}$) at 20°C, which the difference between these two samples was significant ($p < 0.05$; Figure 2a).

The lipid oxidation of uncoated pistachio increased beyond the acceptable level since second month of storage at 35°C, while PV of gelatin-AA-coated nuts was below threshold value over 3 months (Figure 2b). The protective effect of edible coatings against oxidation was greatly reduced at 50°C (Figure 1c), which probably refer to the intensified oxygen permeability of the edible coating materials at high temperature (Mehyar et al., 2012). The effect of high temperature on the gas barrier properties of edible coating on nut has been reported by other authors (Maté & Krochta, 1996; Mehyar et al., 2012).

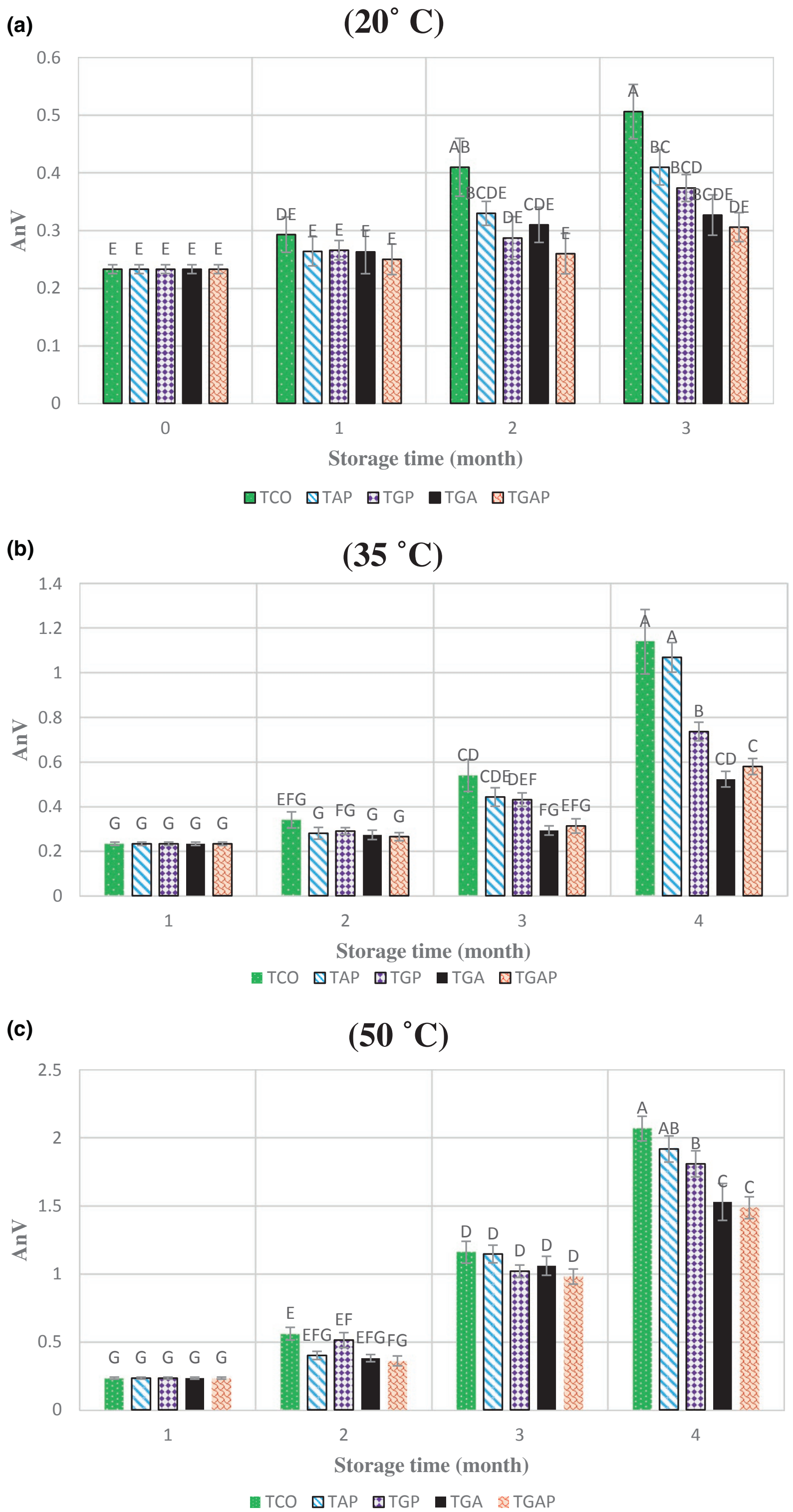

FIGURE 2 Anisidine values (AnV) changes of roasted pistachio nuts during storage at (a) 20°C, (b) 35°C and (c) 50°C

However, Min and Krochta (2007) reported that the WPI coating was significantly effective in delaying the progression of oxidation in peanuts stored at 50°C (Min & Krochta, 2007). The gelatin-AA coatings had been significantly more successful than the gelatin-PG in control of lipid oxidation (Figure 1a–c). This could be due to the low concentration of PG in comparison to the concentration of AA in formulation of gelatin coating. Moreover, AA by interact with the polymer chain and formation of crosslinks among the protein molecules results in improvement of oxygen barrier properties edible coating and film. Also, the addition of hydrophilic components (e.g., AA and PG) in the coating matrix decreased oxygen permeability (oxygen is a hydrophobic component) of coatings (Mehyar et al., 2012). In general, the use of gelatin-AA coating on roasted pistachio induced 40%, 37%, and 19% reduction of oxidation at 20, 35,and 50°C, respectively. The finding

