Shelf Life Quality Changes of ´Camarosa´ Strawberry Fruit in Response to Persian and Wild Sage Gums Application

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Summary

Given the high perishability of strawberry fruit, the edible coating will maintain its postharvest quality. Edible coatings have gained considerable attention due to their ability to extend fruits shelf life. Therefore, in this study two edible coatings were prepared using 0.5 and 1.0% (w/v) of Persian gum and 0.2 and 0.5% (w/v) of wild sage to maintain the shelf-life quality of 'Camarosa' strawberry fruit during 9 days of storage at 20 °C. It was found that fruit firmness, titrable acidity (TA), total anthocyanin, total carotenoid, protein, vitamin C and total antioxidant activity showed a decreasing trend during 9 days of shelf life, while weight loss, total soluble solids (TSS), TSS/TA, total phenolic content, superoxide dismutase (SOD), catalase (CAT), pectin methylesterase (PME) and polygalacturonase activity (PG) activity significantly increased. Fruits coated with Persian and wild sage gums had higher firmness, TA, total anthocyanin, total carotenoid, protein, vitamin C, total phenolic content, total antioxidant activity, SOD and CAT activity along with lower weight loss and PME and PG activity. The results suggested that Persian and wild sage gums especially at 1.0 and 0.5% (respectively) could be successfully employed to maintaining 'Camarosa' strawberry quality up to 9 days of shelf life.

Key words

antioxidant, bioactive compounds, firmness, nutritional quality

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Introduction

Strawberry is an important berry fruit which is consumed worldwide. The characteristic traits related to the fruit quality of strawberry are texture, color and taste. Strawberry is naturally rich in essential nutrients and antioxidants, including vitamin C, anthocyanins, amino acids, flavonoids and phenolic compounds which have healthy influences concerning human (Kalantari et al., 2020; Barkaoui et al., 2021). Strawberry fruit has a very short shelf life, because of physiological disorders, susceptibility to mechanical injuries, fungal infection, fast dehydration, high metabolism, respiration rate, mechanical injury and sensitive tissue, which causes more than 40% losses (Horvitz, 2017; Kalantari et al., 2020). Therefore, reducing the rate of deterioration, without a significant change in antioxidants and global quality attributes, is the main purpose from technological and economic aspects. Many management and preservation techniques have been explored to extend the shelf life of strawberry fruit like modified atmosphere packaging, UV-irradiation, hypobaric storage, ultrasound technique and chemical treatment. Nevertheless, besides having high initial costs, these methods have been rejected by consumers because of their negative influence on fruit quality characteristics such as texture, color, and taste (Khodaei et al., 2021).

Most recently, the application of edible coatings has become one of the prospective techniques, extensively researched as they are biodegradable, eco-friendly, non-toxic, simply accessible, inexpensive, easy to use, renewable, and readily trusted by consumers (Momin et al., 2021; Sivakumar et al., 2021; Saleem et al., 2021). Edible films and treatments change the physiology processes of products by forming a barrier between a product and its surroundings, controlling the transfer of moisture, O_2 and CO_2, minimizing the tissue softening, enzymes activity and entry of microbes, which could prolong the storability of a coated produce (Hamdani et al., 2019; Sivakumar et al., 2021; Momin et al., 2021).

Among edible coatings, Persian gum is typically a natural gum or hydrocolloids exudate from a tree of *Amygdalus* spp. recognized as *Amygdalus scoparia* Spach. This gum, as a novel nonstarch water-soluble exudate gum, is a transparent, semi-cloudy odorless exudate that can be observed in various forms with different colours (Dabestani et al., 2018; Hashemi Gahruie et al., 2022). Jokar et al. (2021) indicate that treated pomegranate arils by Persian gum significantly extend shelf life, keep marketability and bioactive compounds (Jokar et al., 2021). Moreover, it has been revealed that Persian gum has the potential to the application as a proper, novel, and applicable treatment in cucumber and tomato fruits (Mostafavi, 2019). A study on 'Valencia' oranges mentioned that the application of Persian gum reduced water loss and softening during storage time (Khorram et al., 2017).

Another edible coating that has received most attention is wild sage (*Salvia macrosiphon* Boiss.) gum. Its seeds have a mucilage layer that could swell in water, giving viscous suspension attributes which are similar to commercial food hydrocolloids (Salehi, 2017). Some potential of the wild sage gum is recognized by Salehi and Kashaninejad (2015). Although wild sage is mostly used in the bakery industry, there are not any reports about the effect of wild sage gum on fruits quality. In bakery products, wild sage gum is widely applied to increase mixing and extension of shelf life of the products through moisture maintenance and inhibition of syneresis in frozen foods and pie fillings (Salehi, 2017).

Given the importance and expansion of the application of novel edible coatings on fruits and vegetables, this research was performed to estimate the impact of various concentrations of Persian gum (0.5 and 1.0%) and wild sage gum (0.2 and 0.5%) on some physicochemical attributes, colour changes, bioactive compounds and the activity of antioxidant and cell wall degrading enzymes of 'Camarosa' strawberry fruit.

Material and Methods

Materials

The study was conducted on strawberry fruits of cultivar 'Camarosa' due to its extensive use abroad as well as in Iran, and good agronomic performance (Kalantari et al., 2020). Fruits were obtained from a commercial greenhouse in the Pirbazar region of Rasht, Gilan, Iran. Strawberry plants were grown at 25 °C/15 °C (day/night temperatures) and 70% (± 5%) relative humidity with a 14-h photoperiod. The greenhouse was equipped with a drip irrigation system and water was supplied according to evaporation demand. Fruits were harvested at the same ripening stage (> 75% red surface color) (Kalantari et al., 2020), then transferred immediately to the laboratory. Within each replication, only fruits having similar size, color, shape, and without any physical injuries or disease were selected. Physicochemical attributes (discussed below) were assayed at harvest on 30 fruits.

