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Browning inhibition and postharvest quality of button mushrooms (*Agaricus bisporus*) treated with alginate and ascorbic acid edible coating

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Abstract

The effects of alginate and ascorbic acid coating treatment on browning inhibition and quality of button mushrooms (*Agaricus bisporus*) were ascertained during refrigerated storage at 4°C. Mushrooms were treated with 2% sodium alginate (SA), 0.2% ascorbic acid solution (Vc), and 2% SA + 0.2% Vc, and then enclosed in plastic boxes at 4°C for 16 d. Results showed that the use of 2% SA + 0.2% Vc during refrigerated storage could suppress the climacteric peak, reduce weight loss, maintain firmness, decrease colour degradation and Vc level, and inhibit PPO and POD activities. Results also showed that 2% SA + 0.2% Vc could be a useful method for retaining the postharvest quality and prolonging shelf life of button mushrooms.

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Introduction

Button mushroom (*Agaricus bisporus*) is the most widely cultivated mushroom, comprising 10% of all edible mushrooms (Wu *et al.*, 2019). The consumption of button mushrooms has continuously increased in recent years due to their delicious taste and health benefits (Nasiri *et al.,* 2017). However, like other food commodities, fresh button mushrooms are perishable and have a short shelf life due to their high respiration rate and lack of physical barrier or protection to prevent water loss or microbial attack (Singh *et al.,* 2010). The limited shelf life is an obstacle towards the distribution and commercialisation of fresh button mushrooms. Less than half of cultivated button mushrooms are consumed fresh (Singh *et al.,* 2010). Therefore, extending the shelf life of button mushrooms would benefit both the industry and consumers (Fernandes *et al.,* 2012). Various preservation methods have been reported to prolong the shelf life of button mushrooms such as refrigeration, chemical treatment, and modified atmosphere packaging. However, these methods have some shortcomings such as high cost, potential health risks, water accumulation which promotes microbial growth, and sliminess (Singh *et al.,* 2010).

Coating with semi-permeable films is a popular preservation method to extend the shelf life of mushrooms. The coating materials have a unique colloidal characteristic that can help to reduce shrinkage, prevent microbial contamination, and maintain flavour and appearance. Alginate is a type of edible coating material extracted from brown algae. It can react with polyvalent metal cations such as calcium ions to form strong gels or insoluble polymers (Rhim, 2004). As a generally recognised as safe (GRAS) substance approved by the FDA, alginate is the best option to be used as an edible coating other than being cheap, easy to use, non-allergenic, and biocompatible (Hershko and Nussinovitch, 1998). Besides, alginate coating has also been found to reduce natural microflora counts and prolong the shelf life of vegetables (Shigematsu *et al.,* 2018), fruits (Fan *et al.,* 2009), meats (Comaposada *et al.*, 2018), and aquatic products (Song *et al.,* 2011).

In order to enhance the properties of an edible coating, food additives such as anti-browning agents could be added (Lee *et al.,* 2003). Browning is a major problem for button mushrooms during

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postharvest storage which affects their marketability and consumer acceptability. As the best known antioxidant, vitamin C (Vc) interacts enzymatically and non-enzymatically with damaging oxygen radicals and their derivatives. It can thus be used to inhibit enzymatic browning and prolong the shelf life of foods. Prasad *et al.* (2016) found that postharvest dip application of Vc at 150 ppm reduced lenticel browning in mango, and improved the appearance without impairing fruit quality. Ojeda *et al.* (2014) showed that a cassava starch coating containing Vc could prevent the browning of processed sweet potatoes.

To the best of our knowledge, little published data exists on the incorporation of anti-browning agents into alginate coating for application on button mushrooms. Therefore, the present work was undertaken to investigate the effect of alginate coating in combination with Vc on both the physicochemical properties and postharvest quality of fresh button mushrooms.

Materials and methods

Materials

Button mushrooms were harvested from a local farm in Beijing, China, and selected for uniformity and maturity; any bruised or diseased mushrooms were discarded. The selected mushrooms were transported to the laboratory within 1 h after harvest, and refrigerated at 4 ± 1°C in darkness with 90% relative humidity. All chemicals were of analytical grade, and sourced from within China, unless otherwise mentioned.

