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Effect of chitosan coatings on postharvest green asparagus quality

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ABSTRACT

Fresh postharvest green asparagus rapidly deteriorate due to its high respiration rate. The main benefits of edible active coatings are their edible characteristics, biodegradability and increase in food safety. In this study, the quality of the edible coatings based on 0.50%, 0.25% high-molecular weight chitosan (H-chitosan), and 0.50%, 0.25% low-molecular weight chitosan (L-chitosan) on postharvest green asparagus was investigated. On the basis of the results obtained, 0.25% H-chitosan and 0.50% L-chitosan treatments ensured lower color variation, less weight loss and less ascorbic acid, decrease presenting better quality of asparagus than other concentrations of chitosan treatments and the control during the cold storage, and prolonging a shelf life of postharvest green asparagus.

1. Introduction

The addition of natural preservative derived from fruit and vegetable extracts to increase the shelf life of food products has become a popular strategy. Being another natural renewable resource, chitosan is a linear polysaccharide commonly derived from the deacetylation of chitin have attracted much scientific and agricultural interest because of their biocompatibility, biodegradability, non-toxicity, antimicrobial activity and environmentally friendly (Muzzarelli et al., 2012; Zhang, Geng, Jiang, Li, & Huang, 2012). Chitosan has been extensively used as edible coatings to preserve the quality of many fruits and vegetables, but less is known about their effects on quality attributes of fresh green asparagus.

Green asparagus (*Asparagus officinalis* L.) is one of the popular fresh vegetables and a very good source of dietary fiber because it is low in calories, but it has various vitamins and multiple trace mineral which can enhance the ability of insulin to transport glucose from the bloodstream into cells (http://en.wikipedia.org/wiki/Asparagus). Green asparagus is eaten worldwide, though the availability of imports throughout the year has made it less of a delicacy than it once was due to its high respiration rate. Therefore, adequate, economic and efficient postharvest conservation to extend green asparagus shelf-life is very necessary and profitable in terms of export.

Considering an increasing demand for fresh quality food by consumers, many methods have been used to increase the shelf life of asparagus. The usual techniques used to extend the storage life of asparagus include cold storage (Albanese, Russo, Cinquanta, Brasiello, & Di Matteo, 2007), cold storage in combination with chemical 6-benzylaminopurine treatment (Wei & Ye, 2011), aqueous ozone treatment and storage under controlled atmospheric conditions (An, Zhang, & Lu, 2007). The storage of asparagus in modified atmospheres packaging (MAP) may prevent or lessen postharvest changes in flavor, color and chemical composition (An, Zhang, Lu, & Zhang, 2006; McKenzie, Greer, Heyes, & Hurst, 2004). However, the use of controlled atmospheres should be seen as complementary to the appropriate management of temperature and relative humidity during refrigerated storage (Sánchez, Pérez-Marín, Flores-Rojas, Guerrero, & Garrido-Varo, 2009; Villanueva, Tenorio, Sagardoy, Redondo, & Saco, 2005). Although salicylic acid (SA) treatment can extend the shelf-life of asparagus, high concentrations of SA also initially cause deterioration in the color of asparagus (Wei, Liu, Su, Liu, & Ye, 2011). An edible coating comparable to MAP in terms of extending the quality and shelf life of asparagus would be beneficial to the fresh asparagus industry as well as the retail market and consumer (Fuchs, Scott Mattinson, & Feliman, 2008).

The objectives of this study were to investigate the physiological changes of different concentrations and molecular weight chitosan coatings on postharvest green asparagus, including evaluation of weight loss, texture, lignin, and losses of chlorophyll, ascorbic acid of green asparagus.

2. Materials and methods

2.1. Materials

High-molecular weight chitosan (H-chitosan) with viscosity 500 mPa s (1%, 20 °C) and degree of deacetylation 90%,

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low-molecular weight chitosan (L-chitosan) with viscosity 150 mPa s (1%, 20 °C) and degree of deacetylation 90% were purchased from Qingdao Honghai Biotechnology Company (Shandong, China). Fresh green Asparagus spears were obtained from commercial farms in Hangzhou, Zhejiang province. They were cut at ground level between 8:00 and 9:30 AM, 24 ± 2 °C and 65% relative humidity (RH), and placed in crushed ice and transported to the laboratory within 2 h on the day of harvest. Spears selected for the study were straight, undamaged, 16–20 mm in diameter and ~30 cm in length with closed bracts and no visible signs of injury. Spears were stored at 2 °C until time of coating application.