Edible Coating Application

Persian gum exuded by *A. scoparia* trees was collected in Kurdistan Province, Iran. Persian gum was milled by an electrical mill and finally was sieved (by mesh 60) to obtain a fine and homogenous powder. Separation of the soluble part of Persian gum was conducted according to Samari-Khalaj and Abbasi (2017). Persian gum powder was dissolved in distilled water (1% w/v) using a magnetic mixer to separate the soluble part of the gum. The resultant solution was kept at ambient temperature for 24 h to complete the soaking process. Then, the gum solution was at 33,000 g for 15 min. The supernatant containing the soluble part of the gum was separated (Samari-Khalaj and Abbasi, 2017). Finally, 0.5 and 1.0% of Persian gum were prepared and used for coating.

Wild sage seed gum was extracted from whole seeds using distilled water (water to seed ratio of 25:1–85:1) at pH 3–9. The pH was monitored continuously and adjusted by 0.1 mol L^{-1} NaOH and HCl, respectively, while the temperature of the aqueous system ranged from 25–80 °C and was controlled within ± 2.0 °C using an adjustable temperature-controlled water bath. Water was preheated to a designated temperature before the seeds were added. Extraction was carried out in three stages; in the first stage, the seeds (40 g) were mixed with 1000 ml water (25:1 W:S) at a specific pH and temperature and enough time (20 min) was given for complete water absorption. A soaking time of 20 min was selected based on the yield of preliminary trials. Separation of the gum from the swelled seeds was done by passing the seeds through a laboratory extractor. Crude gum was collected and residual seeds were immersed in the remaining water in two stages, according to the water to seed ratio proposed for each run, and again was passed through the extractor. The collected crude gum from different stages was mixed, filtered and dried overnight in a forced convection oven at 70 °C. The dried gum was

then grounded, filtered and after preparing 0.2 and 0.5% (w/v) concentrations, it was used for coating.

There were 930 strawberry in our study, as 30 fruits were used for different analyses at harvest time and 900 fruits [five treatment × three evaluated times during shelf life × three replications (each replication contained 20 fruits)] were uniformly divided into five groups. Deionized water was used for treating the control fruits. The remaining fruits were dipped in 0.5 and 1.0% Persian gum and 0.2 and 0.5% wild sage gum for 3 min, respectively. The fruits were located on a clean-steel sieve to allow draining of excess coating solution and then air-dried for 3 h at room temperature (20 °C). Subsequently, coated fruits were put in clamshell clear polyethylene terephthalate (PET) boxes, and were stored for 9 days at 20 ± 1 °C. All fruit quality traits were assessed at 3, 6, and 9 days. At each sampling time, three replicates (each replication contained 20 fruits) were employed on physicochemical attributes assessments. At each sampling time, tissue samples consisting of both the achenes and receptacles were selected from the fruit central part. The samples were rapidly cut, pooled, frozen in liquid nitrogen, and saved at -80 °C until use for physicochemical attributes.

Traits Measurement

Weight Loss (%)

The fruits weight loss was calculated using the following equation (Dhital et al., 2018):

$$\text{weight loss (\%)} = [(W1\text{-}W2)/W1] \times 100$$

in which, W1 is initial weight, W2 is final weight.

Firmness

The fruit firmness was assayed by a penetrometer (Texture analyzer) fitted with a P5 probe.

Total Soluble Solids Concentration (TSS)

A hand reflectometer (ATAGO PAL-3, Japan) was used to determine the TSS content of the fruits. One drop of fruit juice was placed on the measuring prim, and the reading was taken directly as °Brix (Padmaja et al., 2015).

Titratable Acidity (TA)

Titratable acidity (TA) was determined by titration (0.1 N NaOH) method as described by AOAC (1994).

Ripening Index (TSS/TA)

After the measurement of TSS and TA, the ratio of TSS/TA (as ripening index) was calculated.

Anthocyanin

Anthocyanin content was assayed based on pH differential (pH 1.00 and pH 4.5) protocol by an UV–Vis spectrophotometer at 510 nm and at 700 nm (Cordenunsi et al., 2003).

Total Carotenoid Content

Based on the methods of Lichtenthaler (1987) total carotenoid content was determined at 646, 663, and 470 nm by an UV–Vis spectrophotometer

Protein

The protein amount was measured by spectrophotometry based on Bradford (1976) at 595 nm, since bovine serum albumin was used as a standard.

Vitamin C

Ruck's (1963) method was used to assess the vitamin C content of the fruits. In brief, 0.4% of the concentrated oxalic acid was mixed with 10 mL of strawberry juice. Then, by using a 2,6 dichloroindophenol solution (Sigma–Aldrich, Germany), a 5 mL aliquot was titrated. The standard was L-ascorbic acid (Sigma–Aldrich, Germany), and the vitamin C concentration was measured as mg 100 g^{-1} FW.

Total Phenolic Content

According to the protocol of Singleton et al. (1999), total phenolic content was measured by Folin–Ciocalteu agent at 765 nm, and gallic acid was used as a standard.

Total Antioxidant Activity

We used 1, 1-diphenyl-2- picrylhydrazyl (DPPH) agent to determine the total antioxidant activity of 'Camarosa' strawberry fruit as previously mentioned by Brand-Williams et al. (1995).

