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Chitosan Coating to Preserve the Qualitative Traits and Improve Antioxidant System in Fresh Figs (*Ficus carica* L.)

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Abstract: Chitosan-based coatings are used as a postharvest treatment to extend the shelf-life of several fruits. In this study, the effectiveness of chitosan-based coating to preserve the physico-chemical (weight loss, soluble solid content, and titratable acidity) and nutraceutical traits (total polyphenol, anthocyanin, flavonoid, ascorbic acid content, antioxidant capacity) in fresh fig "Troiano" has been evaluated. Furthermore, antioxidant enzyme activities, such as catalase (CAT) and ascorbate peroxidase (APX), were evaluated as well as the enzymes activities involved in fruit browning (polyphenol oxidase (PPO), guaiacol peroxidase (GPX)). Fruits were treated with 1% chitosan and 1% ascorbic acid coating, stored at 4 °C for nine days, and sampled every three days. Chitosan-based coating significantly reduced the weight loss and the qualitative changes, improving the total polyphenol, anthocyanin, and flavonoid contents and the antioxidant activity in stored figs. The higher activity of antioxidant enzymes allowed to reduce oxidative stress and prevent the browning reactions in chitosan-coated figs. The principal component analysis allowed to distinguish different behaviors among uncoated and chitosan-coated figs, indicating that the combined effects of chitosan-based treatment and storage time influenced the physico-chemical, nutraceutical and antioxidant system of figs during storage.

Keywords: postharvest; fig; chitosan-based coating; nutraceutical compounds; antioxidant enzyme; principal component analysis

1. Introduction

Fig (*Ficus carica* L.) belongs to the *Moraceae* family and it is one of the earliest cultivated fruit trees in the world, being the first domesticated one [1–3]. Nowadays, the fig tree is cultivated in most warm and temperate Mediterranean climates with fifty percent of the world's fig production concentrated in the Mediterranean area [4]. Fresh and dried figs are consumed and appreciated worldwide not only for their unique taste and distinct flavor, but also for their health benefits [5]. In the global world market, consumer demand increases for fresh figs but is stable for dried ones [6]. The short postharvest life of fresh fruits is a critical point for the marketability in respect to dried fruits. However, most dried fruit producers must compete with lower production costs of other countries [7].

Fresh figs harvested between commercial and tree ripe maturity, show the optimal qualitative, nutraceutical and sensorial traits but they are highly perishable fruits being susceptible to postharvest deterioration, such as softening, bruising, splitting, and pathogens growth [8–11].

Postharvest life of fresh figs can be extended by different techniques, such as cold storage, modified atmosphere enriched CO_2, and edible coatings [12–16]. However, refrigeration on its own is not

enough to preserve fresh fig quality at optimum levels during postharvest life, consequently, as in the case of other fruits, innovative technologies are needed. Edible coatings on fresh products can be a valid alternative to other storage techniques by reducing physico-chemical and nutritional changes from "field to table" [17]. In recent years, there has been a growing interest in using bio-based materials in edible coatings to preserve the quality of fresh fruits during postharvest life [18,19]. Chitosan is a polycationic linear polysaccharide with high molecular weight extracted from natural sources, such as the outer shell of crustaceous, cell walls of microorganisms, and fungi [20]. Normally, chitosan is a derivate of chitin, the second most abundant natural polymer after cellulose. Chitosan-based coatings create a safe barrier and a micro-modified atmosphere around the fruits that slow down water loss, gas exchanges, microbial growth, qualitative loss and enzymatic browning [21–23].

Several studies have demonstrated that chitosan-based edible coatings can be valid and innovative methods for improvement of quality and postharvest life of different commodities [20]. The effectiveness of chitosan coating may vary depending on the features of coating, fruit species, fruit ripening, and storage conditions [22].

Ascorbic acid (AsA), is an important organic acid, which plays a role in human health and it can be obtained from plant-based foods. AsA is an anti-browning compound that acts on several metabolic pathways delaying the enzymatic browning [24].

The application of organic acid and chitosan, as edible coatings, to extend the fruit shelf life was described in few published papers [25–27].