2.2. Preparation of H-chitosan and L-chitosan coating solutions

The H/L-chitosan coating solutions were prepared by dissolving the H/L-chitosan in 0.5% acetic acid and stirred for 1 h at room temperature to obtain 0.5% and 0.25% (w/v) H/L-chitosan/acetic acid solutions, respectively.

2.3. Treatment and storage of asparagus samples

Coating was carried out at room temperature by dipping the asparagus spears for 10 min in different chitosan concentration 0.5% and 0.25% (w/v) H-chitosan, 0.5% and 0.25% (w/v) L-chitosan suspensions, respectively. Meanwhile, asparagus spears were dipped in deionized water as control. Then samples were slowly dried at ambient conditions (22 °C, 70% RH) about 2 h, turning them from time to time before laying in the plastic trays. All treatments were stored at 2 °C with 95% RH for subsequent quality assessments at 0, 7, 14, 21, 28 and 35 days throughout storage.

2.4. Weight loss

Weight loss was determined by periodical weighting, and the results were expressed as the percentage loss of initial weight (Sothornvit & Kiatchanapaibul, 2009).

2.5. Texture

According to literature (Tzoumaki, Biliaderis, & Vasilakakis, 2009), the 30 cm in length asparagus spears were marked at 7 cm intervals from the tip and then sectioned at the ink markings into three cylindrical portions; apical, middle and basal. The texture was measured at the middle of each of the three sections of each spear by applying the cutting test using a TA.XT Express-v3.1 texture analyzer (Stable Micro Systems, Godalming, UK), with a 5 mm diameter cylindrical probe. Samples were penetrated 2 mm in depth. The speed of the probe was 2.0 mm s^{-1} during the pretest as well as during penetration. Force and time data were recorded with Texture Expert (Version 1.0) from Stable Micro Systems. From the force *vs* time curves, firmness was defined as the maximum force used.

2.6. Ascorbic acid determination

Ascorbic acid in asparagus was determined according to AOAC official method (An, Zhang, Wang, & Tang, 2008; AOAC, 1995). In brief, a 5 g sample of asparagus was blended with 20 mL of oxalic acid solution to extract ascorbic acid. The mixture was centrifuged (10,000 × *g*, 15 min) (3-30K; Sigma), and then the supernatant was taken and transferred to a volumetric flask. It was rapidly titrated with indophenols solution until light distinct rose pink color persisted for more than 5 s.

2.7. Chlorophyll determination

Chlorophyll concentrations were calculated as follows (Arnon, 1949). About 5 g samples obtained from 9 cm from the asparagus tip until 13 cm from the tip were homogenized in 20 mL of 80% acetone with a tissue homogenizer (Polytron PT-MR2100; Kinematica AG) at a moderate speed for 30 s, and centrifuged (10,000 × *g*, 15 min) (3-30K; Sigma). Absorbance (*A*) was measured at 645 and 663 nm using an UV–Vis recording spectrophotometer (UV-2550; SHIMADZU).

2.8. Lignin determination

The lignin content of the different parts of the asparagus spears was determined with the thioacidoglycolysis method, as described by Bruce and West (1989). About 25 g samples obtained from 21 cm from the asparagus tip until 26 cm of tissue was homogenized with 95% ethanol for 5 min. The mixture was vacuum filtered, the residue was washed with 100 mL of ethanol and then dried at 50 °C for 24 h. About 0.1 g of the above dry residue was mixed with 15 mL of 2 N HCl and 1 mL of thioglycolic acid which was then boiled with occasional shaking for 4 h and centrifuged (7500 × *g*, 15 min). The residue (lignin thioglycolate) was washed with 10 mL of water, suspended again in 20 mL of 0.5 N NaOH with occasional shaking for 18 h at room temperature and centrifuged; 4 mL of concentrated HCl was added to the supernatant liquid. The lignin thioglycolic acid complex was precipitated at 4 °C for 4 h, centrifuged (7500 × *g*, 15 min) and the residue was dissolved in 10 mL of 0.5 N NaOH. After the appropriate dilutions, the absorbance was read at 280 nm, using a UV–Vis spectrophotometer (UV-2550; SHIMADZU). Quantification was carried out using a standard coumaric acid curve (Aquino-Bolanos & Mercado-Silva, 2004; Tzoumaki et al., 2009).