Superoxide Dismutase (SOD) Activity

Based on the Štajner and Popović (2009) protocol, SOD activity was determined using nitro blue tetrazolium (NBT) agent s at 560 nm in an UV–Vis spectrophotometer.

Catalase (CAT) Activity

The CAT activity of 'Camarosa' strawberry fruit was measured spectrophotometrically at 240 nm as described by Liu et al. (2009).

Pectin Methylesterase (PME) activity

We used Hagerman and Austin (1986) protocol to determine of PME activity at 620 nm and finally expressed as mmol acid produced s^{-1}.

Polygalacturonase (PG) Activity

Yoshida et al. (1984) method was used for PG activity of 'Camarosa' strawberry fruit at 540 nm.

Experimental Design and Statistical Analysis

This experiment was done as a factorial experiment according to a completely randomized design with three replications. The data were analyzed by SAS software (ver. 9.1 2002–2003, SAS Institute, Cary, NC). Duncan's multiple range test was calculated to compare the differences between means. It should be noted that, before analysis of variance, data were tested for normality and homoscedasticity using the Kolmogorov–Smirnov and Cochran tests, respectively.

Results and Discussion

Our findings showed that the main and interaction effects of storage time and edible coating treatments (Persian and wild sage gums) significantly ($P < 0.01$) affected all evaluated traits except

total phenolic content, as total phenolic content was significantly affected just by the main effect of storage time and edible coating treatments (Table 1).

Weight Loss

During shelf life, the weight loss of 'Camarosa' strawberry fruit significantly reached 3.54% after 9 days (Table 1). Fruits treated with Persian and wild sage gums had lower weight loss than control fruits (Table 2). In the meantime, Persian gum was more effective than wild sage gum in preventing fruit weight loss, especially after 9 days.

The effects of weight loss on fruit visual appearance and texture cause a reduction in saleable weight, so they are an important challenge during storage time. In general, fruit weight loss increased linearly with an increase in storage time mainly due to water loss and respiration (Kader 2002). Similar to our results, Wani et al. (2021) and Saleem et al. (2021) mentioned that the weight loss of 'Chandler' strawberries increased during storage time while coating fruits with some edible coatings significantly prevented fruit weight loss. Reduction in weight loss of coated fruits might be related to the creation of the film by using coatings on the fruit skin thus acting as semipermeable barriers, subsequently reducing water transfer and thus delaying water loss (Maqbool et al., 2011).

Firmness

Fruit firmness significantly decreased from 4.28 to 1.37 N during shelf life (Table 1). Generally, Persian and wild sage gums significantly maintained fruit firmness at higher levels as compared with control (Table 2). After 9 days, firmer fruits with 1.86 and 1.69 N were found in treated fruits with 0.5 and 1.0% Persian gum.

The softening of flesh during storage could be due to the degradation of pectin compounds by the activity of different enzymes such as PG (Hossain et al. 2020). It has been reported that the softening of strawberry fruits is generally related to pectin solubilization, galactose and arabinose loss, xyloglucan depolymerization, and the activities of various cell wall degrading enzymes during ripening and postharvest conditions (Posé et al., 2011). Similar to our results, Saleem et al. (2021) reported a decline of fruit firmness in strawberry over time, but they announced that treating fruits with gum arabic and chitosan edible coatings maintained fruit firmness at higher levels. Lin et al. (2018) conclude that the application of paper containing 1-MCP edible coatings forms an obstacle on the fruit surface which restricts the O_2 supply and reduces the activities of cell wall degrading enzymes subsequently maintaining fruit membrane integrity.

Total Soluble Solids (TSS)

The results mentioned that TSS significantly increased from 6.23 %Brix at the harvest time to 7.60 %Brix at the end of shelf life time (Table 1). 'Camarosa' strawberry fruits treated with Persian and wild sage gums had lower TSS as compared with control fruits (Table 2).

After 9 days, control fruits had the highest TSS (9.06 %Brix) and fruits treated with Persian gum showed the lowest TSS with 6.82 and 6.89 %Brix at 0.5 and 1.0% concentrations, respectively.

Table 1. Effect of Persian (*Amygdalus scoparia*) and wild sage (*Salvia macrosiphon*) coatings on some traits of strawberry cv. 'Camarosa' during 9 days of shelf life

	Weight loss (%)	Firmness (N)	TSS (%Brix)	TA (%)	TSS/TA	Anthocyani (mg 100 g^{-1} FW)	Carotenoid (mg 100g^{-1} FW)	Protein (mg 100 g^{-1} FW)	Vitamin C (mg 100 g^{-1} FW)	Phenol (mg GAE 100g^{-1} FW)	Antioxidant (%DPPHsc)	SOD (U mg^{-1} protein)	CAT (U mg^{-1} protein)	PME (mmoll acid produced s^{-1})	PG (U mg^{-1} protein)
Time	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Treatment	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Time × Treatment	**	**	**	**	**	**	**	**	**	NS	**	**	**	**	**
Storage time (day)															
0 (at harvest)	0.00^{d}	4.28^{a}	6.23^{d}	8.11^{a}	0.74^{d}	50.40^{a}	0.91^{a}	0.25^{a}	84.33^{a}	22.60^{d}	53.66^{a}	4.58^{d}	2.67^{d}	0.17^{d}	1.11^{d}
3	1.37^{c}	3.47^{b}	7.13^{c}	7.82^{b}	0.91^{c}	50.14^{a}	0.69^{b}	0.20^{b}	68.53^{b}	32.33^{c}	47.60^{b}	8.67^{c}	6.80^{c}	8.91^{c}	6.50^{c}
6	2.70^{b}	2.21^{c}	7.30^{b}	7.51^{c}	0.97^{b}	42.27^{b}	0.65^{c}	0.11^{c}	59.67^{c}	42.27^{b}	41.07^{c}	15.13^{b}	9.39^{b}	11.86^{b}	10.57^{b}
9	3.54^{a}	1.37^{d}	7.60^{a}	7.17^{d}	1.07^{a}	32.33^{c}	0.53^{d}	0.06^{d}	54.53^{d}	50.13^{a}	34.73^{d}	20.93^{a}	13.48^{a}	14.99^{a}	15.30^{a}

