

## Postharvest Application of Chitosan and Low Temperature Storage Affect Respiration Rate and Quality of Plum Fruits

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### ABSTRACT

Application of edible coating as a way of prolonging the shelf-life of perishable fruits and vegetables is promising. Two plum cultivars (Stanley and Giant) were treated with 1% Chitosan and then stored at 0-1°C and relative humidity of 90±5% for 40 days. Changes in weight loss, respiration rate, fruit firmness, soluble solid content, titrable acidity, pH, ascorbic acid as well as decay rate were periodically recorded. The results indicated that Chitosan coating was effective in reducing weight loss, respiration rate as well as decay rate. A parallel trend in weight loss and decay rate was observed for both cultivars. Comparing the two cultivars, 'Giant' exhibited higher weight loss and respiration rate. Weight loss was mitigated through Chitosan application due to its positive effect in reducing respiration. In addition, Chitosan coating resulted in the retainment of a higher content of titrable acid, pH as well as firmness in either cultivar. However, total soluble solids and ascorbic acid contents were not significantly affected by the coating. The results finally indicated that Chitosan treatment is an effective strategy for maintaining organoleptic characteristics and as well for the prolonging of postharvest life in plums.

**Keywords:** Chitosan, Cold storage, Plum fruits, Respiration rate, Quality.

### INTRODUCTION

Plums (*Prunus domestica* L.) are highly perishable and undergo fast ripening following their harvest. Depending on the cultivar, plums may have a commercial life of 2–6 weeks even when stored at 0°C (Abdi *et al.*, 1997). Storage at low temperature delayed effectively fruit ripening and extended postharvest life of plums, but the beneficial effects may be limited by the development of chilling injury-associated disorders, including internal browning, flesh translucency, and/or reddening (Crisosto *et al.*, 2004; Manganaris *et al.*, 2007). The consequences of these changes are an acceleration of quality loss and a reduction in consumer acceptability. Thus, there is a need for either retarding or inhibition of the physico-chemical changes occurring and an improvement of fruit storability.

Considerable economic losses to harvested fruits are brought about through postharvest fungal decay during transportation and storage, which can be significantly controlled by application of synthetic fungicides. However, considering public concern over pesticide residues in food and across the environment, there is a dire need for safer alternatives for the control of postharvest decay to substitute synthetic fungicides (Zhang *et al.*, 2011).

The application of edible coatings is one of the most innovative methods to extend the commercial shelf-life of fruits and vegetables by acting as a gas barrier and having a similar effect as the storage under modified atmosphere. Edible coatings on fresh fruit can provide an alternative to modified atmospheric storage by reducing quality changes and slowing down of quantity losses through modification and control of the internal

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atmosphere of the individual fruits (Turhan, 2009).

Such different kinds of coatings as proteins, polysaccharides, lipids and composed films are employed (Ghasemnezhad *et al.*, 2008). These coatings show promise as environmentally friendly quarantine treatments and can be placed on fruit surfaces through different ways like dipping and spraying. Edible coating consists of a thin layer of protective that is applied to the skin surface of the fruit which is later consumed together with the fruit flesh.

Chitosan is a naturally-occurring compound that enjoys the potential in agriculture as regards its controlling plant diseases. This molecule was shown to display toxicity, inhibiting fungal growth and development (Hadrami *et al.*, 2010; Zhang *et al.*, 2011). Moreover, Chitosan is a polysaccharide produced through Chitin deacetylation that can be used to form an edible semipermeable film on the outside surface of the fruits to extend storage life and reduce some several forms of decay caused by fungi during storage (Bautista-Banos *et al.*, 2006). The effectiveness of Chitosan coating in preserving the quality of fruits may vary depending on the features of coating, fruit species, fruit maturity as well as storage conditions. It has been used to maintain the quality at postharvest of such fruits as peach (Li and Yu, 2000), longan fruit (Jiang and Li, 2001), strawberries (Hernandez-Munoz *et al.*, 2006; Hernandez-Munoz *et al.*, 2008), citrus (Chien *et al.*, 2007), grape (Ardakani *et al.*, 2009), apricot (Ghasemnezhad *et al.*, 2010), papaya (Ali *et al.*, 2011), sweet cherry (Chailoo and Asghari, 2011), apple (Shao *et al.*, 2012), and guava (Hong *et al.*, 2012). Chitosan has also been reported to be more effective in delaying weight loss than starch and cellulose derivatives (Kittur *et al.*, 2001; Ribeiro *et al.*, 2007).

Eum *et al.* (2009) reported that coating plum fruit (*cv.* Sapphire) with Versasheen (carbohydrate along with sorbitol) during storage at 20°C was effective in delaying the

increase in pH and loss of weight, firmness, as well as titratable acidity. Zhao *et al.* (2009) tested the effect of Chitosan coating on quality of 'Dashi Early' plums stored at 25°C. The results of the studies have indicated that coated samples benefited from a better quality than the untreated fruits. However, little has been reported on the effects of Chitosan coating on quality, in the case of plums during their cold storage. The objective of this work was to evaluate the effect of Chitosan coating on respiration rate and quality characteristics of plum fruit during its cold storage.