2.9. Sensory evaluation

Sensory evaluation of asparagus for appearance was carried out for all of the samples. Samples were evaluated by a sensory panel of 10 trained assessors (Chen, Zhu, Zhang, Niu, & Du, 2010; Gómez-López, Ragaert, Jeyachchandran, Debevere, & Devlieghere, 2008; Wright & Kader, 1997). Overall visual quality was scored based on a modification of the 9-point hedonic scale reported by Wright and Kader (1997): 9 = excellent, extremely fresh; 7 = very good, marketable; 5 = good, limit of marketability; 3 = fair, limit of usability; 1 = poor, unusable. The following sensory quality attributes were also scored according to Gómez-López et al. (2008): off-odor (1 = none, 3 = acceptable, 5 = severe); color (1 = fresh, 3 = acceptable, 5 = spoiled); texture (1 = fresh, 3 = acceptable, 5 = spoiled). The end of the shelf-life from the sensory quality point of view was reached when at least one of the mean scores was above the acceptability limit.

2.10. Statistical analysis

Experiments were performed using a completely randomized design, and each was composed of three replicates. Data were subjected to one-way analysis of variance (ANOVA). Mean separations were performed by Tukey's multiple range test (DPS Version 6.55). Differences at $P < 0.05$ were considered significant.

3. Results and discussion

3.1. Effect of asparagus weight loss and texture

The weight loss is considered to be the major determinant of storage life and postharvest quality of asparagus. The weight loss of the control and treatments throughout the entire storage was

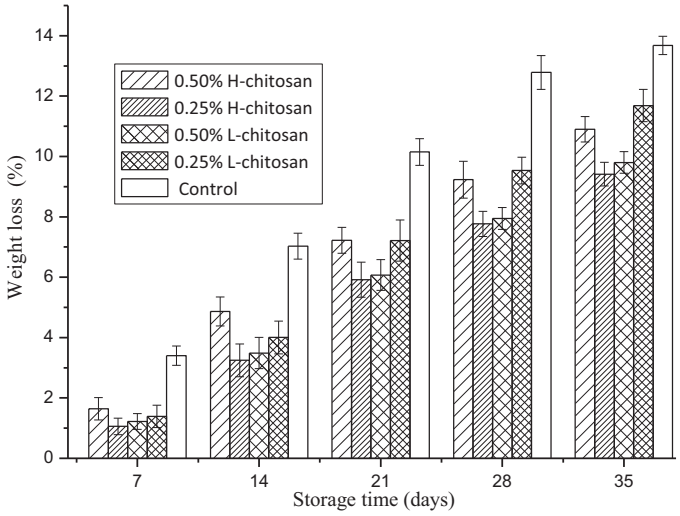

Fig. 1. Changes in weight loss of asparagus stored at 2 °C for 35 days. Each data point is the mean of three replicate samples. Vertical bars represent standard deviation of means.

presented in Fig. 1. As shown in Fig. 1, the weight loss of all sample batches increased as time went by. The highest weight loss was observed in the control sample, it reached 13.68% at the end of storage, whereas, that of 0.50%, 0.25% H-chitosan and 0.50%, 0.25% L-chitosan treated batches was 10.90%, 9.41%, 9.80%, 11.69%, respectively. It indicated that the chitosan coating can reduce the weight loss over the storage period, and it was concentration-dependent. That maybe because edible coatings could create a physical barrier to moisture loss and therefore retarding dehydration and shriveling. That was accordance with other studies which chitosan coatings had been effective at controlling water loss from some commodities, including cucumber, pepper, longan fruit and mushroom (El Ghaouth, Arul, Ponnampalam, & Boulet, 1991; Jiang, Feng, & Li, 2012; Jiang & Li, 2001). Relatively low weight loss in H-chitosan coated asparagus contributed to better quality of asparagus during the cold storage.