To expand the knowledge of chitosan as a fig-coating compound, the influence of the combined effect of chitosan coating and AsA on qualitative traits, bioactive compounds, such as total phenols, anthocyanins, flavonoids, and ascorbic acid content, and the antioxidant capacity in fig fruits during cold storage were investigated. Furthermore, in this study, the effect of the chitosan-based coating postharvest treatment on the antioxidant system during fig storage was also evaluated.

2. Materials and Methods

2.1. Fruit Samples and Experimental Design

Fig fruits cv. "Troiano" were harvested at ripening stage in middle-September in a commercial orchard located at Puccianiello (Caserta-Italy) from ten trees. Fruits were transported to the laboratory of CREA-OFA (Council for Agricultural Research and Economics (CREA)—Research Centre for Olive, Citrus and Tree Fruit, Via Torrino 3, 81100 Caserta, Italy), selected for the absence of defects and uniformity of color and size and randomly distributed into two groups.

Chitosan (Iko Hydro, Rutigliano, Italy) solution (1% w/v) was prepared using chitosan with 90% deacetylation and a molecular weight of 360 kDa, as described by Petriccione et al. [21], adding extra virgin olive oil as plasticizer at 2% (v/v), as reported by Dovale-Rosabal et al. [28] and ascorbic acid 1% (w/v). Fig fruits were dipped for 60 s in the chitosan-based solution and dried at 25 °C for 1 h and stored in a controlled chamber at 4 °C and 95% relative humidity for nine days, while untreated fruits were dipped in distilled water. The chosen storage time, adopted in this study, emerged from our preliminary analysis and literature data by Allegra et al. [16].

Three biological replicates containing ten fruits for each one were prepared per sampling date (zero, three, six and nine days) and treatment. Non-destructive analyses were carried out on each biological replicate, while destructive analyses were performed on two separate pools of 15 fruits for three biological replicates.

2.2. Physico-Chemical Traits

The weight of figs was determined by analytical balance (mod. Gibertini E42, Milano, Italy) at the beginning of the experiment and every three days during cold storage. Using these values, the weight loss (%) was calculated as follows:

$$\text{Weight loss (\%)} = [(W_0 - W_t)/W_0] \times 100 \quad (1)$$

where W_0 is the initial weight (g) and W_t is the weight (g) at sampling day of the figs.

In order, to measure the color changes of all samples, in coated and uncoated figs during cold storage, CIE-Lab L*, a*, and b* color coordinates were recorded. The color measurements were performed on fruits using a CR-200 chromometer (Minolta, Japan), with an aperture size of 10 mm.

The lightness value (L*) indicates the darkness/lightness of the sample, a* is a measure of the greenness/redness of the sample and b* is the extent of blueness/yellowness.

Total titratable acidity (g of citric acid/100 g fresh weight (FW)) (TA) was determined by an alkaline solution (0.1 M sodium hydroxide) to the end point at pH 8.1 [29]. Total soluble solids (TSS; °Brix) were evaluated by a hand refractometer (Model N-10; Atago, Tokyo, Japan). All analyses were obtained in triplicate for each sample.

2.3. Bioactive Compounds and Antioxidant Activity

Bioactive compounds were extracted as described by Caliskan and Polat [30]. Total phenol content (POL) was determined using the colorimetric Folin–Ciocalteu method [31] and expressed as milligrams of gallic acid equivalents (GAE) per 100 g fresh weight (FW). Total flavonoid content (FLAV) was determined by the aluminum chloride colorimetric method [32] and expressed as milligrams of catechin equivalent (CE) per 100 g fresh weight (FW).

The free radical scavenging activity was measured by 1,1-diphenyl-2-picryl-hydrazil (DPPH) according to the method described by Adiletta et al. [18] and expressed in μmol Trolox equivalent (TE) per gram fresh weight (FW).

The ascorbic acid content (AsA) was determined following the method described by Petriccione et al. [33] and expressed as mg ascorbic acid (AsA) per 100 g fresh weight (FW).