## MATERIALS AND METHODS

### Materials

'Stanley' and 'Giant' plums (*Prunus domestica* L.) were harvested at optimum commercial maturity from an orchard located in Tekirdag (Turkey) (lat. 40° 59' N, long. 27° 29' E). The samples were handled carefully after harvest and promptly taken to the laboratory. The fruit samples were selected for uniformity of size, free from diseases and defects.

### Chitosan Coating Application

Coating solution was prepared by dissolving 1% Chitosan (Sigma Chemical Co.) in a 0.5% glacial acetic acid and distilled water. The pH value of the Chitosan solution was then adjusted to 5.6 using 0.1M NaOH. An acid solution containing no Chitosan and of pH 5.6, was used as control. Chitosan coating treatment as well as control contained 0.5% Tween-80 to improve the wetting properties of the solutions (Zhao *et al.*, 2009). The fruits were all dipped in the solution for one minute, then allowed to dry for 2 hours at 25°C (Ghasemnezhad *et al.*, 2010). For both cultivars, the treated as well as control fruits were placed in polypropylene baskets (2 kg) and stored at

0-1°C environment of  $90 \pm 5\%$  relative humidity for 40 days.

### Quality Analysis

During the storage period, such various chemical and physical analyses as weight loss (%), respiration rate ( $\text{mg kg}^{-1} \text{h}^{-1}$ ), fruit firmness (kg), total soluble solids (TSS) content (%), titratable acidity (as malic acid, TA) (%), pH, ascorbic acid ( $\text{mg } 100 \text{ g}^{-1}$ ) and decay rate (%) were performed within 10-day intervals. The respiratory rate, expressed in  $\text{mg kg}^{-1} \text{h}^{-1}$  (Demirdoven and Batu, 2004), was determined by incubating one kilogram fruit of known mass and volume in 7,000 ml hermetic genbox jar for 1 hour and then, determining the  $\text{CO}_2$  concentration in the flask by means of a Systech Gaspac advance GS3L gas analyzer. The method of 2,6-dichloroindophenol titrimetry was employed to determine the ascorbic acid content of the pressed fruit extracted juice (Cemeroglu, 2007).

### Statistical Analysis

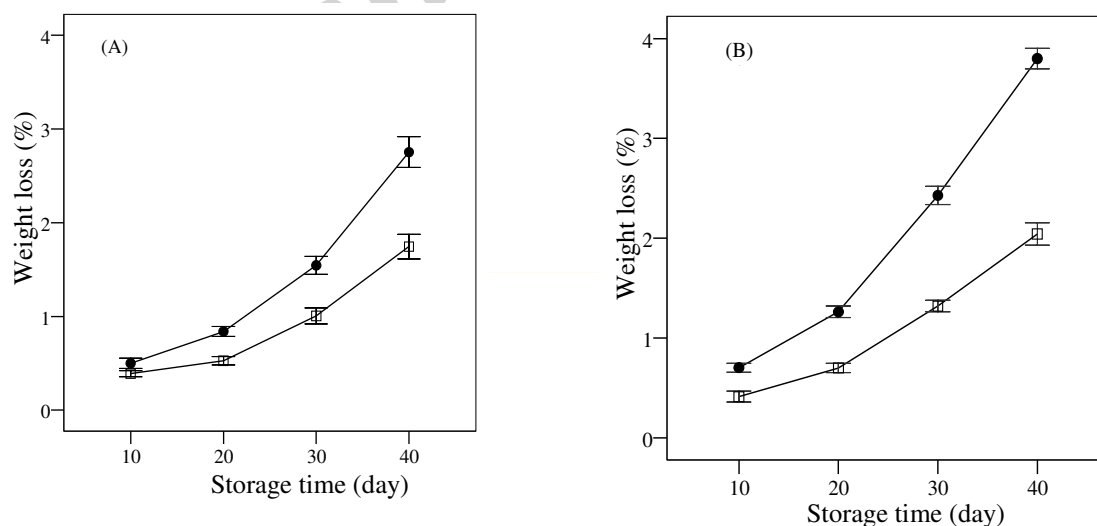
The experiment was of a completely randomized factorial design of four

replications with one kilogram of fruit per plot. Analysis of Variance (ANOVA) was the means for analyzing the difference between means and while LSD test being applied for mean separation at  $P < 0.05$ . All the analyses were carried out through SPSS and MSTAT-C as statistical software. Results are reflected as the mean  $\pm$  SE.