Coating preparation

Food-grade sodium alginate (SA; Nanshan Biological Technology Co., Ltd. Qingdao, China) was used to prepare the edible coating. SA concentrations were selected based on preliminary screening; 2% (w/v) SA solution was prepared by dissolving 20 g SA powder in 1 L distilled water at 70°C, and then stirred with a magnetic stirrer until the mixture became clear. The prepared SA solution was mixed with food-grade glycerol (10%, w/w) which served as a plasticiser.

In a preliminary experiment, SA solution with one of three different concentrations of Vc [0.1, 0.2, and 0.3% (w/v)] was coated onto fresh button mushrooms, and the inhibition of mushroom browning was observed. The alginate coating with ascorbic acid (SA + Vc) at the concentrations of 0.1 and 0.2% had significant inhibitory effects, especially at 0.2%. Some physiological injuries were found on button mushrooms with 0.3% Vc treatment. Therefore, 0.2% Vc concentration was selected.

Freshly harvested button mushrooms were randomly divided into four groups, then dipped into their respective solutions for 2 min: (1) control group (CK; distilled water); (2) SA (2% sodium alginate solution); (3) Vc (0.2% ascorbic acid solution); and (4) SA + Vc (2% sodium alginate + 0.2% ascorbic acid solution). The samples were drained and air-dried for 10 min, and immersed in 2% (w/v) calcium chloride solution for another 1 min. The treated mushrooms were then placed in food-grade polypropylene boxes. All samples were refrigerated in a cold room at 4 ± 1°C at a relative humidity of 80 - 90% for 16 d. Three replicate samples from each treatment group and the control group were analysed initially, and then every 4 d thereafter during the storage period.

Respiration rate

The respiration rate was measured according to Luo *et al.* (2007) with slight modifications. Approximately, 200 g of button mushrooms per replicate were enclosed in a glass jar at 4°C with air flow. The effluent air was connected to a GXH-3051 infrared CO_2 analyser (Institute of Junfang Scientific Instrument of Beijing, China), and measured every 4 d during the storage period. Measurements were replicated three times for each of the treatment and control samples. Respiration rate (R) was expressed as rate of CO_2 production, using Eq. 1:

$$R\ (\mathrm{mg\ CO_2 kg^{-1} h^{-1}}) = \frac{F \times 60 \times C}{22.4} \times \frac{44}{W} \times 10^{-6} \times \frac{273}{273+T} \quad \text{(Eq. 1)}$$

where, F = flow rate (500 mL/min); C = concentration of CO_2; W = weight of the samples; and T = temperature (Luo *et al.,* 2007).

Weight loss

The weight loss (WL) was determined by weighing each sample every 4 d during the storage period, and expressed as a percentage of loss in weight with respect to the initial weight, using Eq. 2:

$$WL\% = \frac{IW - FW}{IW} \times 100 \quad \text{(Eq. 2)}$$

where, IW = initial weight; and FW = final weight.

Firmness

A penetration test was applied on the mushroom caps of samples using a 5-mm-diameter cylindrical probe of a fruit sclerometer (GY-J, Top Instrument Co., Ltd, Zhejiang, China). Ten mushroom caps from each treatment group were subjected to a penetration of 5 mm in depth at a constant speed (1 mm/s), and the maximum force was measured (Mohebbi *et al.,* 2012).