2.4. Enzymes Activity

Fresh fig fruits (2.5 g) were homogenized in 10 mL of sodium phosphate buffer (200 mM pH 6.5) containing 4% (w/v) polyvinylpolypyrrolidone (PVPP) and centrifuged at 18,000× *g* for 30 min at 4 °C. Supernatant was used for catalase (CAT; EC 1.11.1.6), ascorbate peroxidase (APX; EC 1.11.1.11) and guaiacol peroxidase (GPX; EC 1.11.1.7). Total protein content was determined using Bradford assay [34], and bovine serum albumin was used as standard.

The CAT activity was assayed according to the method described by Pasquariello et al. [35] using 200 μL of crude enzyme extract in a final reaction volume of 1.5 mL, and the activity was expressed as μmol H_2O_2 per min per mg proteins.

APX activity was estimated by the method of Petriccione et al. [36] recording the decrease in optical density due to ascorbic acid at 290 nm. The reaction mixture contained 100 μL of crude enzyme extract in a final reaction volume of 1.5 mL, and the activity was expressed as μmol per min per mg proteins.

GPX activity was determined according to Petriccione et al. [36], monitoring the formation of tetraguaiacol at 470 nm. The GPX activity was expressed as μmol per min per mg proteins.

Polyphenoloxidase (PPO) activity was determined following the method described by Adiletta et al. [18] with some modifications. A total of 2 g of whole fruit was homogenized in 5 mL of 200 mM sodium phosphate buffer (pH 6.5) containing 5% (w/w) PVPP. The homogenate was centrifuged at 12,500 × g for 10 min at 4 °C and was used for PPO activity determination. The specific activity was expressed as μmol catechol per min per mg proteins.

2.5. Statistical Analysis

All data are expressed as the mean ± standard deviation (S.D). Statistical differences between uncoated and coated fruits were determined by ANOVA and Duncan's test. Differences were considered

significant at $p < 0.05$ and are indicated with different letters. Principal components analysis (PCA) was used to identify the principal components contributing to most of the variations within the dataset, evaluating the physico-chemical, nutraceutical, and enzymatic changes during storage in uncoated and coated figs. All analyses were carried out using the SPSS software package, version 20.0 (SPSS Inc., Chicago, IL, USA).

3. Results and Discussion

3.1. Effect of Chitosan Treatment on Weight Loss and Firmness

Chitosan coating reduced the changes of the most important quality parameters involved in the fig acceptability by consumers. Weight loss increased significantly throughout cold storage, but chitosan-coating treatment significantly delayed the fruit weight loss compared to control (Table 1). The higher weight loss values were registered after nine days of cold storage in uncoated fruits, reaching 22.2% at the end of cold storage.

Weight loss in fruits and vegetables is mainly due to the water loss caused by transpiration and respiration processes [37]. These processes are strongly influenced by the gas exchanges and by the gradient of water vapor pressure between the fruit and the surrounding air [38]. Chitosan coating forms a thin and transparent layer on the fig skin surface that contributes to slowing down the dehydration process, responsible for the fruit weight loss. Our results are in agreement with previous studies that demonstrated that chitosan coating retarded fruit weight loss in different fruit crops, such as strawberry, sweet cherry, loquat, and plum [22,39]. Alginate-chitosan bilayer coating had a significant effect on the weight loss of fresh figs since weight loss for coated and uncoated figs reached up to 5–7% and 18%, respectively [15]. A lower weight loss percentage was also registered in "Dottato" figs coated with *Opuntia ficus-indica* (L.) Mill. mucilage [16]. Furthermore, other postharvest treatments based on natural antimicrobial compounds, such as defatted soybean meal extract, combined with macro- or microperforated films slowed down the weight loss in "Cuello Dama Blanco" and "Cuella Dama Negro" fig cultivars during 14 days of cold storage at 0 °C [17]. As reported by Dollahite et al. [40], the weight loss in fresh fig can be reduced by maintaining the cooling chain after fruit harvest in the field.