Note: ** and NS indicate significant at $P < 0.01$ and non-significant; Means (n=3) with different letters denote significant differences ($P < 0.01$ level) according to Duncan's multiple range test

Table 2. Changes of some traits of strawberry cv. 'Camarosa' in response to Persian (*Amygdalus scoparia*) and wild sage (*Salvia macrosiphon*) coatings during 9 days of shelf life

Time	Treatment	Weight loss (%)	Firmness (N)	TSS (%Brix)	TA (%)	TSS/TA
At harvest						
3	Control	2.12^{a}	3.12^{c}	7.56^{a}	7.71^{a}	0.98^{a}
	Persian 0.5%	1.27^{b}	3.79^{a}	6.58^{c}	7.56^{a}	0.87^{cd}
	Persian 1.0%	1.13^{b}	3.80^{a}	6.70^{c}	7.91^{a}	0.84^{d}
	Wild sage 0.2%	1.19^{b}	3.19^{c}	7.48^{ab}	7.97^{a}	0.94^{ab}
	Wild sage 0.5%	1.15^{b}	3.44^{b}	7.31^{b}	7.95^{a}	0.91^{bc}
6	Control	3.03^{a}	2.09^{b}	7.96^{a}	7.41^{a}	1.07^{a}
	Persian 0.5%	2.34^{b}	2.26^{a}	6.72^{d}	7.43^{a}	0.91^{c}
	Persian 1.0%	2.36^{b}	2.23^{a}	6.82^{d}	7.76^{a}	0.88^{c}
	Wild sage 0.2%	2.83a^{b}	2.20^{a}	7.61^{b}	7.43^{a}	1.02^{ab}
	Wild sage 0.5%	2.94^{ab}	2.22^{a}	7.39^{c}	7.51^{a}	0.98^{b}
9	Control	4.63^{a}	1.10^{c}	9.06^{a}	6.38^{d}	1.42^{a}
	Persian 0.5%	3.12^{bc}	1.86^{a}	6.82^{d}	7.58^{a}	0.90^{c}
	Persian 1.0%	2.81^{c}	1.69^{a}	6.89^{d}	7.54^{ab}	0.91^{c}
	Wild sage 0.2%	3.29^{b}	1.03^{b}	7.71^{b}	7.16^{c}	1.08^{b}
	Wild sage 0.5%	3.65^{b}	1.02^{b}	7.50^{c}	7.21^{bc}	1.04^{b}

Note: For each traits and storage time means (n=3) followed with the same letters are not significantly different at $P < 0.01$ level according to Duncan's multiple range test. Slicing was performed based on the storage time

Generally, the TSS content of fruits is enhanced during storage time. The increasing TSS during storage time might be related to water losses, changes of polysaccharides and pectin materials into various sugars, destruction of starch, changes in juice content, enhancing of mono- and disaccharides amounts in response to degradation (Hossain et al. 2020). The use of edible treatment significantly delays senescence and degradation of starch. Due to delayed senescence and a lower extent of starch breakdown into sugars, TSS rises at a lowered level (Khaliq et al., 2015). Khaliq et al. (2015) and Anjum et al. (2020) reported similar results about the effect of gum Arabic coating in mango and strawberry fruits, respectively.

Titratable Acidity (TA)

According to Table 1, TA significantly reduced from 8.11 to 7.17% after 9 days. After 3 days and 6 days, no significant difference was obtained between treated and control fruits in terms of TA (Table 2). But, after 9 days Persian and wild sage treatments significantly prevented TA reduction and had higher TA than control fruits (Table 2). At the last stage, strawberry fruits coated with Persian gums had higher TA content (7.58 and 7.54%, respectively at 0.5 and 1.0% concentrations) as compared with wild sage treated fruits (7.16 and 7.21%, respectively at 0.2 and 0.0% concentrations).

TA reduction is attributed to the metabolism and respiration, so that the acidic compounds are consumed in various biochemical processes and changed to other nonacidic substances (Hossain et al. 2020). Similar to our results, Jokar et al., (2021) in pomegranate arils, Anjum et al. (2020), and Wani et al. (2021) in strawberry announced a reduction of TA content during storage time, but they stated that treated fruits with different edible coatings, maintained TA content at higher levels. Furthermore, the decrement of TA content might be attributed to the enzymatic activities in fruit juice (Vargas et al., 2006). In the meantime, edible coatings were capable of creating a modified atmosphere conditions around fruit skin and keep CO_2 at higher levels; consequently, they declined the loss of organic acids by a reduction in respiration and production of ethylene (Khaliq et al., 2019; Salehi, 2020).