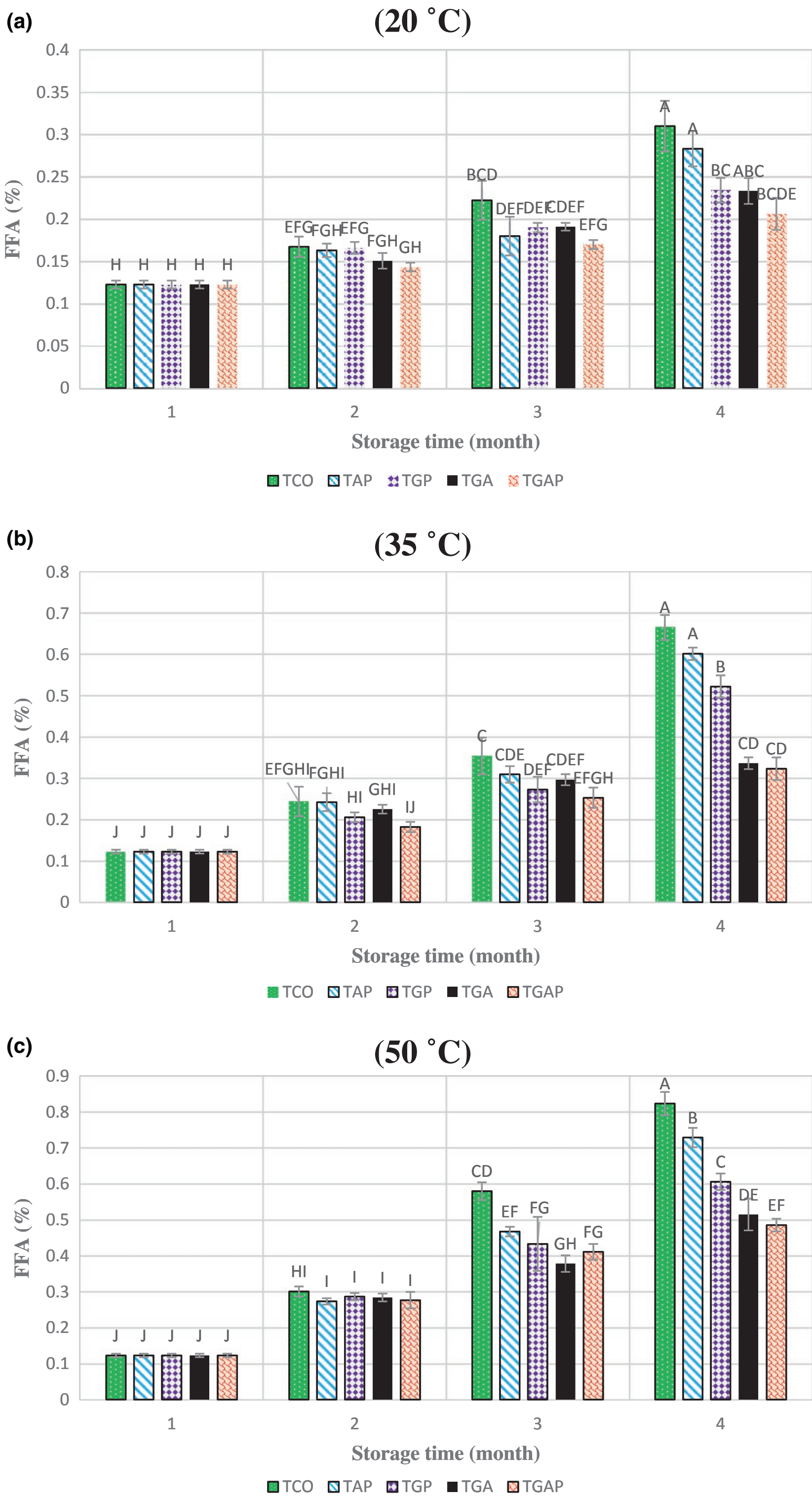

FIGURE 3 FFA content of roasted pistachio nuts during storage at (a) 20°C, (b) 35°C and (c) 50°C

related to the effect of edible film/coating on control of lipid oxidation in kernel nuts also in agreement with previous studies (Gounga et al., 2008; Min & Krochta, 2007; Pinto et al., 2015; Suppakul et al., 2016).

3.2 | Anisidine value

AnV determines the level of secondary lipid oxidation products that they were formed by the degradation of peroxides (Haq et al., 2013). Change in the amount of AnV of roasted pistachio nuts during the storage period is shown in Figure 2a–c. The amount of peroxides should be accumulated before the degradation of peroxides and generation of secondary lipid oxidation products (Haq et al., 2013). Therefore, the AnVs were almost remained constant during one month storage at 20°C (Figure 2a). This value corresponded to a PV of 2.61 meq·O^2kg^{-1}. These results were agreed with previous studies (Bonilla et al., 2018; Haq et al., 2013; Kang et al., 2013; Min

& Krochta, 2007). Moreover, there was no significant difference between samples during first-month storage at 20 and 35°C. The AnVs continuously increased during storage time in all of the samples. At various storage times and temperature, the maximum AnV took place in the control sample and the minimum were recorded in the T_{GAP} and T_{GA} samples. Similar to the PV assay, AnV of the coated pistachio nuts with gelatin-antioxidant agents was significantly lower than the control samples during storage time at 20 and 35°C ($p \le 0.05$). According to the AnV and PV of various samples, at the end of storage period, it can be observed that gelatin coating containing antioxidant agents, especially T_{GAP}, improves chemical stability of roasted pistachio nuts by preventing the development of oxidative rancidity.

3.3 | Free fatty acids

Hydrolysis of fats and oils resulting from the enzyme reactions generated FFA, which catalyzed by heat and moisture. FFA undergo further autoxidation to produce highly reactive molecules responsible for off flavor (Gadge et al., 2012). The effect of gelatin coatings on FFA content of roasted pistachio nut during storage at various temperature is presented in Figure 3a–c. The FFA content of samples were increase continuously during storage at three temperature conditions. However, the FFA content in the samples coated with gelatin containing antioxidants (T_{GAP}, $T_{GA,}$ and T_{GP}) was lower than other samples.