## RESULTS AND DISCUSSION

### Weight Loss

Water loss usually occurs from the vapor phase in fresh horticultural crops. Chitosan coatings act as barriers, thereby restricting water transfer and protecting fruit skin from mechanical injuries, as well as sealing small wounds and thus delaying dehydration (Hernandez-Munoz *et al.*, 2006). In the present study, Chitosan coating also helped retain moisture and weight loss of fruits increased during storage period which was significantly higher in control than coated fruits for both cultivars (Figure 1). After 40 days past, and for in *cv.* Stanley, the highest weight loss was determined in control fruits (2.75%), while the least observed in coated



**Figure 1.** Changes in weight loss of plum fruits coated with Chitosan during cold storage. (A) *cv.* Stanley, (B) *cv.* Giant; (●) Control, (□) Chitosan.

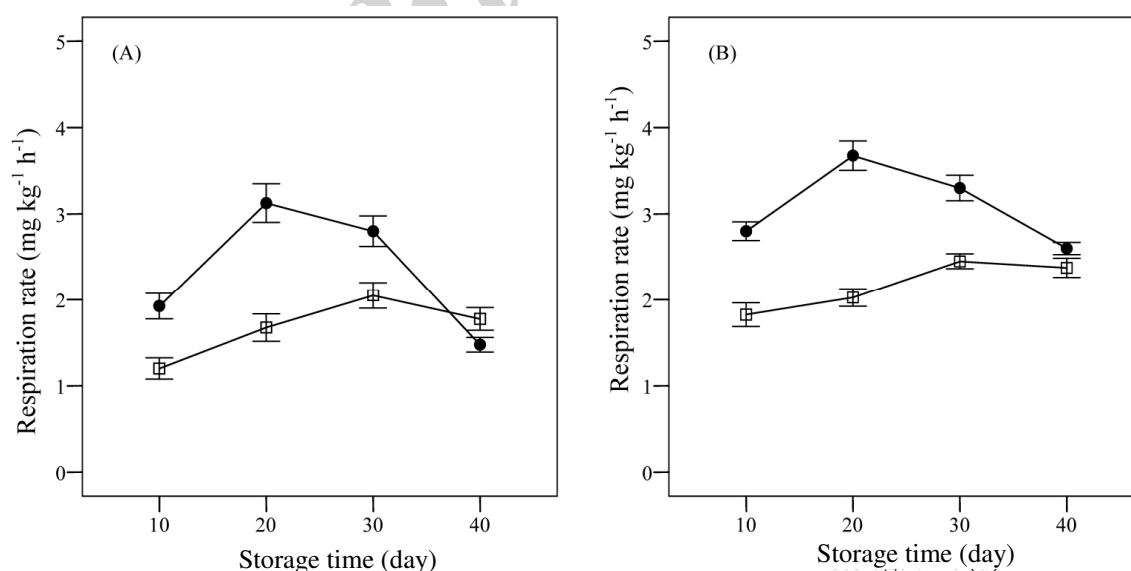


fruits (1.74%). Similarly, in *cv.* Giant, the highest weight loss was determined for control fruits (3.8%) while the least being observed in coated fruits (2.04%). The reduction in weight loss in Chitosan treated fruits may be due to the formation of a high relative humidity atmosphere around fruits which reduce the water vapor transmission and therefore respiration rates. In agreement with the results, previous studies showed that wax coating could reduce the rate of water loss, depending upon coating type and fruit variety (El-Badawy and El-Salhy, 2011; Hong *et al.*, 2012; Jiang *et al.*, 2012). Studies also carried out by Hernandez-Munoz *et al.* (2008), on strawberries coated with Chitosan, showed that at the end of storage, untreated fruits showed 28.7% loss in weight, whereas the weight losses for samples coated with 1 and 1.5% Chitosan were 19.6 and 14.2%, respectively.

### Respiration Rate

Fruits and vegetables are living commodities and their rate of respiration is of key importance to maintenance of quality. It has been commonly observed that the greater the respiration rate of a fruit, the

shorter the postharvest life (Aked, 2002). Several researchers have demonstrated that fruit with surface covering were reduced in respiration rate (Hernandez-Munoz *et al.*, 2008; Eum *et al.*, 2009; Ali *et al.*, 2011; Shao *et al.*, 2012). In the present study, Chitosan treated fruit exhibited a significantly lower respiration rate than control during the storage period in both cultivars. However, 'Stanley' showed a lower respiration rate than 'Giant'. The effects of the Chitosan coating on the respiration rates of the plums are shown in Figure 2. The respiration rates showed a typical climacteric pattern during ripening, similar to that described by various authors (Luo *et al.*, 2009; Singh *et al.*, 2009). The climacteric peak of the control was observed on the 20<sup>th</sup> day of storage while the Chitosan treated fruit had a delayed climacteric peak on the 30<sup>th</sup> day of storage for both cultivars. The results obtained were similar to those by Chen and Zhu (2011) who observed that after reaching the peak value, the respiration rates began to decrease in plum fruits until the end of storage. It was observed that after 30 days of storage, the control fruits spoiled rapidly, and correspondingly, the respiration rate decreased fast in both cultivars. Zhao *et*



**Figure 2.** Changes in respiration rate of plum fruits coated with Chitosan during cold storage. (A) *cv.* Stanley, (B) *cv.* Giant; (●) Control, (□) Chitosan.

al. (2009) also reported that plums coated with Chitosan decreased in the peak of respiration rate as compared with control in the course of storage at 25°C.