Ripening Index (TSS/TA)

It was revealed that TSS/TA of 'Camarosa' strawberry fruits significantly increased from 0.77 to 1.07 during 9 days of shelf life (Table 1). According to changes of TSS and TA content, TSS/TA significantly reduced in response to Persian and wild sage treatments (Table 2). After 9 days fruits treated with Persian gums with 0.90 and 0.91 (respectively at 0.5 and 1.0% concentrations) had lower TSS/TA (Table 2).

The ratio between TSS and TA decides the overall acceptability of fruits. Many biochemical changes that change TSS/TA ratio take place during storage time and finally cause fruit unacceptable. Our findings indicate an enhancement in TSS/TA ratio during 9 days of shelf life, which was related to the increment of TSS content and decline of acidity of strawberry fruits. Therefore, the ongoing decline of acidity along with enhancement of TSS content enhanced TSS/TA ratio. A higher value of TSS/TA ratio (as ripening index) shows the high-level grade of fruit ripening. Gum treatments may inhibit starch hydrolysis and keep a higher TA content, so having a lower ripening index (Jiang et al., 2013). Additionally, our results are in accordance with Saleem et al. (2020), who mention that Arabic gum edible treatment delays ripening (kept lower TSS/TA) in persimmon fruits during storage.

Total Anthocyanin

As shown in Table 1, total anthocyanin content significantly increased from 50.40 to 32.33 mg 100 g^{-1} FW during 9 days of shelf life. It was observed that at the last stage of shelf life fruits treated with Persian and wild sage gums had higher total anthocyanin content as compared with control fruits (Table 3).

In strawberry fruit, red color (total anthocyanin) is one of the most important external quality attributes for consumers' acceptability. Total anthocyanin of all samples decreased during the shelf life time, which may be caused by oxidation reactions (Shirzad et al., 2021). One idea about the decline of total anthocyanin during storage might be associated with enhancing respiration level, declining of water content, changes of acidity and TSS content. Besides, according to the Bhatia et al. (2015) findings, pH and fruits structure have the main roles in preventing total anthocyanin changes (Bhatia et al., 2015).

Saleem et al. (2021) reported a decline of total anthocyanin content in strawberry, but they announced that treating fruits with ascorbic acid in chitosan-based edible coatings, maintained fruit total anthocyanin content at higher levels, which is in line with our findings. A change of fruit color may occur due to a change in oxygen level in the fruit surroundings. Covering fruits with edible coatings could alter their internal carbon dioxide and oxygen levels, which could result in a reduction in oxygen supply for the enzymatic oxidation of anthocyanins (Ghasemnezhad et al., 2013).

Total Carotenoid Content

A decrease in total carotenoid content of 'Camarosa' strawberry fruit was observed during shelf life, as total carotenoid content decreased from 0.91 to 0.53 mg 100 g^{-1} FW after 9 days (Table 1). Treated fruits with 0.5 and 1.0% Persian gum and also 0.2 and 0.5% wild sage significantly prevented total carotenoid reduction

Table 3. Changes of some traits of strawberry cv. 'Camarosa' in response to Persian (*Amygdalus scoparia*) and wild sage (*Salvia macrosiphon*) coatings during 9 days of shelf life

Time	Treatment	Anthocyanin (mg 100g^{-1} FW)	Carotenoid (mg 100g^{-1} FW)	Protein (mg 100g^{-1} FW)	Vitamin C (mg 100g^{-1} FW)	Antioxidant (%DPPHsc)
At harvest		50.40	0.91^{a}	0.25^{a}	84.33	53.66
3	Control	40.06^{c}	0.56^{c}	0.15^{c}	60.27^{c}	37.67^{c}
	Persian 0.5%	58.68^{a}	0.74^{ab}	0.20^{b}	71.02^{a}	53.15^{a}
	Persian 1.0%	51.67^{b}	0.73^{ab}	0.25^{a}	72.61^{a}	52.71^{a}
	Wild sage 0.2%	50.14^{b}	0.78^{a}	0.16^{c}	70.67^{ab}	48.60^{b}
	Wild sage 0.5%	50.33^{b}	0.65^{bc}	0.20^{b}	68.27^{b}	46.83^{b}
6	Control	32.33^{b}	0.56^{b}	0.07^{d}	50.03^{c}	28.14^{d}
	Persian 0.5%	44.06^{ab}	0.67^{a}	0.13^{b}	64.30^{a}	48.06^{a}
	Persian 1.0%	48.69^{a}	0.69^{a}	0.18^{a}	66.17^{a}	47.30^{a}
	Wild sage 0.2%	42.16^{ab}	0.74^{a}	0.11^{c}	60.00^{b}	41.65^{bc}
	Wild sage 0.5%	44.23^{ab}	0.62^{ab}	0.08^{d}	57.61^{b}	40.33^{c}
9	Control	14.05^{b}	0.60^{b}	0.03^{c}	39.25^{c}	19.07^{c}
	Persian 0.5%	38.35^{a}	0.72^{a}	0.09^{b}	60.39^{a}	41.68^{a}
	Persian 1.0%	40.17^{a}	0.73^{a}	0.11^{a}	61.32^{a}	41.40^{ab}
	Wild sage 0.2%	31.00^{a}	0.69^{a}	0.05^{c}	54.62^{b}	36.64^{ab}
	Wild sage 0.5%	38.31^{a}	0.77^{a}	0.04^{c}	52.06^{b}	35.06^{b}

Note: For each traits and storage time means (n=3) followed with the same letters are not significantly different at $P < 0.01$ level according to Duncan's multiple range test. Slicing was performed based on the storage time

and showed higher total carotenoid content at the last stage (Table 3).