The results show that there was not any significant differences between samples at 20°C during first month of storage. Furthermore, in the second month of storage, only the difference between T_{CO} and T_{GAP} was statistically significant. The FFA content of gelatin-antioxidant coating was significantly lower than uncoated and T_{AP} samples at 35°C. These results are in agreement with those reported by Suppakul et al. (2016). The rate of hydrolysis in all samples stored at 50°C was significantly higher than other storage temperatures. Like most chemical reactions, the rate of enzyme reaction intensified with an increase in temperature ($p < 0.05$). This is apparently due to increased water vapor and oxygen permeability of coatings with increasing temperature, which accelerated the hydrolytic reaction of lipase de-esterification (Garcia, Martino, & Zaritzky, 2000; Suppakul et al., 2016). Among the coated samples with gelatin, T_{GAP} and T_{GA} samples had significantly lower FFA content than another sample. The difference between T_{GAP} and T_{GA} sample was not significant ($p > 0.05$). Edible coating protects foods from moisture and temperature (catalysis of hydrolysis reaction), thus reduce the rate of FFA production. As shown in Figure 3b,c, antioxidant activity of T_{AP} treatment is significantly reduced at the end of third month of storage and FFA content of this sample follow the same trend as uncoated sample, whereas addition of antioxidants into the gelatin matrix (T_{GAP}) maintained the antioxidant activity of AA and PG for the longer time period. These results are consistent with other researcher's findings, Mehyar et al. (2012) reported that the use of pea starch, whey protein isolate, and carnauba wax coating had a significant effect on reduction of FFAs formation in walnuts.

3.4 | Hardness

According to Table 2, hardness of samples which were coated with gelatin significantly ($p < 0.05$) higher than control and T_{AP} samples storage at 20 and 35°C, due to significant higher moisture content of gelatin-coated samples ($p < 0.05$, the results of moisture content were not showed). The results of previous studies showed that the gelatin coating and film have a relatively moderate barrier to water vapor (Nur Hanani et al., 2012). It may be a reason for resistance of gelatin-coated samples to moisture transmission. Therefore, the moisture content of coated samples were more than other ones and consequently the hardness of theses samples was also higher than uncoated samples. However, no significant difference was observed between hardness of gelatin-coated samples and T_{PA} samples at 50°C. This is apparently due to the increased water vapor permeability of coatings in high temperature. In the other words, the motion of the molecules were accelerated by increasing temperature and leading to increase moisture transfer.

The effect of storage time on hardness was also significant ($p < 0.05$). Hardness in control samples increased during storage while that gelatin-coated samples showed decreasing trend to reach water balance. It was possible due to different moisture content that lead to different water vapor pressure values (AgnieszkaKita, 2007; Khoshnoudinia, Sedaghat, & Radmard-Ghadiri, 2013). Nikzadeh and Sedaghat (2008) observed that the minimum pistachio nut hardness was obtained instantly after the roasting process, whereas gradually increased during storage. The increasing trend in the hardness of these samples can be attributed to increased moisture content, besides the formation of oxidation products (Nikzadeh & Sedaghat, 2008). T_{GA} samples showed significantly more hardness than other gelatin coatings. It can be attributed to increase the cross-linking between the polymer chains and the carboxylic acid (e.g., AA), which leads to a tight structure, making difficult the moisture transfer

TABLE 2 Effect of temperature and coating formulation on hardness (newton: N) of roasted pistachio nuts (mean ± *SD*)

Coating	20°C	35°C	50°C
TCO	64.85 ± 4.37^{H}	61.742 ± 4.933^{I}	60.402 ± 4.767^{I}
TPA	82.10 ± 5.26^{E}	78.53 ± 4.39^{F}	75.51 ± 4.40^{G}
TGP	84.88 ± 6.85^{BCD}	82.73 ± 4.47^{DE}	76.82 ± 5.58^{FG}
TGA	87.758 ± 6.06^{A}	86.00 ± 5.32^{ABC}	77.61 ± 3.19^{FG}
TGAP	87.273 ± 2.955^{AB}	84.63 ± 3.34^{CDE}	77.69 ± 5.43^{FG}

Note: Different letters in the table indicate significant differences ($p < 0.05$).