The texture is one of the most critical quality attributes and used by consumer to assess asparagus quality (Barrett, Beaulieu, & Shewfelt, 2010; Siomos, Sfakiotakis, & Dogras, 2000). It had been related to fibrousness and the process of hardening that occurs after harvesting, the latter was accompanied by the lignification of the pericyclic (schlerenchyma) fibers. Additionally, changes in texture may also reflect the losses of tissue water and the increase other phenolic compounds apart from lignin (Rodríguez et al., 2004; Tzoumaki et al., 2009). As shown in Fig. 2, the shear force of the three distinct parts for the different treatments of asparagus spears increased along with the storage till the 21 days. Then, the firmness values of all parts of all samples decreased. Relatively, three parts of 0.50% L-chitosan coated asparagus spears maintained their texture compared to other samples throughout the storage. This result was consistent with the weight loss of asparagus (Fig. 1). Although the apical and middle parts of uncoated asparagus spears seemed to maintain their texture to initial firmness levels after 21 days storage, thereafter, the values significantly decreased at the end of the storage time. Previous studies reported that the use of modified atmosphere packaging in green asparagus (Villanueva et al., 2005), and edible coating (sodium carboxymethyl-cellulose) on white asparagus (Tzoumaki et al., 2009) exhibited well effect in regarding the hardening press, especially of the basal part of the stalks. Herein, the slower textural changes were observed in 0.50% L-chitosan coated asparagus spears during the storage. That maybe 0.50% L-chitosan coating could modify the internal gas composition of asparagus and reduce the respiration rate, finally retard the texture changes.

3.2. Effect of asparagus ascorbic acid

Ascorbic acid content is also used as the evaluation parameter in this study. As shown in Fig. 3, changes in ascorbic acid content of all samples decreased during the storage time. However, the use of chitosan coating significantly reduced the loss of ascorbic acid in asparagus samples, especially 0.25% H-chitosan and 0.50% L-chitosan. After 35 days of storage, the ascorbic acid retention of asparagus treated with 0.50% H-chitosan and 0.50% L-chitosan were 8.33 and 8.80 mg/100 g FW, respectively, whereas control samples was only 5.52 mg/100 g FW. Since ascorbic acid loss could be greatly

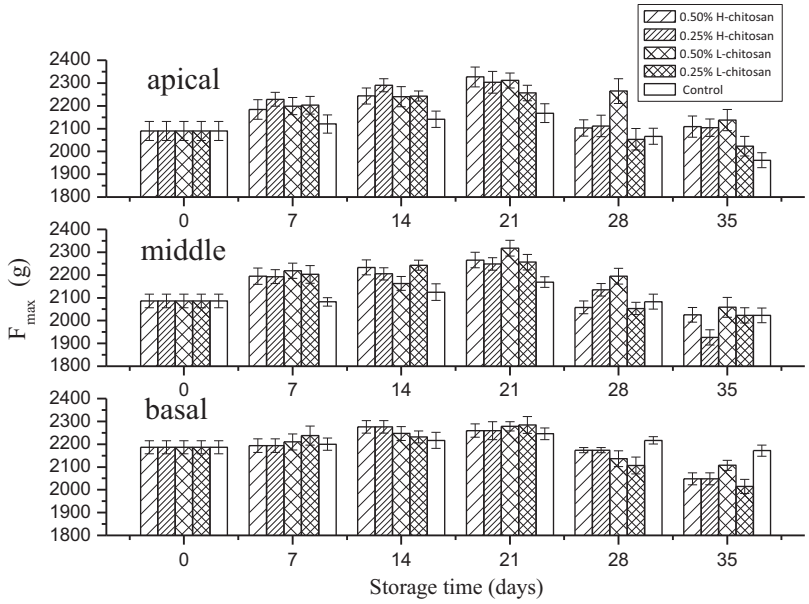

Fig. 2. The texture of the three distinct parts for asparagus stored at 2 °C for 35 days. Each data point is the mean of three replicate samples. Vertical bars represent standard deviation of means.