Regarding TSS increase during the ripening process, several studies reported that fructose and galactose were the main sugars in fig fruits, followed by glucose, while sucrose was present in trace amounts [30,41]. The low content of sucrose could be the result of the anabolic process and respiration during fruit development and, consequently, of a high invertase activity during fruit ripening [42]. The sugar composition can influence the sweetness that is an important indicator of fruit quality and it is highly correlated to the ripeness in most fruits. Fig accessions showed different total sugar content [42] and their perception of sweetness can be linked to their fructose content [30]. The TSS values increased during storage in coated and uncoated fruits with higher values in uncoated ones (Table 1). As reported in other studies, the slowdown of the ripening process in chitosan-coated fruits was accompanied by reprogramming of carbon metabolism that controls the sugar levels during storage [43,44]. Our results were confirmed by other studies that reported the effects of chitosan-based postharvest treatments on different commodities, such as mango, banana, papaya, and guava [45,46].

Organic acids are important nutrients in figs, and they contribute, with sugars, to the nutritional quality of this fruit for a healthy diet. Citric acid is the main organic acid found in figs followed by malic acid [47]. TA significantly decreased with increasing storage time with higher values in uncoated fruits compared with coated ones (Table 1). The higher acidity loss in uncoated fruits could be due to the use of organic acids as substrates for respiratory metabolism [48,49]. The lower acidity loss in chitosan-coated fruits during storage was also reported by other studies on strawberry, sweet cherry, loquat, peach, tomato, guava, and litchi suggesting that chitosan treatment has an important role in delaying fruit ripening [35,46,50–54]. As suggested by Irfan et al. [55] and Marpudi et al. [56], a TA decrease and TSS increase occurred during the ripening process, and the highest TSS and the lowest

TA values in uncoated fruits were probably due to moisture loss during cold storage. Chitosan-coated fruits exhibited a slight increase in the TSS/TA ratio during cold storage due to a slowdown in ripening and senescence processes induced by chitosan treatment.

Color is an important qualitative trait in the fruit, and it influences consumer's choice and preference [57]. Lightness was improved by chitosan treatment and delayed the decrease during cold storage. The fig skin color exhibited an increase of a* value during storage, while the b* values decreased with the same trend in both coated and uncoated fruits. These results denoted a faster ripening in uncoated fruits stored at day nine. Similar results were obtained by Reyes-Avalos et al. [15] in alginate–chitosan coated figs with higher lightness and chroma values in treated fruits throughout the storage period. Furthermore, AsA controlled the color changes due to enzymatic browning, in coated figs, as previously reported by Liu et al. [27].

Table 1. Weight loss (WL; %), total soluble solid content (TSS; °Brix), titratable acidity (TA; g of citric acid /100g FW), ratio TSS/TA and colorimetric parameters (L*, a*, b*), in treated (chitosan 1% and ascorbic acid 1.5%; T) and untreated fruits (C) during nine days of cold storage at 4 °C.

Samples	Days	WL	TSS	TA	TSS/TA	L*	a*	b*
C	0	-	14.87 ± 0.21 ^{a}	5.67 ± 0.20 ^{e}	2.63 ± 0.13 ^{a}	61.49 ± 5.83 ^{bc}	−6.78 ± 3.10 ^{c}	44.71 ± 1.41 ^{ab}
	3	7.82 ± 0.70 ^{b}	16.20 ± 0.43 ^{bc}	4.56 ± 0.26 ^{c}	3.56 ± 0.26 ^{c}	58.17 ± 2.42 ^{ab}	−6.06 ± 1.57 ^{c}	44.50 ± 0.35 ^{ab}
	6	14.74 ± 1.04 ^{d}	16.90 ± 0.43 ^{c}	3.91 ± 0.12 ^{b}	4.32 ± 0.23 ^{d}	54.50 ± 4.80 ^{a}	−3.82 ± 1.85 ^{b}	43.85 ± 1.39 ^{ab}
	9	22.23 ± 0.21 ^{e}	18.17 ± 0.25 ^{d}	2.94 ± 0.06 ^{a}	6.18 ± 0.22 ^{e}	52.54 ± 3.86 ^{a}	−2.41 ± 3.27 ^{a}	40.69 ± 2.15 ^{a}
T	0	-	14.77 ± 0.32 ^{a}	5.59 ± 0.16 ^{e}	2.64 ± 0.08 ^{a}	68.11 ± 7.15 ^{d}	−6.99 ± 2.54 ^{c}	45.13 ± 1.22 ^{b}
	3	4.02 ± 0.13 ^{a}	15.07 ± 0.25 ^{a}	5.02 ± 0.08 ^{d}	3.00 ± 0.08 ^{ab}	64.92 ± 0.91 ^{cd}	−6.06 ± 1.59 ^{c}	44.67 ± 0.35 ^{ab}
	6	6.6 ± 50.97 ^{b}	15.20 ± 0.26 ^{a}	4.45 ± 0.30 ^{c}	3.42 ± 0.21 ^{bc}	56.01 ± 3.35 ^{ab}	−5.48 ± 2.08 ^{bc}	43.86 ± 1.56 ^{ab}
	9	12.30 ± 1.67 ^{c}	16.03 ± 0.57 ^{b}	3.57 ± 0.32 ^{b}	4.52 ± 0.51 ^{d}	55.26 ± 3.98 ^{ab}	−4.25 ± 5.28 ^{b}	40.56 ± 3.06 ^{a}