A decrease in total carotenoid content might be due to degradations of carotenoids by oxidative enzymes during storage and senescence processes (Cristea et al., 2021). Edible coatings are effective in delaying the decrease in total carotenoid, possibly by interrupting the ripening-related metabolic functions (Saleem et al., 2020). Carotenoid content correlates with a color change and also higher content of carotenoids is regarded beneficial. Moreover, any treatment that can conserve higher carotenoids is also appropriate. Gums treatments play the main role in preventing the decrement of carotenoid content during storage time (Daisy et al., 2019). So, a higher amount of total carotenoid could be considered suitable regarding quality perspectives of guava fruits (Anjum et al., 2020).

Protein

During 9 days of shelf life protein content significantly decreased, from 0.25 (at harvest time) to 0.06 mg 100 g^{-1} FW (at the last stage) (Table 1). It was found that after 9 days fruits treated with Persian gums with 0.11 and 0.09 mg 100 g^{-1} FW (respectively at 1.0 and 0.5% concentrations) had higher protein content as compared with other treatments (Table 3).

Because mitochondria are a major source of intracellular reactive oxygen species (ROS) generation, mitochondrial proteins and various antioxidant proteins of fruits are prone to oxidative damages, especially under the adverse conditions that happen during fruit storage, and deteriorate protein amount and fruit quality attributes (Chen et al., 2021). Similar to our results Hasani and Yazdanpanah (2020) mentioned that protein content of apple fruits significantly increased with the addition of gum Cordia concentration. They reported that this increment might be due to the protein content of gum.

Vitamin C

A decreasing trend was found in vitamin C content of 'Camarosa' strawberry fruits during shelf life time, as vitamin C content decreased from 84.33 to 54.53 mg 100 g^{-1} FW after 9 days (Table 1). Fruits treated with Persian wild sage gums significantly prevented vitamin C reduction over the whole storage time, as after 9 days of shelf life treated fruits with 1.0 and 0.5% Persian gum showed the maximum vitamin C level (61.32 and 60.39 mg 100 g^{-1} FW, respectively) as compared with others (Table 3).

Vitamin C (ascorbic acid) is very sensitive to degradation due to its oxidation as compared to other nutrients during storage time. As previously mentioned by Ishaq et al. (2009), change of ascorbic acid levels during storage time is associated with the oxidation of ascorbic acid to dehydroascorbic acid further degraded to 2,3-diketo-gluconic acid by the activity of different oxidation enzymes such as ascorbic acid oxidase (Shiri et al., 2016b; Akhtar et al., 2010). Reduction in vitamin C loss in coated strawberry fruits could be due to low oxygen permeability of gum treatments, which decreases the enzyme activity and therefore inhibits ascorbic acid oxidation (Atress et al., 2010). Our findings are in accordance with the results of Wani et al. (2021) and Saleem et al. (2021) and Anjum et al. (2020), who concluded that edible coating treatments maintained higher vitamin c levels in strawberry and guava fruits than control.

Total Phenolic Content

It was observed that total phenolic content was significantly affected just by the main effect of storage time and edible coating treatments (Table 1). The total phenolic content significantly increased from 22.60 mg GAE 100 g^{-1} FW at the harvest time to 50.13 mg GAE 100 g^{-1} FW after 9 days. All Persian and wild sage treatments had higher total phenolic content as compared with control, and fruits treated with Persian gum had the highest (44.25 and 41.17 mg GAE 100 g^{-1} FW, respectively at 1.0 and 0.5% concentrations) total phenolic content (Fig. 1).

An increment in phenolic compounds could be due to ethylene action. It has been confirmed that ethylene mainly enhances the activity of phenylalanine ammonium lyase (PAL) as the main enzyme in polyphenol biosynthesis, which leads to the formation of polyphenols (Matthes and Schmitz-Eiberger, 2009).

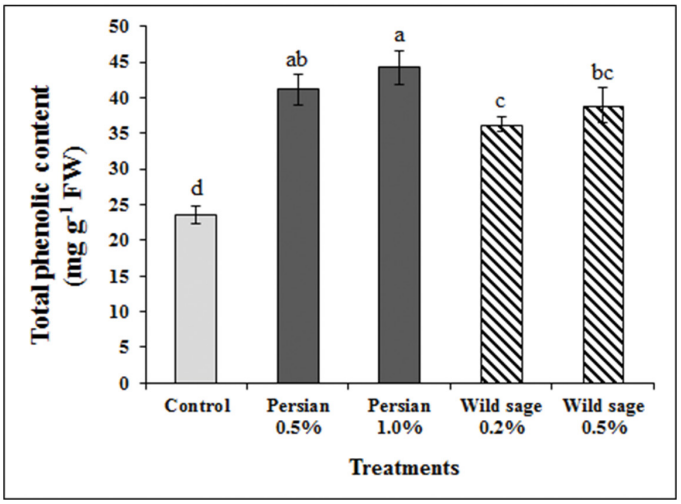

Figure 1. Effect of Persian (*Amygdalus scoparia*) and wild sage (*Salvia macrosiphon*) coatings on total phenolic content of strawberry cv. Camarosa during shelf life. The values are the means (n = 3) ± standard error. Different letters indicate significant differences at $P < 0.01$ according to Duncan's multiple range test.

The increment effect of edible coatings on total phenolic content is perhaps related to the semi-permeable barrier properties of coatings which restrict CO_2 and O_2 exchange, prevent water loss, and reduce ripening processes by altering the endogenous gases content and ethylene generation (Wani et al., 2021). The findings of this experiment are in agreement with the results of Khaliq et al. (2019), Anjum et al. (2020), and Wani et al. (2021), who mentioned that total phenolic content was higher in treated fruits with edible coatings.