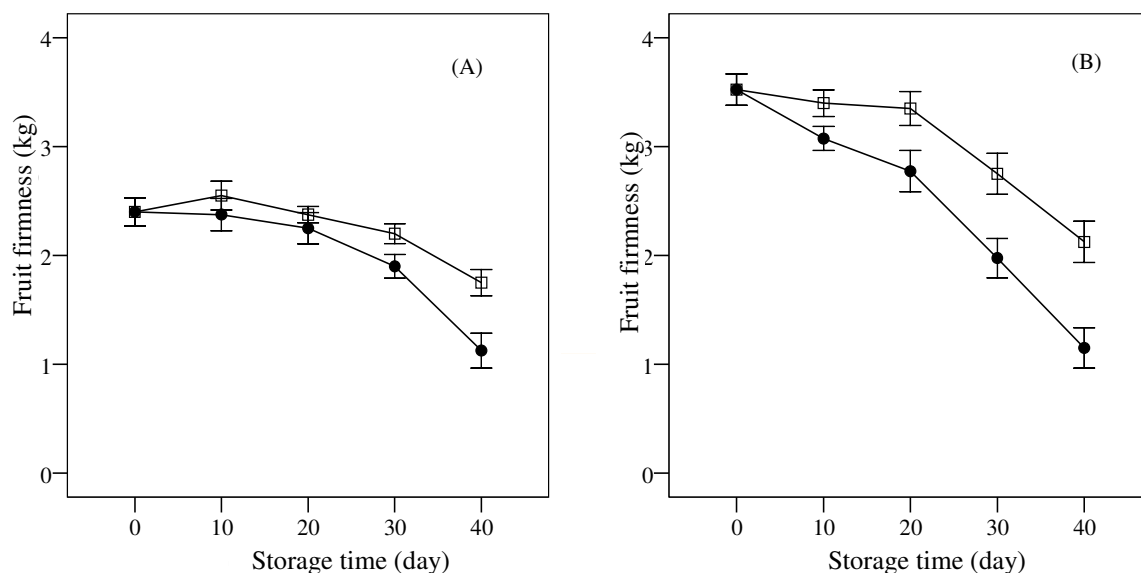
### Fruit Firmness

Fruit texture is often the first of many quality attributes judged by the consumer and excessive softening is a major factor limiting plum shelf life. The changes in the fruit firmness in plums are depicted in Figure 3. There were statistically significant differences observed in fruit firmness between Chitosan coated fruits and the control ones in both cultivars. Chitosan coating provides beneficial effects on flesh firmness. It is thought that due to coating there occurred reduction in cell wall degradation which in turn maintained cell turgidity and the protected structure of cell wall. At harvest, 'Giant' plums were firmer (3.5 kg) than 'Stanley' plums (2.4 kg) and firmness loss from harvest to the end of cold storage was more in Giant cultivar (1.7 kg) as compared with Stanley (2.1 kg). At the end of the storage period, and for both cultivars the coated fruits were firmer than

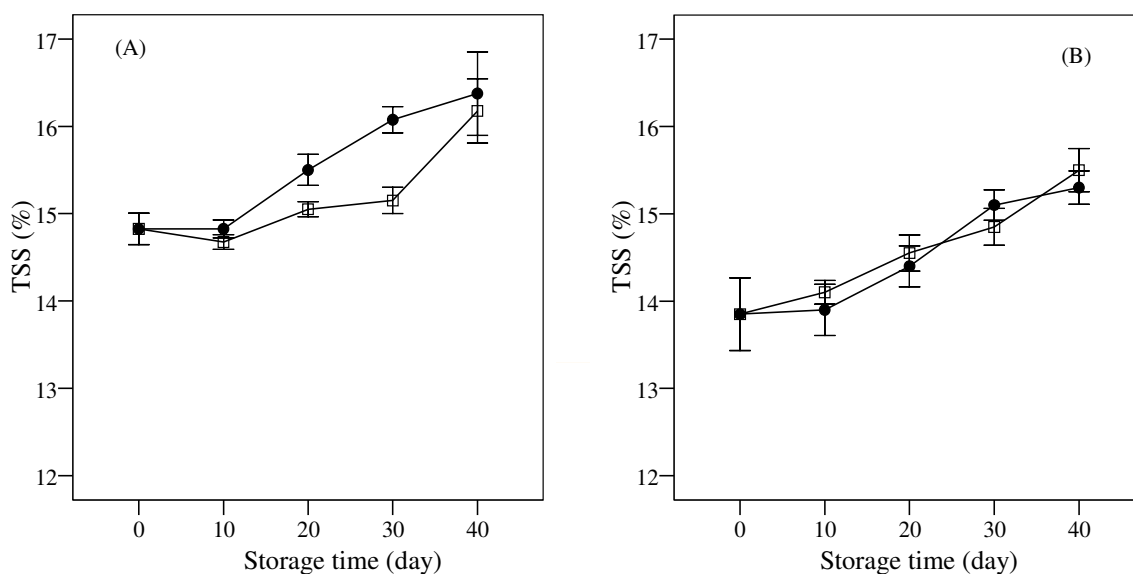
the control ones. This could be explained by the Chitosan's reducing of the respiration phenomenon and quick ripening. Several reports indicate that the loss of firmness in such Chitosan-treated fruits as strawberries, peaches, grape, apple and others was delayed during the storage period and while various reports also indicating that the treated fruit come out firmer at the end of the storage period (Li and Yu, 2000; Hernandez-Munoz *et al.*, 2006; Ardakani *et al.*, 2010; Shao *et al.*, 2012).