(Atarés et al., 2011). The sensory hardness of edible coated nuts has been reported by previous researchers (Haq et al., 2013; Larrauri et al., 2016; Mehyar et al., 2012).

3.5 | Sensory properties

Sensory quality of foods can be evaluated based on total impression made on the mind of the consumers (Tahsiri, Niakousari, Khoshnoudi-Nia, & Hosseini, 2017). The mean of sensory scores for various properties are shown in Figure 4. No significant different (p > 0.05) in taste and rancidity score were detected by the sensory panel for coated and uncoated samples at 20°C during storage. The significant changes (p < 0.05) in rancidity taste of pistachio nuts were observed after 2 months storage at 35°C, while this change was observed in samples stored at 50°C after first month. In general, it is agreement with the AnV results. The use of edible coating containing antioxidant agents had no significant difference on sensory taste score at various temperature. However, at the end of the third month and in the mean of taste and overall acceptability scores of T_{CO} and T_{AP} samples had dropped below 3 at 50°C. According to evaluators comment, the taste of T_{PA} samples were sweeter than other samples at the end of storage at 50°C, likely due to oxidation of AA. The T_{CO} samples showed more off-flavor and bitter taste than the coated samples, likely due to more secondary oxidation products were naturally produced at higher temperatures. Hardness of gelatin coated samples significantly more than control and T_{AP} samples at 20 and 35°C(p < 0.05), probably because of higher moisture content (Haq et al., 2013; Khoshnoudinia & Sedaghat, 2014; Lee et al., 2002; Mehyar et al., 2012; Riveros, Nepote, & Grosso, 2016). However, Javanmard (2008) reported that whey protein and soy oil (40% of the protein content) coating improved crunchiness of pistachio nuts (Javanmard, 2008).

There was no significant difference between hardness of samples at 50°C; however, gelatin-coated samples showed higher hardness score. There was a significant difference between color of coated and uncoated pistachio. The color score of control and T_{GP} samples higher than other ones and the lowest score was obtained for T_{AP} sample. Min and Krochta, (2007) reported that the reddish color of the AA-whey protein-coated samples which may be attributed to red pigment, forming by Maillard browning reaction of AA (Min & Krochta, 2007). Haq et al. (2013) reported that the cordial coated samples were significantly darker than other samples, they related this color difference to the presence of colored substances in gum Cordia or high thickness of the coatings (Haq et al., 2013). Also, Larrauri et al. (2016) reported the initial differences between color of coated (CMC—peanut skins extract) and uncoated almond samples (Larrauri et al., 2016). But some authors reported no significant difference in color of coated and uncoated kernels (Riveros et al., 2016; Suppakul et al., 2016).

Changes in overall acceptability scores of T_{GAP} and T_{GA} samples were minimum during storage time, while the lowest scores were recorded for control samples at 35 and 50°C at the final day of storage and the highest overall acceptability score were observed for control samples at 20°C. According to the panelists comment, control sample had better texture than the other samples at 20°C (p < 0.05).

Pistachio nuts were considered acceptable if their mean value for overall acceptance scores was above 3 (neither like nor dislike).