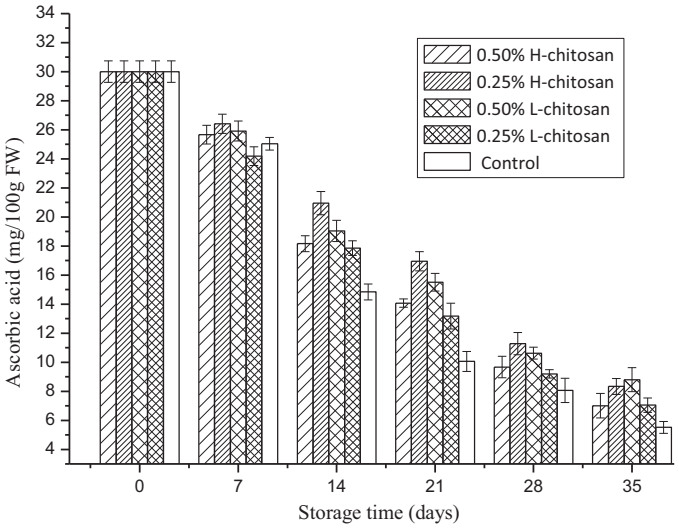

Fig. 3. Changes in ascorbic acid content of asparagus stored at 2 °C for 35 days. Each data point is the mean of three replicate samples. Vertical bars represent standard deviation of means.

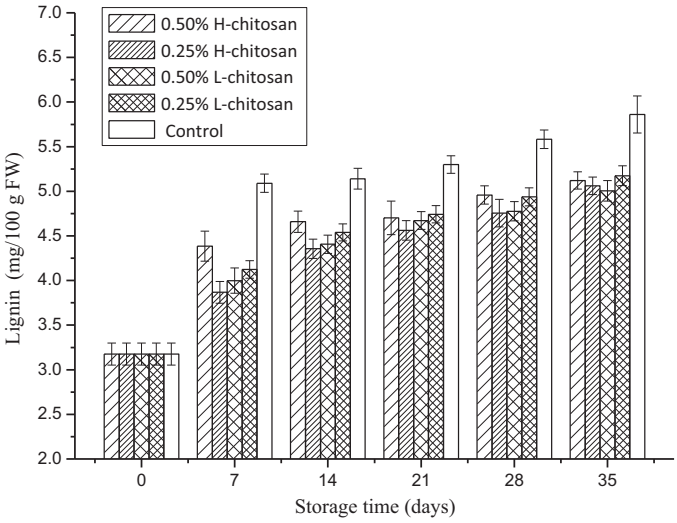

Fig. 5. Changes in lignin content of asparagus stored at 2 °C for 35 days. Each data point is the mean of three replicate samples. Vertical bars represent standard deviation of means.

favored by the presence of O_2, the incorporation of chitosan to coating formulations may reduce O_2 diffusion, slow down the ripening rate, and consequently better maintain ascorbic acid content and delay senescence of asparagus.

3.3. Effect of chlorophyll

Chlorophyll, the pigment that makes green asparagus green, is the fat soluble and sensitive to acids. A significant loss of chlorophyll content was observed during the storage period in control samples compared to chitosan treatment samples (Fig. 4). From the appearance of all of the asparagus samples, the green was gradually discolored during the storage. Subsequently, asparagus samples turned to light yellow while the total chlorophyll content was under 40.00 mg/100 g FW after 28 days. However, to the extent, chitosan coating can retard the loss of total chlorophyll content of green asparagus. At the 35th day, the total chlorophyll content of 0.25% H-chitosan coated green asparagus was 40.15 mg/100 g FW, and 0.50% L-chitosan coated was 38.96 mg/100 g FW. Whereas, the total chlorophyll content of the uncoated green asparagus was only 30.00 mg/100 g FW. Based on the above results, chitosan coating exhibited beneficial effect on the reduction of color changes in asparagus.

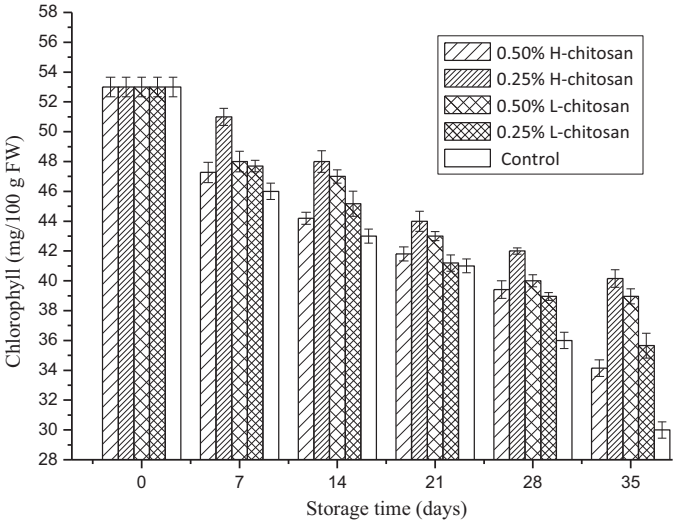

Fig. 4. Changes in chlorophyll content of asparagus stored at 2 °C for 35 days. Each data point is the mean of three replicate samples. Vertical bars represent standard deviation of means.