### Total Soluble Solids

The effects of Chitosan coating treatment on the pattern of TSS changes in plum fruits during cold storage for Stanley and Giant varieties are shown in Figure 4. as whole, there was gradual increase observed in TSS during cold storage. Significant differences in changes between Chitosan coated and control were observed in 'Stanley' but not for 'Giant' plums. After 40 days, and for *cv.* Stanley, the highest TSS content was determined in control fruits (16.3%) while the least observed in coated ones (16.1%). On the other hand, in *cv.* Giant, the highest



**Figure 3.** Changes in fruit firmness of plum fruits coated with Chitosan during cold storage. (A) *cv.* Stanley, (B) *cv.* Giant; (●) Control, (□) Chitosan



**Figure 4.** Changes in TSS of plum fruits coated with Chitosan during cold storage (A) *cv.* Stanley, (B) *cv.* Giant; (●) Control, (□) Chitosan.

TSS content was determined in coated fruits (15.5%) while the least in control ones (15.3%). Similar TSS increases have also been reported on plum storage in the literature (Bal and Celik, 2008; Eski and Erkan, 2008). Bautista-Banos *et al.* (2006) reported that after storage, TSS of Chitosan coated fruits differed according to the kind of fruit. Lower TSS than in control fruits were reported for mangoes and bananas coated with Chitosan while higher values reported for treated peaches (Du *et al.*, 1997; Kittur *et al.*, 2001; Srinivasa *et al.*, 2002). However, other studies reported that TSS of Chitosan-dipped papayas and apricots were the same as those in the untreated fruits (Bautista-Banos *et al.*, 2003; Ghasemnezhad *et al.*, 2010).

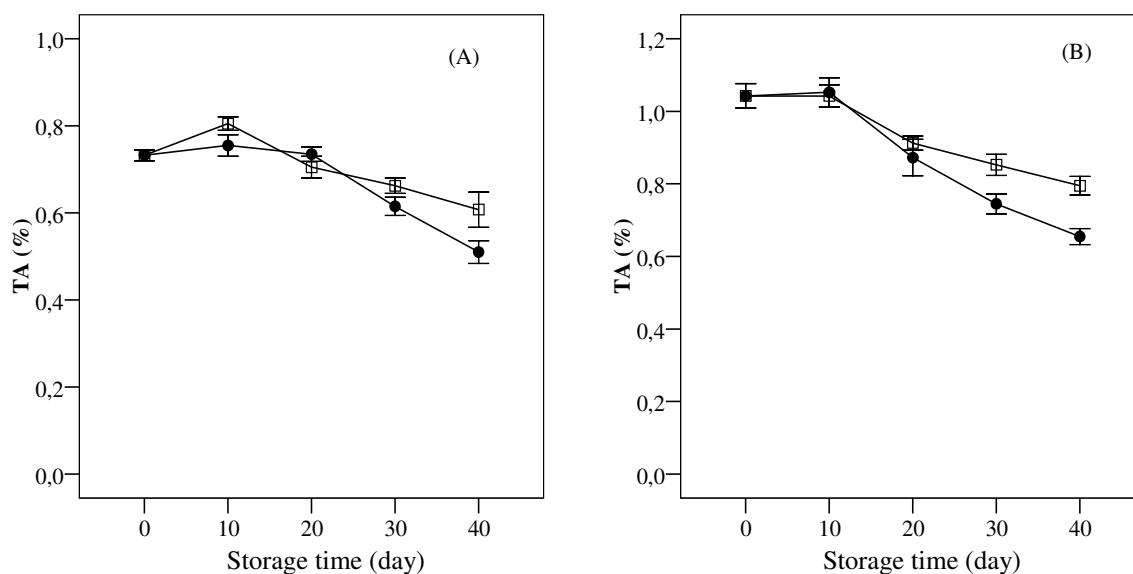
#### Titratable Acidity

Figure 5 shows that Chitosan coatings significantly reduced the loss in TA content of plum fruit during storage in both cultivars. TA contents at harvest were 0.73 and 1.04% in *cv.* Stanley and *cv.* Giant, respectively, which gradually decreased

throughout the storage period. At the end of the storage, in *cv.* Stanley the highest TA loss was determined in control fruits (0.65%) while the least TA was observed in coated ones (0.79%). Similarly, in *cv.* Giant the highest TA loss was determined in control fruits (0.51%) while the least observed in coated fruits (0.60%). This result is consistent with reports by Ghasemnezhad *et al.* (2010) and Ali *et al.* (2011) who reported that TA of Chitosan coated apricot and papaya kept under cold storage decreased with time but to a lesser extent than that of uncoated fruits. Han *et al.* (2004) also reported that in raspberry and strawberry, the Chitosan coatings slowed down the changes in titratable acidity, effectively delaying fruit ripening. It suggests that faster reduction in titratable acidity gave rise to a faster senescence (Hong *et al.*, 2012).