Colour

The surface colour of the mushroom caps was determined by measuring L* (lightness), a* (red-green), and b* (yellow-blue) parameters with a Minolta spectrophotometer (CR-400, Konica Minolta Sensing Inc., Tokyo, Japan). The instrument was calibrated with a standard white calibration plate. Readings were taken at three equidistant points on each mushroom cap. Twelve mushrooms of each treatment were analysed, and the measured values were averaged. The ΔE was used to describe the comparison with the ideal mushroom colour values of L^* = 97, a* = -2, and b* = 0, using Eq. 3:

$$\Delta E = \left[(L-97)^2 + \left(\mathrm{a}-(-2)\right)^2 + \mathrm{b}^2\right]^{\frac{1}{2}} \quad \text{(Eq. 3)}$$

The browning index (BI), which has previously been proven effective in monitoring browning of fresh mushrooms (Cliffe-Byrnes and O'Beirne, 2008), was determined using Eqs. 4 and 5:

$$\mathrm{BI} = \frac{100(\mathrm{x}-0.31)}{0.172} \quad \text{(Eq. 4)}$$

where,

$$x = \frac{\mathrm{a}+1.75L}{5.645\mathrm{L}+\mathrm{a}-3.012\mathrm{b}} \quad \text{(Eq. 5)}$$

Malondialdehyde

MDA was determined following the method described by Ge *et al.* (2017) with slight modifications. For each treatment group and control group, 2 g mushroom sample from 12 fruiting bodies was ground in 2 mL of 100 g/L trichloroacetic acid (TCA), and centrifuged at 13,000 *g* (D-37520, Sigma Laborzentrifugen GmbH, German) for 30 min. Next, 2 mL of the supernatant was mixed with 2 mL of 100 g/L TCA and 2 mL of 0.67% thiobarbituric acid. The mixture in the tube was heated in a boiling water bath for 20 min, cooled, and further centrifuged at 15,000 *g* for another 10 min. Absorbance of the supernatants were measured at 450, 532, and 600 nm, respectively. The MDA content was determined using Eq. 6, and expressed as μmol/g FW (fresh weight):

$$\mathrm{MDA} = [6.45 \times \mathrm{OD}_{532} - \mathrm{OD}_{600}] - 0.56 \times \mathrm{OD}_{450}] \times 10^3 \quad \text{(Eq. 6)}$$

Electrolyte leakage

Electrolyte leakage was measured and calculated as described by Cliffe-Byrnes and O'Beirne (2008) with slight modifications. Disks (2 mm thick) of the pileus were excised with a 10-mm diameter stainless steel cork-borer. Next, 2 g disks were placed into a tube with 20 mL of deionised water, and shaken for 30 min. The initial conductivity (IC) was measured with a conductivity meter (EC215, Hanna Instruments, Inc., Padova, Italy). Samples in the tubes were then boiled for 10 min, cooled, and the final conductivity (FC) was recorded. The relative electrolyte leakage rate (C) was calculated using Eq. 7:

$$\mathrm{C}\,(\%) = (\mathrm{IC}/\mathrm{FC}) \times 100\% \quad \text{(Eq. 7)}$$

Ascorbic acid

Ten whole mushrooms from each treatment group and control were ground with mortar and pestle. The resulting juice was evaluated by refractometer (PR-100, Atago Co. Ltd, Japan). The ascorbic acid content in mushroom samples was determined as described by Jiang *et al.* (2012).

Polyphenol oxidase (PPO) and suppressed peroxidase (POD) activates

The peeled mushrooms were homogenised at 4°C. Next, 4 g of homogenised sample was mixed with 12 mL of 100 mM sodium phosphate (pH 6.4) buffers and 0.2 g of polyvinyl polypyrrolidone (PVPP). The homogenate was centrifuged at 15,000 *g* for 30 min at 4°C, and the supernatant was used for the enzyme assay. The protein content was determined according to the method of Bradford (1976), with bovine serum albumin used as the standard. The activities of PPO and POD were analysed following the method of Jiang (2013) with slight modifications. PPO activity was determined by adding 100 μL of enzyme preparation to 4.0 mL of catechol substrate solution (prepared by 500 mM

catechol substrate in 100 mM pH 6.0 sodium phosphate buffer), and the increase in absorbance at 398 nm was measured immediately. One PPO unit was defined as the amount causing 0.01 increase in absorbance per minute. The specific PPO activity was expressed as U/mg protein. POD activity was determined with guaiacol as substrate. The reaction mixture consisted of 1 mL of enzyme prepared, 1 mL of 24 mM H_2O_2, 2 mL of 100 mM (pH 6.4) sodium phosphate buffer, and 8 mM guaiacol; the mixture was incubated for 30 min at 30°C. After boiling the enzyme for 10 min, the enzyme solution was used for the blank control. One POD unit was defined as the amount causing 0.01 increase in absorbance at 460 nm per minute. The specific POD activity was expressed as U/mg protein.