3.4. Effect of lignin

Lignin is the cell wall component frequently associated with tissue hardening and plays an important role in the textural attributes of asparagus. Fig. 5 represents the lignin content of the different treatments of samples, expressed in mg of lignin/kg fresh weight (FW). During storage of asparagus, very rapid increases were observed in the lignin levels. None of the treatments applied was able to maintain the lignin levels close to those of the fresh product. However, H-chitosan and L-chitosan treatments could slow the rate of increase in this composition levels during the storage, especially 0.25% H-chitosan and 0.50% L-chitosan coated. At the 35th day, the lignin content of 0.25% H-chitosan and 0.50% L-chitosan treated sample were 5.06, 5.00 mg/100 g FW, respectively. Whereas the lignin content of untreated sample was up to 5.86 mg/100 g FW. The lignification in asparagus is controlled by different enzymes, among them phenylalanine ammonialyase (PAL) which is a key enzyme in the biosynthetic pathway of flavonoids such as anthocyanins and lignin; its activity is stimulated by low temperature and light (Flores, Oosterhaven, Martínez-Madrid, & Romojaro, 2005; Tzoumaki et al., 2009). The result exhibited that 0.25% H-chitosan and 0.50% L-chitosan treated could inhibit and regulate of this enzyme activity thus maintain the asparagus quality.

3.5. Sensory quality

Changes in sensory quality of coated and control asparagus stored at 2 °C for 35 days were presented in Table 1. Kramer (1965) stated that the appearance of the product usually determines whether a product is accepted or rejected; therefore this is one of the most critical quality attributes. On the basis of data in Table 1, sensory quality of the control dramatically declined along with the storage. However, overall visual quality, off-odor color and texture of the samples treated with 0.25% H-chitosan and 0.50% L-chitosan maintained higher sensory quality scores compared to the control ($P < 0.05$), and remained marketable (overall visual quality score >7) during 35 days storage. From the sensory quality point of

Table 1
Effect of H-chitosan and L-chitosan on the sensory evaluation of asparagus spears during storage at 2 °C for 35 days.