#### pH

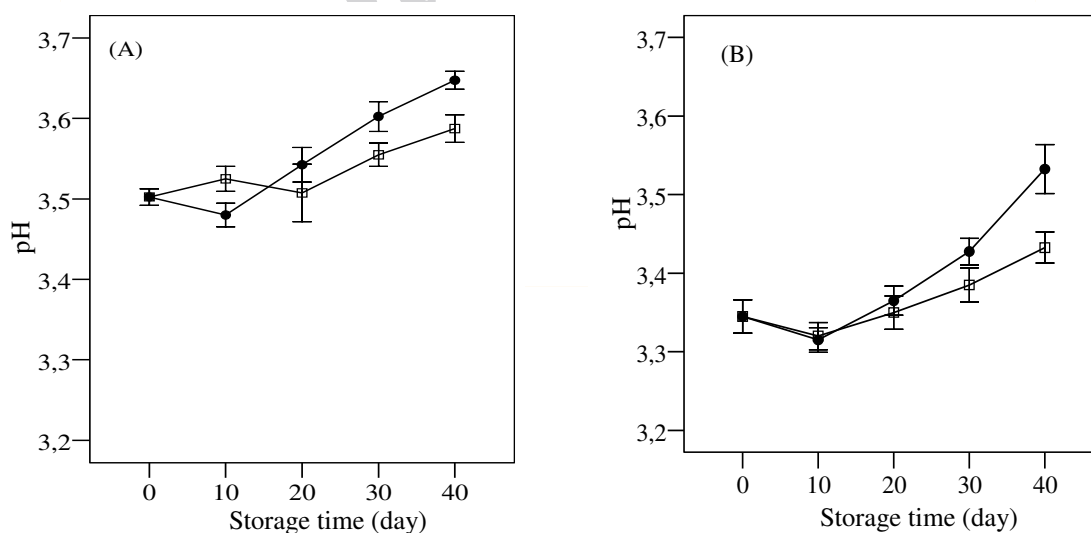
The pH of plum gradually increased during cold storage (Figure 6). In 'Giant' plums there were significant differences



**Figure 5.** Changes in TA of plum fruits coated with Chitosan during cold storage. (A) *cv.* Stanley, (B) *cv.* Giant; (●) Control, (□) Chitosan.

between Chitosan treated and control fruits, but not in ‘Stanley’ cultivar of plums. For both cultivars, pH increase from harvest to the end of cold storage was more in control fruits as compared with Chitosan coated fruits. At the beginning of storage, pH of plums was 3.50 in *cv.* Stanley and 3.34 for *cv.* Giant. At the end of storage, the minimum pH rise occurred in coated fruits for both cultivars (3.58 and 3.53). The change in pH is associated with a number

of reasons. Throughout the present study, pH increase might have been resulted from a decrease in titrable acid content in fruits and while the higher levels of titratable acidity in coated fruits may have been due to protective O<sub>2</sub> barrier or reduction of O<sub>2</sub> supply to the internal fruit surface inhibiting respiration rate (Jiang and Li, 2001). Similar results of the effect of Chitosan on pH values have been reported in apricots (Ghasemnezhad *et al.*,



**Figure 6.** Changes in pH of plum fruits coated with Chitosan during cold storage. (A) *cv.* Stanley, (B) *cv.* Giant; (●) Control, (□) Chitosan.



2010) and on apples (Shao *et al.*, 2012).