Total Antioxidant Activity

During the shelf life of 'Camarosa' strawberry fruits, a decrease in total antioxidant activity was observed, as total antioxidant activity significantly decreased from 53.66 to 34.73% DPPHsc after 9-days (Table 1). As compared with control fruits, fruits treated with Persian and wild sage gums maintained total antioxidant activity at higher levels (Table 3).

It was mentioned that the antioxidant content of fruits or vegetables decreased during postharvest storage. The generation of ROS during these conditions depletes antioxidant compounds through a plethora of reduction-oxidation reactions (Ali et al., 2018). Similar to our results, Saleem et al. (2021) and Wani et al. (2021) reported a decrease of total antioxidant activity in strawberry fruits during storage time, but they found that coating the fruits with edible coatings maintained total antioxidant activity content at higher levels. This could be due to coatings that form a film around the fruit surface thus demoting the O_2 supply necessary for enzymatic oxidation of phenolics, hence retained DDPH activity (Khaliq et al., 2016). Furthermore, Wang and Gao (2013) indicated that edible coating caused higher DPPH radical scavenging activity in strawberry fruits. This could considerably better protect vitamin C and carotenoid content and delay senescence (Saleem et al., 2020).

Antioxidant Enzymes

As shown in Table 1, SOD and CAT activities significantly enhanced during 9 days of shelf life (Table 1). It was found that as compared with control fruits, fruits treated with Persian and wild sage gums showed higher SOD, especially after 9 days (Fig. 2). Among gum treatments, Persian gum was more effective as compared with wild sage gum in terms of SOD activities. Since fruits treated with Persian gum showed higher CAT activity over the whole shelf life time, fruits treated with wild sage gum had no significant difference compared with control fruits in terms of CAT activity (Fig. 3).

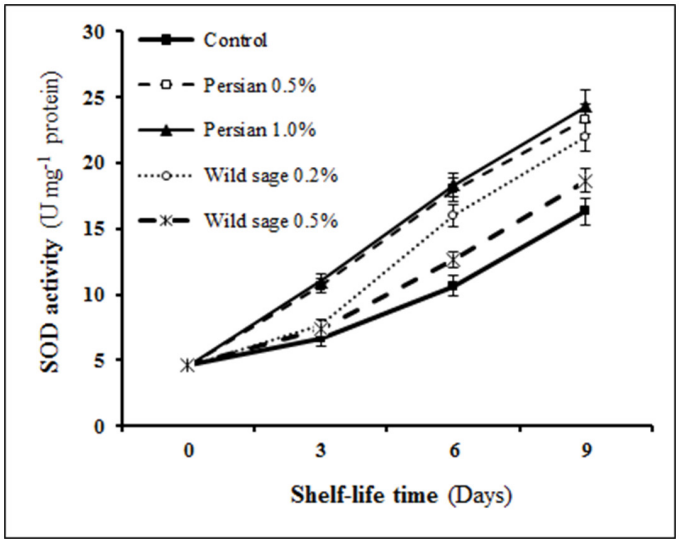

Figure 2. Effect of Persian (*Amygdalus scoparia*) and wild sage (*Salvia macrosiphon*) coatings on SOD activity of strawberry cv. Camarosa during shelf life. The values are the means (n = 3) ± standard error. Different letters indicate significant differences at $P < 0.01$ level according to Duncan's multiple range test.

Saleem et al. (2021) reported that in strawberry fruits the activity of antioxidant enzymes changed during storage time and coated fruits with edible coatings significantly showed higher activity of antioxidant enzymes. After fruit harvesting and during cell senescence, oxidative stress starts and causes the production of ROS which gives rise to oxidative damages to the fruit tissues (Ali et al., 2021). Cells have self-protective tools by the activity of various antioxidant enzymes such as SOD and CAT as these enzymes detoxify different types of ROS, so the activities of some antioxidant enzymes are enhanced during storage time (Guo et al., 2018).

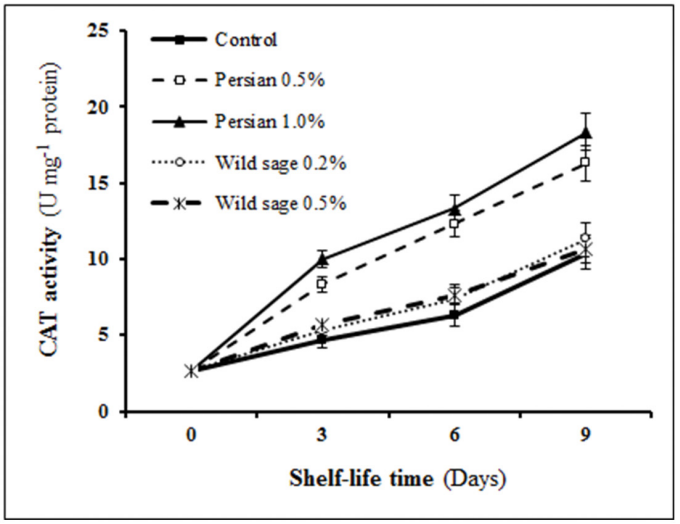

Figure 3. Effect of Persian (*Amygdalus scoparia*) and wild sage (*Salvia macrosiphon*) coatings on CAT activity of strawberry cv. Camarosa during shelf life. The values are the means (n = 3) ± standard error. Different letters indicate significant differences at $P < 0.01$ according to Duncan's multiple range test.