Statistical analysis

All experiments were performed in triplicate. Data were subjected to One-way ANOVA, and mean separations were carried out by Duncan's multiple range test (DPS Version 7.05). Differences at $p < 0.05$ were considered significant.

Results and discussion

Effects of edible coatings on respiration rate of stored button mushrooms

The effects of SA and Vc on the respiration rate of button mushrooms during 16 d of storage are shown in Figure 1A. As a climacteric fruit, button mushrooms exhibited a high initial respiration rate (139.18 mg CO_2/kg/h) which may have resulted from harvest stress due to the cutting process, and the initial loss of nutrients and water. The control group showed a higher rate of respiration in the first 8 d after harvest as compared to the treatment groups, with an initial mild increase to a climacteric peak (161.21 mg CO_2/kg/h) on day 4, then a gradual decrease thereafter. The climacteric peaks of button mushrooms treated with SA (135.1 mg CO_2/kg/h, day 8) and SA + Vc (138.74 mg CO_2/kg/h, day 12) were delayed relative to the control. Similar respiratory behaviour was found in mango (Prasad *et al.,* 2016). It was reported that treatments with a coating could suppress the production of a climacteric peak. In the present work, after 12 d of storage, there was no difference between control and coated samples (SA and SA + Vc treatments). Mushrooms treated with Vc showed a lower respiration rate than control mushrooms in the first 8 d, which may be attributed to the antioxidant capacity of Vc in the edible coating. After 8 d, the respiration rate rapidly increased which may be due to the minor injury on mushroom surface caused by the low pH of Vc.

Effects of edible coatings on weight loss of stored button mushrooms

The weight loss of all samples increased during the 16 d of storage (Figure 1B). At the end of the total storage time, the weight losses were all smaller than 3% of the initial weights of their respective samples. Similar results were observed by Jiang for button mushrooms (Jiang, 2013). In the present work, the control sample and the sample treated with Vc showed higher weight losses of 2.7 and 2.8%, respectively. The higher weight losses for these samples could be explained by the lack of a cuticle to protect the mushroom from superficial dehydration. The final weight losses during storage of the mushroom samples coated with SA and SA + Vc were significantly lower ($p < 0.05$) than those of the control and the Vc treatment, at 47.7 to 53.3% lower. This could be due to the fact that biopolymer-based films reduce transpiration and create a mini-modulated atmosphere as a semi-permeable barrier around each coated mushroom.

Effects of edible coatings on texture of stored button mushrooms

Texture is an important quality characteristic of button mushrooms, and an indicator of their water content and metabolism. The firmness values of button mushroom samples during 16 d of storage are illustrated in Figure 1C. Coating button mushrooms with SA had a significant positive effect ($p < 0.05$) on the maintenance of the firmness during storage as compared to Vc and control. SA + Vc yielded the highest firmness values for button mushrooms at each tested storage time, thus implying a synergistic effect of SA and Vc. The SA + Vc samples lost only about 19.4% of their initial firmness by the end of 16 d of storage. In contrast, Vc had the greatest loss in firmness, greater even than the control, at each storage time; Vc lost about 34% of their initial firmness by the end of the study. SA was found to be able to significantly inhibit the loss of firmness, which was similar to the conclusions obtained by Jiang *et al.* (2012). Softening of mushroom tissue was shown to be related to protein and polysaccharide losses, and cell wall degradation due to the increased activity of endogenous autolysins and extracellular

enzymes of bacteria (Jiang, 2013; Gao *et al.,* 2014). The micro-atmosphere provided by coating a food may inhibit the enzymatic activities, thus maintaining the food's firmness.