Sensory quality attribute	Storage time (days)						
		0	7	14	21	28	35
Overall	Control	9.0 ± 0.0	8.2 ± 0.1^{b}	7.6 ± 0.2^{b}	7.2 ± 0.3^{d}	7.0 ± 0.1^{b}	6.3 ± 0.4^{b}
visual quality	0.50% H-chitosan	9.0 ± 0.0	8.6 ± 0.2^{a}	8.2 ± 0.1^{a}	7.8 ± 0.2^{b,c}	7.6 ± 0.2^{a,b}	7.0 ± 0.2^{a,b}
	0.25% H-chitosan	9.0 ± 0.0	8.6 ± 0.1^{a}	8.4 ± 0.2^{a}	8.2 ± 0.2^{a,b}	8.0 ± 0.4^{a}	7.2 ± 0.3^{a}
	0.50% L-chitosan	9.0 ± 0.0	8.6 ± 0.2^{a}	8.4 ± 0.2^{a}	8.3 ± 0.1^{a}	8.2 ± 0.1^{a}	7.3 ± 0.1^{a}
	0.25% L-chitosan	9.0 ± 0.0	8.6 ± 0.1^{a}	8.1 ± 0.2^{a}	7.5 ± 0.3^{c,d}	7.2 ± 0.3^{b}	6.5 ± 0.4^{b}
Off-odor	Control	1.0 ± 0.0	1.7 ± 0.3^{a}	2.1 ± 0.2^{a}	2.5 ± 0.3^{a}	2.8 ± 0.3^{a}	3.5 ± 0.1^{a}
	0.50% H-chitosan	1.0 ± 0.0	1.2 ± 0.1^{b}	1.7 ± 0.1^{a,b}	2.0 ± 0.1^{a,b}	2.5 ± 0.2^{a,b}	3.0 ± 0.2^{a,b,c}
	0.25% H-chitosan	1.0 ± 0.0	1.1 ± 0.1^{b}	1.5 ± 0.2^{a,b,c}	1.8 ± 0.2^{b}	2.3 ± 0.4^{a,b}	2.8 ± 0.3^{b,c}
	0.50% L-chitosan	1.0 ± 0.0	1.1 ± 0.2^{b}	1.4 ± 0.3^{c}	1.7 ± 0.1^{b}	2.1 ± 0.1^{b}	2.6 ± 0.2^{c}
	0.25% L-chitosan	1.0 ± 0.0	1.3 ± 0.1^{a,b}	1.9 ± 0.2^{a,b}	2.3 ± 0.3^{a}	2.5 ± 0.2^{a,b}	3.2 ± 0.4^{a,b}
Color	Control	1.0 ± 0.0	1.4 ± 0.2^{a}	1.7 ± 0.2^{a}	2.0 ± 0.3^{a}	2.3 ± 0.2^{a}	2.8 ± 0.1^{a}
	0.50% H-chitosan	1.0 ± 0.0	1.1 ± 0.1^{a}	1.3 ± 0.1^{b}	1.6 ± 0.1^{a,b}	1.8 ± 0.2^{a}	2.0 ± 0.2^{b}
	0.25% H-chitosan	1.0 ± 0.0	1.1 ± 0.1^{a}	1.3 ± 0.1^{b}	1.5 ± 0.2^{b}	1.7 ± 0.4^{a}	2.0 ± 0.3^{b}
	0.50% L-chitosan	1.0 ± 0.0	1.1 ± 0.2^{a}	1.3 ± 0.1^{b}	1.5 ± 0.1^{b}	1.8 ± 0.1^{a}	2.1 ± 0.2^{b}
	0.25% L-chitosan	1.0 ± 0.0	1.1 ± 0.1^{a}	1.4 ± 0.2^{a,b}	1.7 ± 0.3^{a,b}	1.9 ± 0.2^{a}	2.3 ± 0.2^{a,b}
Texture	Control	1.0 ± 0.0	1.8 ± 0.3^{a}	2.2 ± 0.2^{a}	2.5 ± 0.3^{a}	2.9 ± 0.2^{a}	3.5 ± 0.2^{a}
	0.50% H-chitosan	1.0 ± 0.0	1.3 ± 0.1^{a,b}	1.7 ± 0.1^{a,b}	2.0 ± 0.1^{a,b}	2.4 ± 0.2^{a,b}	3.1 ± 0.2^{a,b,c}
	0.25% H-chitosan	1.0 ± 0.0	1.2 ± 0.2^{b}	1.5 ± 0.2^{b}	1.8 ± 0.2^{b}	2.3 ± 0.4^{a,b}	2.7 ± 0.1^{b,c}
	0.50% L-chitosan	1.0 ± 0.0	1.4 ± 0.2^{a,b}	1.8 ± 0.2^{a,b}	2.0 ± 0.2^{a,b}	2.1 ± 0.1^{b}	2.6 ± 0.2^{c}
	0.25% L-chitosan	1.0 ± 0.0	1.5 ± 0.1^{a,b}	1.8 ± 0.3^{a,b}	2.1 ± 0.2^{a,b}	2.5 ± 0.2^{a,b}	3.2 ± 0.3^{a,b}

Mean of three replications ± standard deviation. Means in the same row with different letters are significantly different ($P < 0.05$).

view, a shelf-life extension of 7 days was achieved by the treatment with 0.25% H-chitosan and 0.50% L-chitosan.

4. Conclusions

Fresh postharvest green asparagus rapidly deteriorates due to its high respiration rate. The present work studied the effects of postharvest green asparagus quality by coating with different chitosan and stored at 2 °C for 35 days. On the basis of the results including evaluation for texture, lignin increase and losses of chlorophyll, ascorbic acid and weight loss too, it can be safely concluded that chitosan coatings could extend the shelf life of postharvest green asparagus. Basically, 0.25% H-chitosan and 0.50% L-chitosan treatments ensured lower color variation, weight loss and ascorbic acid, exhibiting better quality of asparagus compared with others, and prolonging a shelf life of postharvest green asparagus. In a word, 0.25% H-chitosan coating could extend the shelf life of the postharvest green asparagus about 9 days, and it is up to 43% prolongation compared to control from the sensory quality. Thereby, the present results are useful for further development of natural biomaterials which can be widely used as food preservative.

Acknowledgments

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