Means followed by the same letter in the same column do not differ significantly at $p = 0.05$ (Duncan's test).

3.2. Bioactive Compounds

Figs treated with chitosan maintained better nutraceutical quality with higher levels of bioactive compounds. Total phenolic and flavonoid contents of chitosan-coated figs during cold storage were higher compared to uncoated ones (Table 2). Phenolic compounds are ubiquitously distributed in fruits and vegetables, known as health-supporting compounds [58]. In fresh fig fruits, phenols are concentrated almost exclusively in the peel compared to the pulp with content strongly dependent on the fig cultivars and genotypes [10,59]. Several studies have demonstrated a higher level of polyphenols, anthocyanins, and flavonoids in black-skin cultivars compared to fig varieties with lighter skin [2,59]. Postharvest treatments can highly influence the phenol content and nutraceutical composition of fig fruits [10,59].

The application of chitosan coating delayed the decrease in ascorbic acid content in fresh fig fruits during cold storage (Table 2). Genotypes with green and purple skin contained different ascorbic acid content, as demonstrated by Veberic et al. [42]. Chitosan treatment delayed the decrease of ascorbic acid content during storage due to its barrier properties to oxygen permeability, which caused a lowering of the enzyme activity and prevented the oxidation of ascorbic acid [60].

Moreover, chitosan-coated figs also maintained a higher antioxidant capacity than uncoated ones during nine days of cold storage (Table 2). Total antioxidant capacity of fig fruits is variable in cultivar-dependent manner. Dark-skin genotypes showed a higher antioxidant capacity due to a greater concentration of phenols and a positive correlation between these nutraceutical traits has also been confirmed [30,61].

Table 2. Polyphenol (POL; mg GAE/100 g FW), flavonoid (FLAV; mg CE/100 g FW), ascorbic acid content (AsA; mg /100 g FW) and antioxidant activity (DPPH method; µmol TE/g FW) in coated (chitosan 1% and ascorbic acid 1.5%; T) and uncoated fruits (C) during nine days of cold storage at 4 °C.

Samples	Days	POL	FLAV	AsA	Antioxidant Activity
C	0	47.95 ± 0.83 ^{f}	23.25 ± 0.33 ^{de}	16.14 ± 0.84 ^{de}	8.71 ± 0.13 ^{de}
	3	40.61 ± 2.36 ^{c}	19.73 ± 0.40 ^{b}	15.20 ± 0.26 ^{cd}	7.67 ± 0.28 ^{c}
	6	37.46 ± 0.74 ^{b}	18.41 ± 0.6 ^{b}	12.10 ± 0.33 ^{b}	6.24 ± 0.27 ^{b}
	9	30.94 ± 1.10 ^{a}	15.41 ± 0.77 ^{a}	10.75 ± 0.63 ^{a}	5.67 ± 0.36 ^{a}
T	0	47.72 ± 0.98 ^{ef}	24.52 ± 1.36 ^{e}	16.63 ± 0.74 ^{e}	8,98 ± 0.13 ^{e}
	3	45.35 ± 0.73 ^{de}	22.39 ± 0.27 ^{cd}	16.00 ± 0.10 ^{de}	8.78 ± 0.09 ^{de}
	6	44.23 ± 0.90 ^{d}	22.02 ± 0.63 ^{cd}	14.57 ± 0.29 ^{c}	8.33 ± 0.48 ^{d}
	9	38.70 ± 1.47 ^{bc}	21.42 ± 1.17 ^{c}	13.18 ± 1.24 ^{b}	7.49 ± 0.27 ^{c}

Means followed by the same letter in the same column do not differ significantly at $p = 0.05$ (Duncan's test).