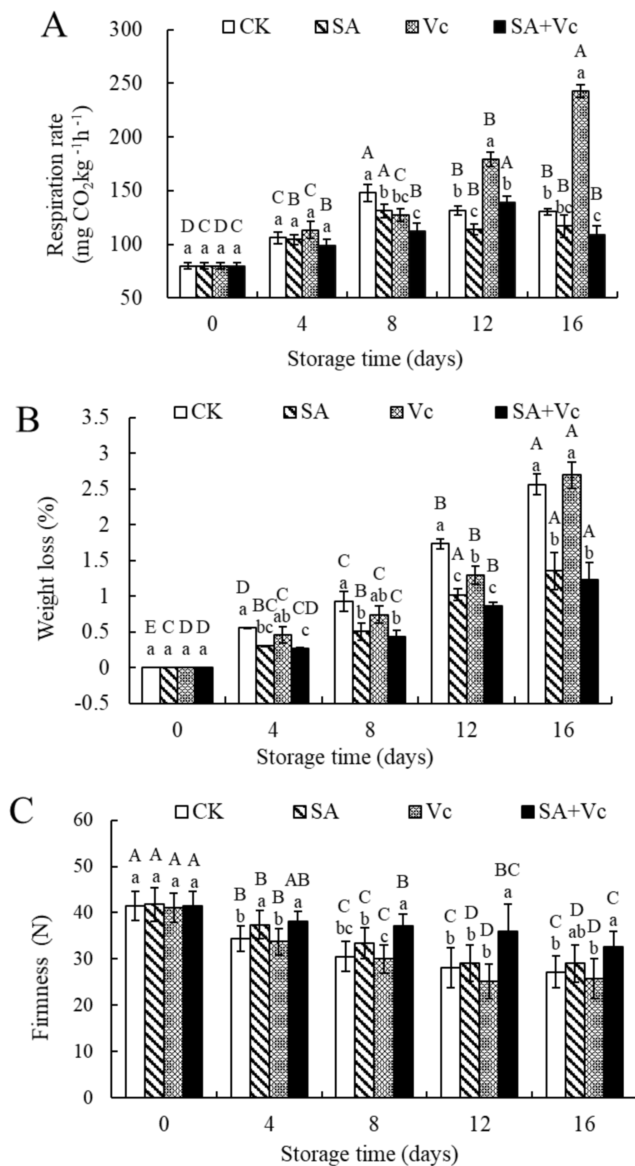

Figure 1. Changes in respiration rate **(A)**, weight loss **(B)**, and firmness **(C)** of button mushrooms treated with control (CK), 2% sodium alginate solution (SA), 0.2% ascorbic acid solution (Vc), and 2% sodium alginate solution + 0.2% ascorbic acid solution (SA + Vc) stored at 4°C for 16 days. Values are mean with bar indicating standard error of three replicates (n = 3). Means followed by different lowercase letters within a column are significantly different ($p < 0.05$) between treatments for a same storage time. Means followed by different uppercase letters within a column are significantly different ($p < 0.05$) between values measured at different storage times for a same treatment.

Effects of edible coatings on malondialdehyde of stored button mushrooms

As shown in Figure 2A, the content of MDA in treated and untreated mushrooms increased gradually, whereas MDA in the samples treated with SA + Vc retained lower levels than control during the entire storage. SA + Vc significantly attenuated the accumulation of MDA at 4 d of storage. MDA, one of the end products of membrane lipid peroxidation, and electrolyte leakage show the level of membrane damage (Janero, 1990; Ge *et al.,* 2017; Nasiri *et al.,* 2017). Therefore, SA + Vc could alleviate the injury caused by lipid peroxidation and delay senescence during the storage.