Cell Wall Degrading Enzymes

The results mentioned that PME and PG activities of 'Camarosa' strawberry fruit significantly increased, which caused a decrease in fruit tissue firmness (Table 1). All Persian and wild sage treatments significantly prevented the enhancement of PME and PG activities and maintained fruit firmness at higher levels (Fig. 4 and 5). Among gum treatments, Persian gum was more effective to decrease the activity of cell wall degrading enzymes as compared with wild sage gum.

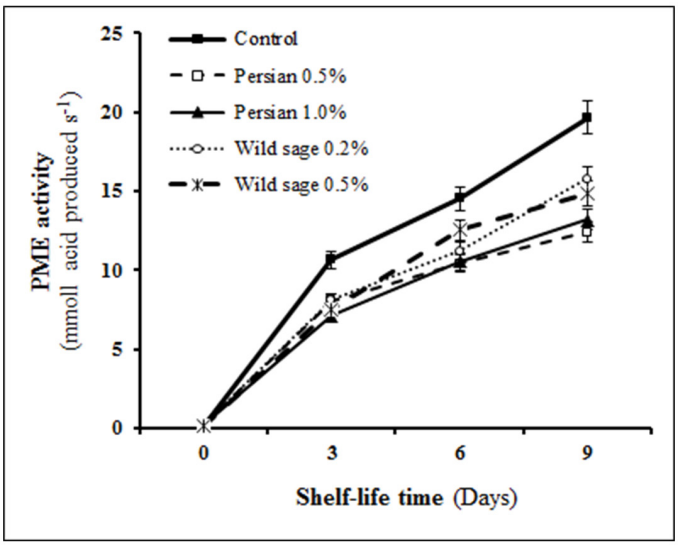

Figure 4. Effect of Persian (*Amygdalus scoparia*) and wild sage (*Salvia macrosiphon*) coatings on PME activity of strawberry cv. Camarosa during shelf life. The values are the means (n = 3) ± standard error. Different letters indicate significant differences at $P < 0.01$ according to Duncan's multiple range test.

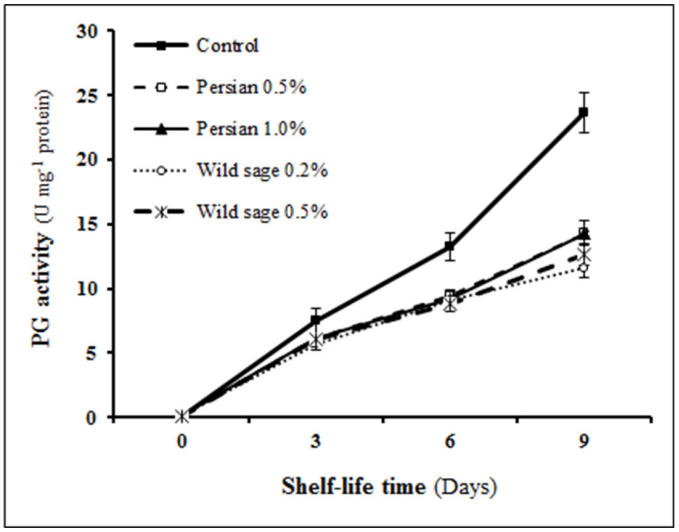

Figure 5. Effect of Persian (*Amygdalus scoparia*) and wild sage (*Salvia macrosiphon*) coatings on PG activity of strawberry cv. Camarosa during shelf life. The values are the means (n = 3) ± standard error. Different letters indicate significant differences at $P < 0.01$ according to Duncan's multiple range test.

Fruit softening occurs due to an increase in the cell wall degradation process catalyzed by different enzymes such as PG, PME, and cellulase (Lin et al., 2018; Singh et al., 2019). Mainly, depolymerization of pectin by the activity of PG and PME enzymes contributes to cell wall degradation and fruit softening during ripening and senescence. Hence, fruit softening is probably prevented if the activity of PG, PME and cellulase enzymes is stopped (Zhao et al., 2019). This could be achieved by applying edible coatings which limit the gases exchange between a fruit and its micro-climate, therefore decreasing the activities of degrading enzymes (Maftoonazad et al., 2008).

Similar to our results, Saleem et al. (2021) in strawberry and Saleem et al. (2020) in persimmon reported an increase in PG and PME activity during storage time, but they announced that treating fruits with ascorbic acid in chitosan-based and gum arabic edible coatings significantly reduced enzymes activity. The inhibition in PG activity by edible coatings is perhaps related to that biopolymer treatment such as gums binding with pectin compositions and subsequently significantly inhibiting the activity of pectinolytic enzymes (PG) to the cell wall structure (Wani et al., 2021). Furthermore, reduce of PME activity in response to edible coatings might be due to the fact that these treatments perhaps have concealed the activity of cell wall degradation enzymes such as PME (Wani et al., 2021). Overall, the results of this study support the assumption that lower enzymatic activities of PME and PG in treated fruits with gums cause higher maintenance of fruit tissue firmness during storage time.

Conclusion

Persian and wild sage gums effectively maintained firmness, bioactive compounds (TA, total anthocyanin, total carotenoid, total phenolic content, and total antioxidant activity), and the activity of antioxidant enzymes (SOD and CAT) of strawberry fruit. Gum-based edible coating mainly prevented the activity of cell wall degrading enzymes (PME and PG) involved in fruit softening and ripening processes. Our findings could be valuable to understand how the storage time influences the quality traits of gum-treated and untreated 'Camarosa' strawberry fruits during shelf life.

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