3.3. Effect of Chitosan-Based Coating on Antioxidant Enzymes and Enzymatic Browning

Antioxidant enzymes protect fruit cells from oxidative stress due to imbalance in reactive oxygen species (ROS) production and scavenging. During fruits' postharvest life, high intracellular levels of ROS can damage cell membranes and other biomolecules causing cell damage [62].

CAT and APX involved in controlling the level of H_2O_2 showed different trends in uncoated and coated figs (Figure 1a,b). CAT and APX are both involved in the decomposition of hydrogen peroxide to water and oxygen, with different reaction kinetics. During cold storage, H_2O_2 overproduction could be caused by an increase in APX activity that shows a high affinity for this substrate compared to CAT activity [63].

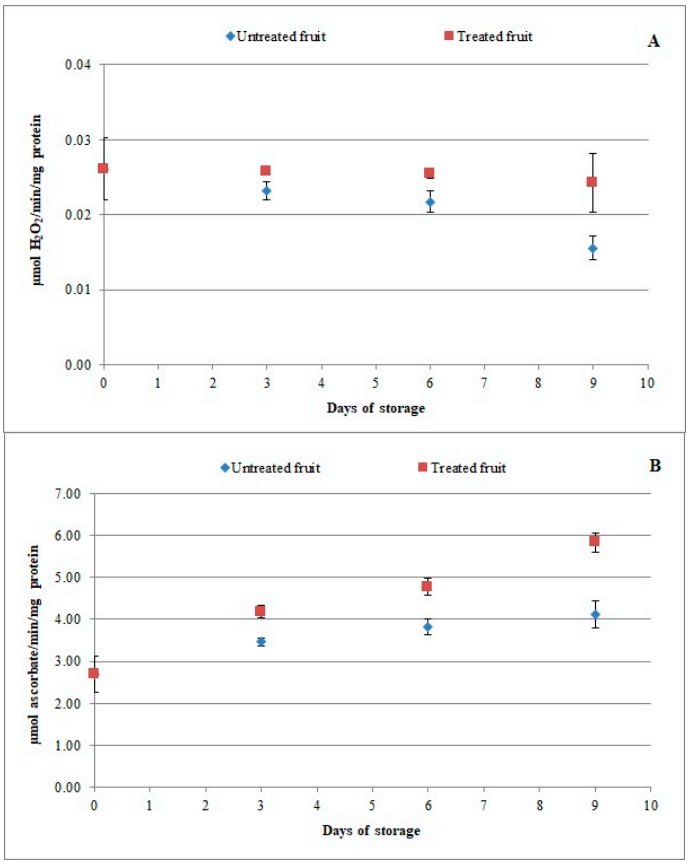

Figure 1. Activity of catalase (CAT) (**A**), ascorbate peroxidase (APX) (**B**) in uncoated (untreated) and chitosan-based coated figs (treated fruits) at harvest (0) and after three, six and nine days of cold storage at 4 °C. Error bars indicate standard deviation.

The CAT activity significantly decreased in uncoated fruits while showed a stable trend toward storage in coated fruits. APX activity significantly increased, in chitosan-coated fruits compared to the uncoated ones, during cold storage. These findings are in agreement with previous studies that showed that chitosan coating improved the activity of antioxidant enzymes in different fruit crops [18,20,36,37].