Effects of edible coatings on colour of stored button mushrooms

In the case of button mushrooms, browning is one of the most serious postharvest problems affecting both consumer acceptance and marketability. The external colour was evaluated by measuring lightness (L*), total colour variation (Δ*E*), and browning index (BI). From the whiteness point of view, L* values under 80 are considered as commercially unacceptable (Briones *et al.,* 1992). As shown in Table 1, the L* values gradually decreased in coated and uncoated mushrooms during storage. As compared to control, significantly higher L* values were observed after day 8 in mushrooms coated with SA + Vc. SA had lower L* values than control during the first 8 d, showing no significant differences. Vc slowed the rate of decrease in L* value, and maintained the mushroom whiteness until day 12, after which it rapidly decreased, and there were no significant differences between Vc and control in terms of L* values. By day 4 of storage, Δ*E*- and BI values of SA + Vc were the lowest, and significantly different from SA.

In general, edible coating are not colourless and transparent. Due to the native colour of coating, SA had lower L* value than control, which was similar to the effect of chitosan coating (Kim *et al.* 2006). Both alginate and chitosan coating had negative effects on the whiteness of mushrooms. Vc has been reported extensively for its anti-browning activity in processed fruits and vegetables because of its non-toxic qualities (Son *et al.,* 2001; Singh *et al.,* 2010). The delay in mushroom browning by Vc is due to the ability of Vc to scavenge the damaging radicals immediately and reduce the quinones produced by PPO (Prasad *et al.,* 2016).

Mushrooms treated with SA + Vc generally looked whiter than other mushrooms after 8 d, which may be ascribed to a synergistic effect of Vc and SA. SA coating around the mushroom surface postponed the enzymatic browning by decreasing the oxygen-uptake. Combined with the radical-scavenging effects of Vc, SA + Vc significantly improved the mushroom colour relative to SA by day 8.

Effects of edible coatings on electrolyte leakage of stored button mushrooms

The changes in electrolyte leakage with storage time can indicate integrity degree of the cell membrane (Hildebrand *et al.,* 1989). As shown in Figure 2B, the electrolyte leakage of all samples gradually increased during storage. Compared with other treatments, SA + Vc slowed the increase in electrolyte leakage rate to a significant extent. The electrolyte leakage rate of the SA + Vc mushrooms was 9.56% in comparison to 10.35% of the control group on day 4. At the end of storage, electrolyte leakage rates of the mushrooms coated with SA + Vc and the control were 13.47 and 18.41%, respectively. The lowest relative leakage rate (day 16) indicated that SA + Vc showed higher membrane integrity, thus consequently extending the mushroom's shelf life.

Effects of edible coatings on vitamin C of stored button mushrooms

The Vc losses during fruits and vegetables ripening are attributed to its antioxidant ability which can reduce the damage caused by reactive oxygen species (ROS). The changes in the Vc content of mushrooms during storage are shown in Figure 2C. The Vc content of all samples decreased rapidly during the first 4 d, then steadily decreased thereafter, while any coating treatment significantly decreased the loss of Vc in mushrooms. The addition of Vc may improve the antioxidant activity of SA; however, by the end of storage, no significant difference was found in the Vc content of mushrooms treated with SA (49.5 mg/kg FW) as compared to SA + Vc treatment (50.6 mg/kg FW). Coating treatments could decrease oxygen diffusion, and consequently could have maintained the content of Vc. Similarly, Jiang (2013) reported that alginate coating delayed losses in the Vc content of button mushrooms even in the presence of 100% O_2. As another commonly used edible coating, chitosan coating was also effective in retaining the content of Vc in vegetables such as sponge gourd (Han *et al.,* 2014). In conclusion, edible coatings could delay losses of the Vc content.