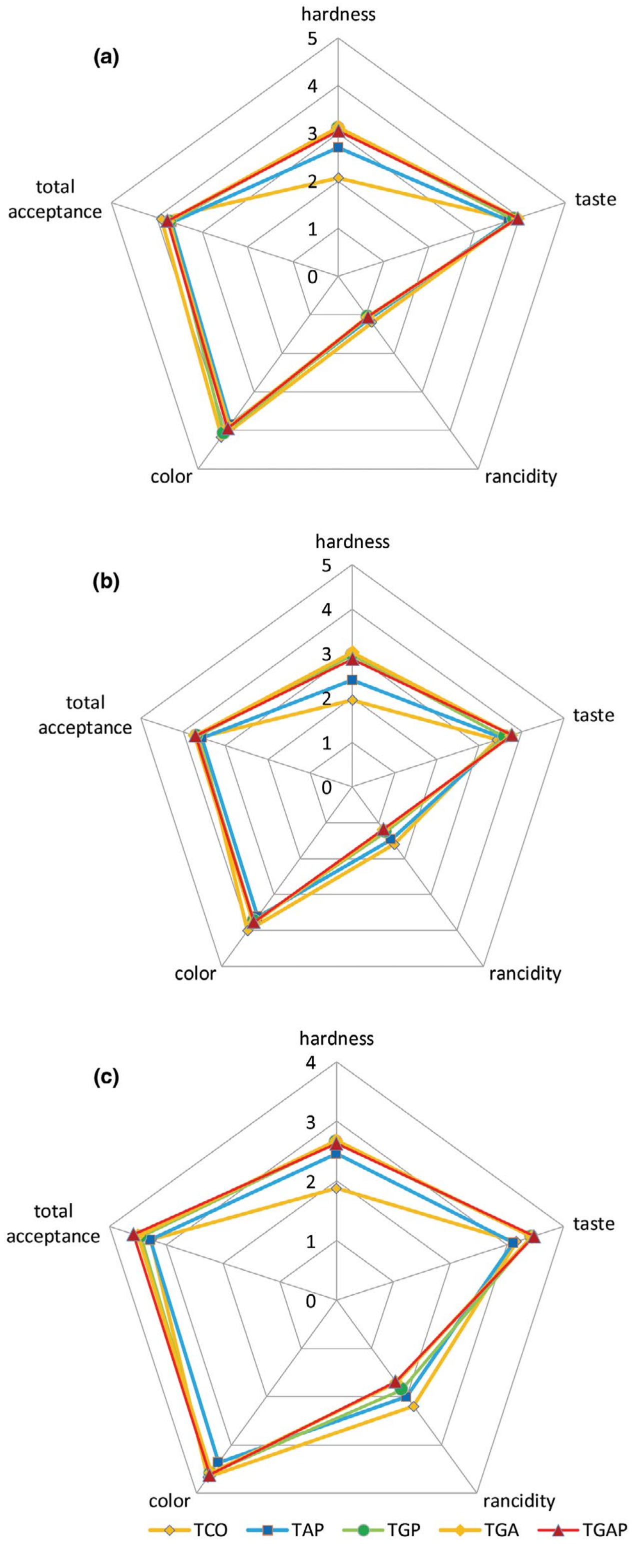

FIGURE 4 Sensory properties of uncoated and coated nuts at (a) 20°C, (b) 35°C and (c) 50°C

TABLE 3 Pearson's correlation coefficients instrumental (PV, AnV, FFA, and hardness) and sensory attributes (rancidity and hardness) of roasted pistachio nuts

Variable	PV	AnV	FFA	Instrumental hardness
Rancidity taste	0.927	0.962	0.915	–
Sensory hardness	–	–	–	0.920

3.6 | Correlation

Correlation between instrumental and sensory variables is presented in Table 3. The greatest correlation coefficient was observed between AnV and rancidity taste. Positive and powerful correlation (>0.9) was found between sensory and instrumental data.

4 | CONCLUSION

The results of this study revealed that gelatin coatings containing AA and/or PG, protect roasted pistachio from oxygen and delay lipid oxidation. The antioxidative activity of the gelatin coatings was more effective at the lower temperature (20 and 35°C compared to 50°C). In general, all coatings were effective to reduce the development of oxidative and hydrolytic rancidity of pistachio kernels and among them, T_{GAP} and T_{GA} were the most effective. Gelatin-coated nuts increased instrumental hardness and sensory firmness of pistachio. However, active gelatin coatings by protection of roasted pistachio nuts against lipid oxidation and reduction of rancidity taste, improved overall acceptability of roasted pistachio nuts during the storage. Gelatin coatings containing ascorbic acid effectively can be used as a natural and commodious edible coating to increase the shelf life of pistachio and other similar nuts and fatty foods by decreasing oxidation.

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