Enzymatic browning, that occurs during cold storage, is mainly due to PPO and GPX activities that catalyze the reactions responsible for this symptom. An increase in GPX and PPO activities was registered during cold storage in figs, with higher values in uncoated samples (Figure 2a,b). Chitosan coating induced a significant ($p < 0.05$) delay in PPO and GPX activities, as demonstrated by previous studies [18,36,37]. The combined coating treatment between citric acid or ascorbic acid and chitosan delayed the PPO activity in cherimoya and plum fruits stored at 15 °C for 10 days and at 5 °C for 20 days, respectively [26,27]. Furthermore, a significantly lower PPO activity and a higher polyphenol content in chitosan-coated fruits are due to a separation of PPO enzyme from its phenolic substrates [18,21,37,54]. In wine grape partial dehydration, chitosan coating inhibited PPO activity and reduced the berry browning [36].

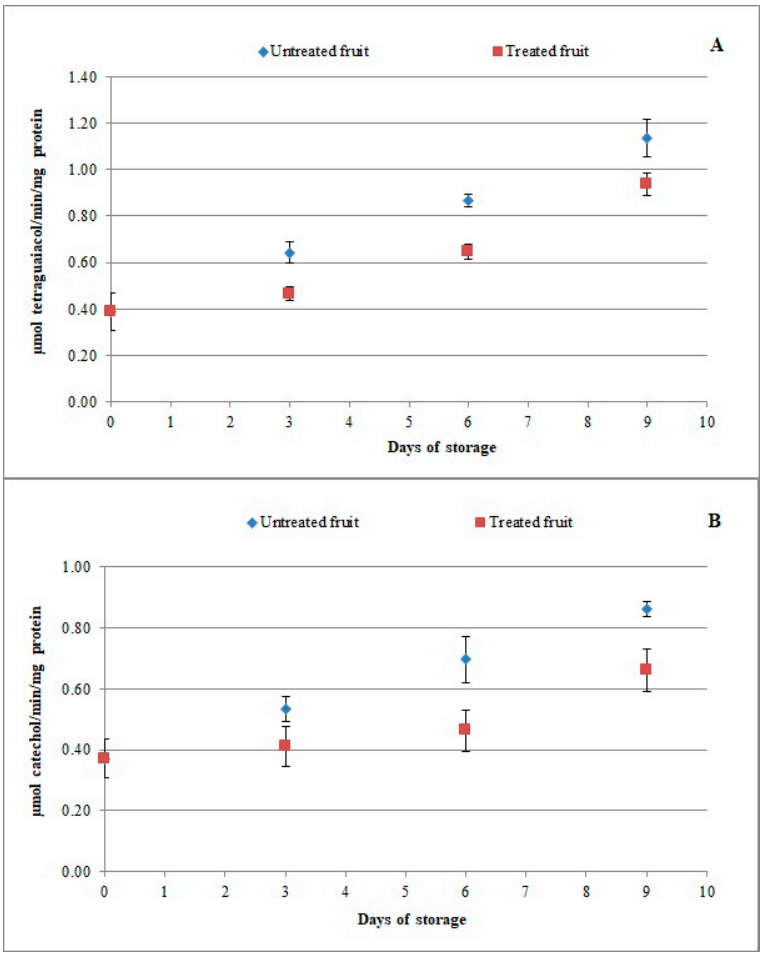

Figure 2. Activity of guaiacol peroxidase (GPX) (**A**), polyphenol oxidase (PPO) (**B**) in uncoated (untreated) and chitosan-based coated figs (treated fruits) at harvest (0) and after three, six and nine days of cold storage at 4 °C. Error bars indicate standard deviation.

Chitosan-based coating in fig fruits contributed to control ROS metabolism, enhancing antioxidant enzyme activity and reducing browning and oxidative damage. The positive role of combined ascorbic acid and chitosan coating in maintaining steady-state ROS levels and membrane cellular integrity in plum fruit has been demonstrated by Liu et al. [27].

3.4. Evaluation of the Effects of Chitosan-Based Coating by PCA

The effectiveness of chitosan-based coating in figs during cold storage was evaluated by PCA analysis, including all evaluated traits of this study in the dataset. Covariance matrix showed that the eigenvalues were able to account for 82.15% of the total variance in the dataset using two principal components (PCs). PC1 explained 57.78% of the variance in the dataset, whereas PC2 explained an additional 24.37% of the variance. The first component was positively correlated with TA, AsA, CAT, POL, FLAV, DPPH, and negatively with WL, TSS, TSS/TA ratio, PPO and GPX. PC2 was only positively correlated with the a* value and APX activity and negatively with L* and b* values (Figure 3).