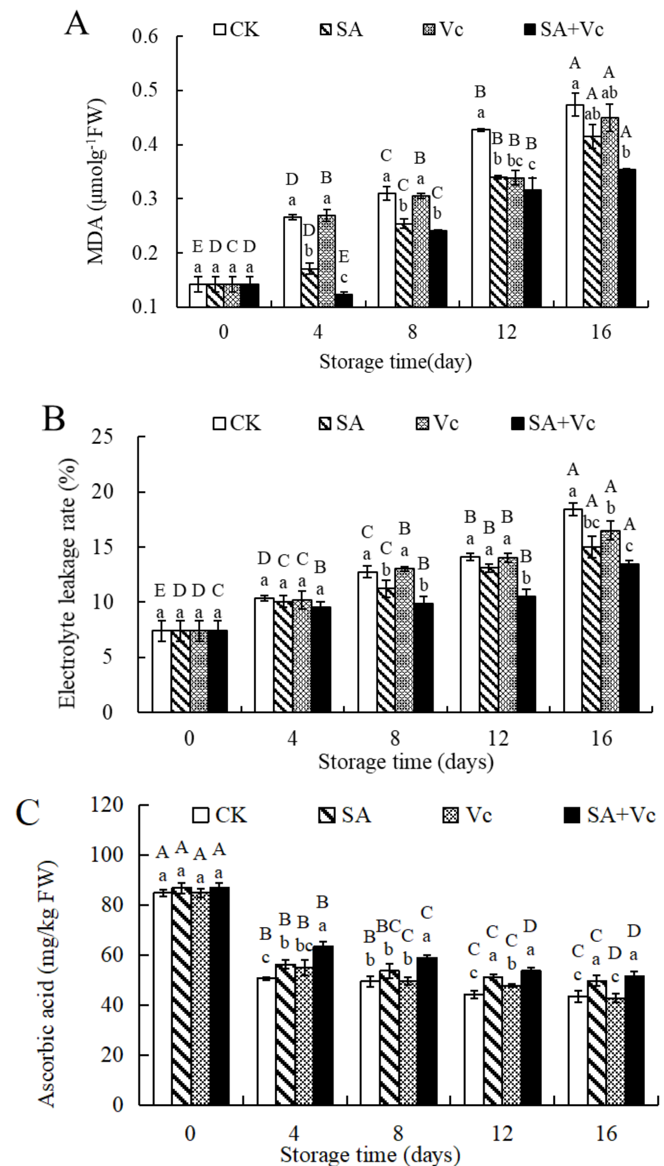

Figure 2. Changes in MDA **(A)**, electrolyte leakage rate **(B)**, and ascorbic acid **(C)** of button mushrooms treated with control (CK), 2% sodium alginate solution (SA), 0.2% ascorbic acid solution (Vc), and 2% sodium alginate solution + 0.2% ascorbic acid solution (SA + Vc) stored at 4°C for 16 days. Values are mean with bar indicating standard error of three replicates (n = 3). Means followed by different lowercase letters within a column are significantly different (p < 0.05) between treatments for a same storage time. Means followed by different uppercase letters within a column are significantly different (p < 0.05) between values measured at different storage times for a same treatment.

Table 1. Changes in colour (L*), total colour variation (ΔE), and browning index (BI) of button mushrooms treated with control (CK), 2% sodium alginate solution (SA), 0.2% ascorbic acid solution (Vc), and 2% sodium alginate solution + 0.2% ascorbic acid solution (SA + Vc) stored at 4°C for 16 days.