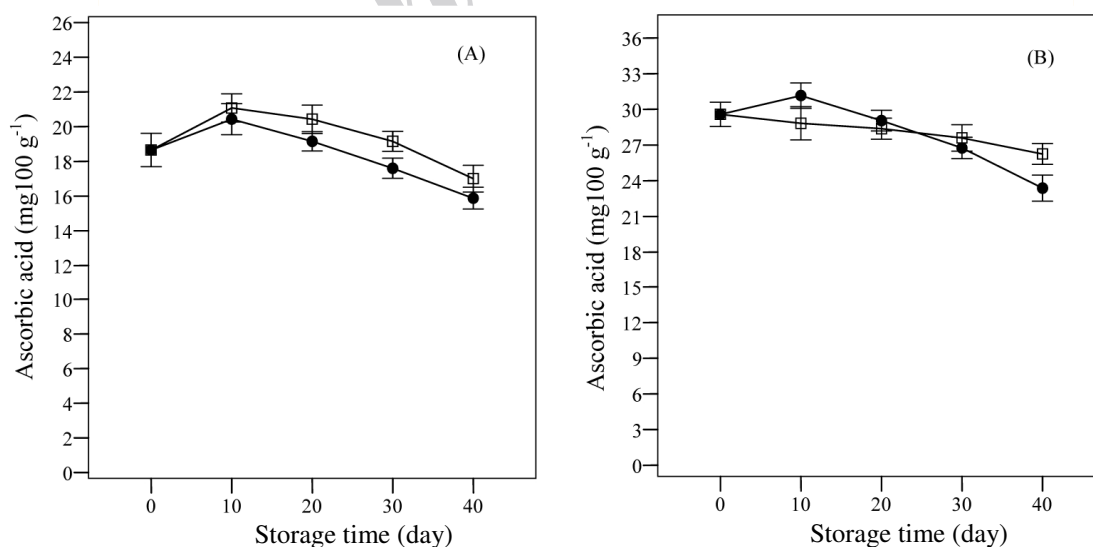
### Ascorbic Acid

Ascorbic acid is sensitive to destruction when fruits are subjected to adverse postharvest handling and storage conditions (Lee and Kader, 2000). Stone fruit varieties vary widely in vitamin C content. In the study, ascorbic acid content of Stanley and Giant plum fruits gradually decreased during storage, and this reduction was effectively slowed down through Chitosan coating (Figure 7). Although the content of ascorbic acid in coated fruit ( $17 \text{ mg } 100 \text{ g}^{-1}$ ,  $26.2 \text{ mg } 100 \text{ g}^{-1}$ ) was higher than that in control ( $15.8 \text{ mg } 100 \text{ g}^{-1}$ ,  $23.3 \text{ mg } 100 \text{ g}^{-1}$ ) for both cultivars and at the end of the storage, no statistically significant differences were observed in changes of the acid between Chitosan coated and control treatments in either cultivars. Ascorbic acid loss from harvest to the end of storage was more in Giant cultivar as compared with Stanley. The reduction of ascorbic acid loss in coated plums could be due to the low oxygen penetrability of the Chitosan coating, which caused a lowering of the activity of the enzymes and prevented the oxidation of ascorbic acid. Because, keeping oxygen

away from fruits delays the deteriorative oxidation reaction of vitamin C. Several studies have on the contrary reported that the content of this vitamin in the coating treated fruits gradually decreased during the storage period and was lower than that in the untreated ones (Srinivasa *et al.*, 2002; Chien *et al.*, 2007; Sun *et al.*, 2010; Ali *et al.*, 2011; El-Badawy and El-Salhy, 2011; Hong *et al.*, 2012).

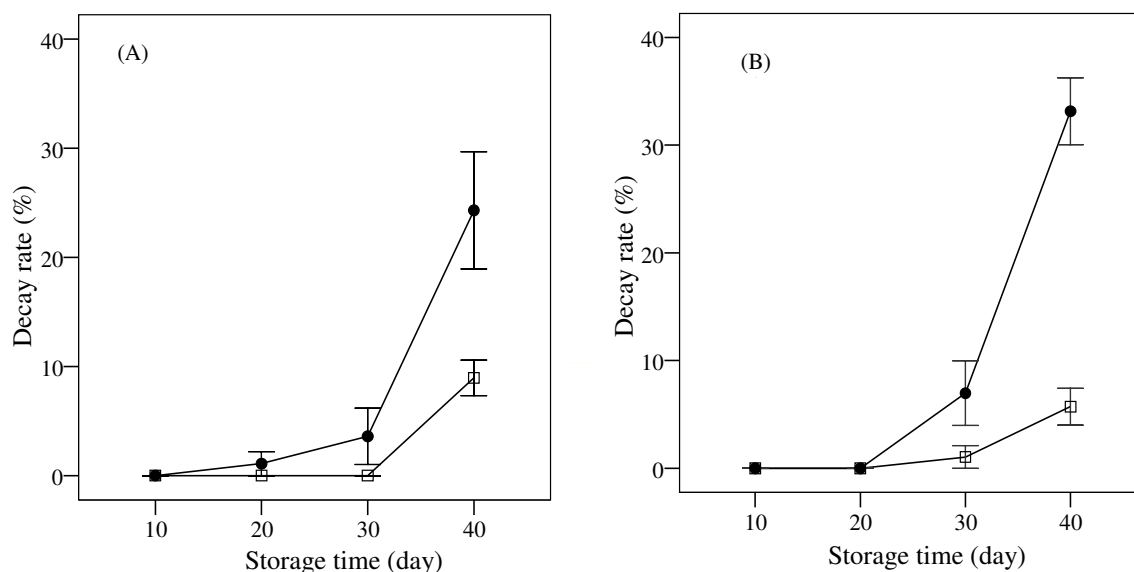
### Decay Rate

Coatings and films can slow deteriorative changes in coated products by reducing desiccation. Previous studies have indicated that Chitin and Chitosan could effectively inhibit postharvest diseases of fruits by direct inhibition of spore germination, germ tube elongation and mycelial growth of phytopathogens as well indirect inducement of defense-related enzymes (Zhang *et al.*, 2011). Throughout the present study, the changes in decay rate occurred more slowly in Chitosan treatment than in control for both cultivars and Chitosan treatment tended to maintain significantly lower rates of decay than control during storage period (Figure 8). As for *cv.* Stanley, decayed fruits