Scoring and loading plot allowed to distinguish different behaviors between uncoated and chitosan-coated figs, indicating that the combined effects of chitosan-based treatment and storage time influenced the physico-chemical, nutraceutical and antioxidant system of figs during storage (Figure 3). Scores in uncoated fruits shifted from positive values to negative ones along PC1, while scores in coated fruits showed a shift from negative values to positive ones along PC2. This suggests that during cold storage in fig fruits occurred changes in physico-chemical and nutraceutical traits, and in the antioxidant system, influenced by chitosan-based coating. PPO and GPX displayed a high negative load with PC1, suggesting that these enzymes have an important role in browning reactions in uncoated figs.

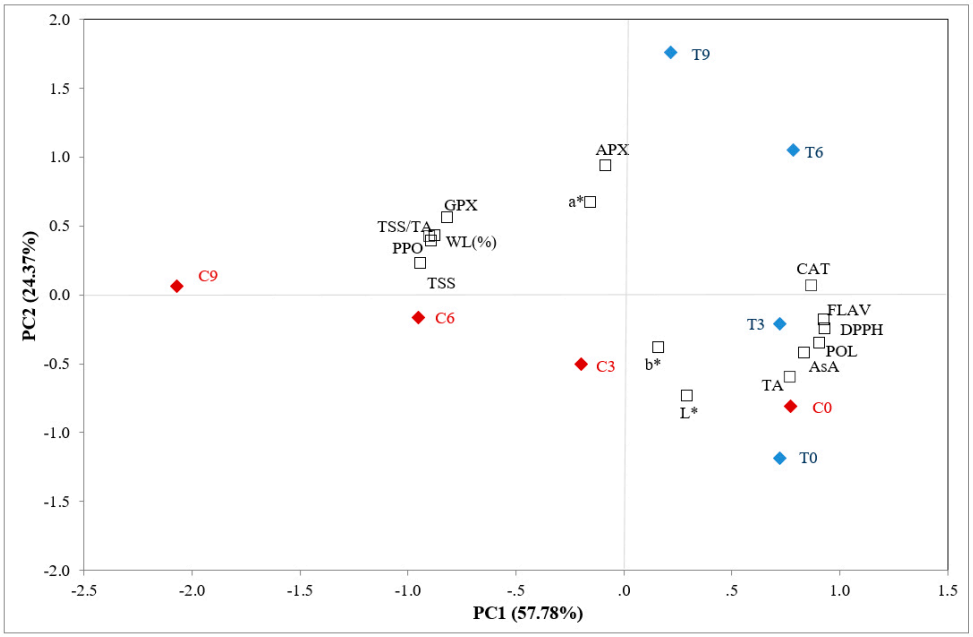

Figure 3. Two-dimensional principal component analysis of the physico-chemical and nutritional traits, and antioxidant enzyme activities during cold storage, at harvest (0), after three days (3), six days (6), and nine days (9) for uncoated (C) and chitosan-coated (T) fruits. (WL = weight loss; TSS = total soluble solid content; TA = titratable acidity; TSS/TA = ratio between total soluble solid content and titratable acidity; L*, a*, b* = colorimetric parameters; POL = polyphenol; FLAV = flavonoid; AsA = ascorbic acid content; DPPH = antioxidant activity; APX = ascorbate peroxidase; CAT = catalase; GPX = guaiacol peroxidase; PPO = polyphenol oxidase).

4. Conclusions

Chitosan-based coating is a valid postharvest treatment that contributes to extending the shelf-life of fresh figs. This treatment preserved physico-chemical and nutraceutical traits, slowed down browning reactions and counteracted the oxidative stress of coated figs during cold storage at 4 °C. Chitosan-based coating contributed to reducing the weight loss and preserved the ascorbic acid, polyphenol, and flavonoid content in fresh figs. Furthermore, its beneficial effects on the antioxidant system allowed to delay oxidative damage during postharvest life.

These findings suggest that chitosan-based treatment can be used for extending marketable shelf-life of fresh figs.

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