**Figure 7.** Changes in Ascorbic acid of plum fruits coated with ( $\text{mg } 100 \text{ g}^{-1}$ ) during cold storage. (A) *cv.* Stanley, (B) *cv.* Giant; (●) Control, (□) Chitosan.





**Figure 8.** Changes in decay rate of plum fruits coated with Chitosan during cold storage. (A) *cv.* Stanley, (B) *cv.* Giant; (●) Control, (□) Chitosan.

were observed in control after 10 days past, while in Chitosan coated fruits it happened after 30 days of storage. In *cv.* Giant, decayed fruits were observed in both control and Chitosan coated fruits after 20 days past of storage. On the 40<sup>th</sup> day, the decay rates of control fruits were recorded 33.1% in *cv.* Giant and 24.3% in *cv.* Stanley, while the decay rate in Chitosan treated fruits were 5.7% in *cv.* Giant and 8.9% for *cv.* Stanley. Previous similar experiments, applying Chitosan coatings revealed benefits from reduced decay in peach, strawberry, litchi and sweet cherry (Li and Yu, 2000; Hernandez-Munoz *et al.*, 2006; Hernandez-Munoz *et al.*, 2008; Sun *et al.*, 2010; Chailoo and Asghari, 2011). El-Ghaouth *et al.* (1991) suggested that Chitosan induces chitinase, a defense enzyme, which catalyzes the hydrolysis of Chitin, a common component of fungal cell walls (Hou *et al.*, 1998), thus preventing the growth of fungi on the fruit. The results suggest that Chitosan coating is an effective way of preserving fruits and slowing down the oxidation process.

## CONCLUSIONS

Chitosan treating of plum followed by storage at 0-1°C, 90±5% RH was found to be beneficial because it helped to extend the storage life without any considerable deterioration of the quality of the fruits in either cultivar. Fruit coating reduce respiration, and weight loss, so significantly retarding of the otherwise swift ripening process. Chitosan coating of plum fruits can provide an alternative to the modified atmospheric storage through a reduction in quality changes as well in and quantity losses through modification and control of the internal atmosphere of each individual fruits.

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## کاربرد کیتوزان (Chitosan) و پروت بعد از برداشت روی میزان تنفس و حفظ کیفیت در میوه آلو تاثیر می گذارد

### ای. بال

#### چکیده

استفاده از پوشش (ماده قابل خوردن) در میوه و سبزیجات فاسد شدنی و در جهت افزایش عمر انبارمانی آنها قابل تصور و امید بخش است. دو رقم (cultivar) آلو به نامهای استانلی (Stanley) و جایانت (Giant) پس از پوشش داده شدن با کیتوزان (Chitosan) یک درصد، در پروت  $1-0^{\circ}\text{C}$  و رطوبت نسبی  $90 \pm 5\%$  به مدت چهل روز نگهداری شدند. تغییرات بوجود آمده در خصوصیات میوه شامل کاهش وزن، میزان تنفس، سفتی میوه، محتوای مواد جامد محلول (Soluble Solid content)، اسیدیته قابل تیتراسیون، pH، مقدار اسید اسکریک و روند زوال پذیری میوه به طور متناوب مورد بررسی قرار گرفتند. نتایج حاکی از آن بود که پوشش کیتوزان در کم کردن پدیده "کاهش وزن"، کم کردن تنفس و در نتیجه به تأخیر انداختن خرابی و فساد میوه نقش داشت و مؤثر بود. روند "کاهش وزن" و خراب شدن میوه برای دو رقم میوه یکسان بود منتها میزان کاهش وزن و خراب شدن در رقم جایانت (Giant) بیشتر به چشم می خورد. پدیده کاهش وزن به این دلیل (پس از پوشش داده شدن میوه بوسیله کیتوزان) کمتر شد، چون پوشش باعث پایین آمدن میزان تنفس در میوه شد. بعلاوه پوشش کیتوزان باعث حفظ سطح اسید قابل تیتراسیون، pH و در نتیجه سفت باقی ماندن میوه شد. اما در عین حال میزان مواد جامد و اسید اسکوریک به میزان معنی داری تحت تأثیر پوشش کیتوزان قرار نگرفتند. نتایج نهایتاً نشان می دهد که آغشته شدن میوه به کیتوزان راهبرد مؤثری در حفظ خصوصیات مطلوب میوه و طولانی شدن عمر پس از برداشت میوه آلو می باشد.