Treatment	L*	ΔE	BI
0 d			
Control	90.53 ± 0.57^{Aa}	15.58 ± 0.47^{Ed}	16.92 ± 0.30^{Ed}
SA	87.50 ± 0.71^{Ad}	18.69 ± 0.48^{Ea}	20.68 ± 0.24^{Ea}
Vc	90.02 ± 0.17^{Ab}	16.25 ± 0.79^{Ec}	17.81 ± 0.64^{Ec}
SA + Vc	89.24 ± 0.69^{Ac}	16.89 ± 0.37^{Db}	18.41 ± 0.57^{Db}
4 d			
Control	89.39 ± 0.85^{Ba}	17.50 ± 0.59^{Dbd}	19.47 ± 0.71^{Db}
SA	87.14 ± 0.80^{Ad}	19.77 ± 0.46^{Da}	22.35 ± 0.62^{Da}
Vc	89.11 ± 0.93^{Bab}	17.63 ± 0.66^{Db}	19.68 ± 0.78^{Db}
SA + Vc	88.78 ± 0.65^{Ab}	17.11 ± 0.74^{Dd}	18.56 ± 0.94^{Dd}
8 d			
Control	87.21 ± 0.67^{Ca}	20.74 ± 0.63^{Cb}	23.93 ± 0.98^{Ca}
SA	85.45 ± 0.90^{Bb}	21.52 ± 0.47^{Ca}	24.45 ± 0.72^{Ca}
Vc	87.20 ± 0.95^{Ca}	20.46 ± 0.87^{Cb}	23.66 ± 0.80^{Ca}
SA + Vc	87.39 ± 0.65^{Ba}	18.92 ± 0.87^{Cd}	20.91 ± 1.19^{Cb}
12 d			
Control	83.57 ± 0.59^{Dc}	23.29 ± 0.41^{Bb}	27.72 ± 0.52^{Bb}
SA	84.99 ± 0.42^{BCb}	22.48 ± 0.25^{Bc}	25.93 ± 0.32^{Bc}
Vc	83.10 ± 0.88^{Dd}	24.05 ± 0.48^{Ba}	29.17 ± 0.43^{Ba}
SA + Vc	86.78 ± 0.59^{Ca}	20.99 ± 0.69^{Bd}	23.58 ± 0.63^{Bd}
16 d			
Control	82.07 ± 1.56^{Eb}	25.28 ± 0.45^{Ab}	30.89 ± 0.89^{Ab}
SA	84.53 ± 0.85^{Ca}	23.24 ± 0.25^{Ac}	27.11 ± 0.24^{Ac}
Vc	82.68 ± 2.08^{Db}	26.79 ± 0.61^{Aa}	32.46 ± 0.61^{Aa}
SA + Vc	85.45 ± 0.89^{Da}	22.06 ± 0.76^{Ad}	25.33 ± 0.76^{Ad}

Data are mean ± standard deviation of three replications ($n = 3$). Means followed by different lowercase superscripts within a column are significantly different ($p < 0.05$) between treatments for a same storage time. Means followed by different uppercase superscripts within a column are significantly different ($p < 0.05$) between values measured at different storage times for a same treatment. L* values under 80 are considered as commercially unacceptable.

Effects of edible coatings on PPO and POD of stored button mushrooms

PPO and POD play an essential role as enzymes that catalyse browning reactions in mushrooms. The activity of PPO in control group increased rapidly during the storage, however, a more slightly increase was observed in SA + Vc as compared to the other treatment (Figure 3A). The changes in POD activity of button mushrooms during storage are shown in Figure 3B. The POD activity of all samples gradually increased throughout the storage, while SA + Vc significantly inhibited POD activity in button mushrooms.

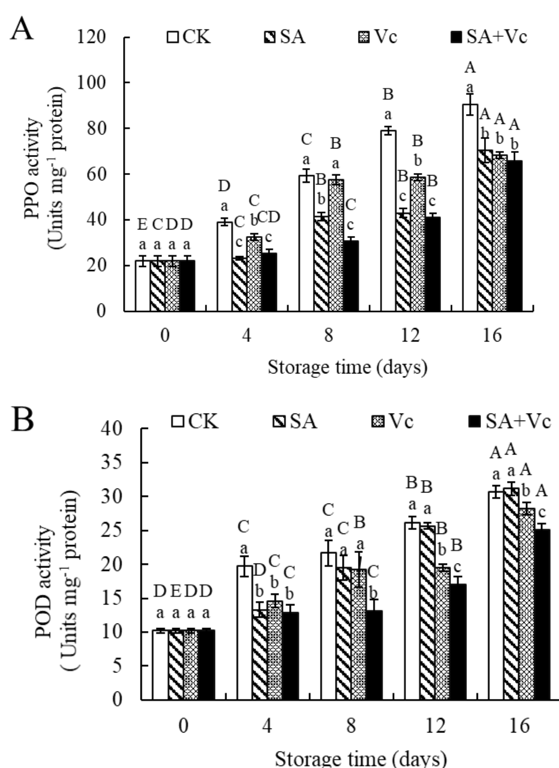

Figure 3. Changes in PPO activity **(A)**, and POD activity **(B)** of button mushrooms treated with control (CK), 2% sodium alginate solution (SA), 0.2% ascorbic acid solution (Vc), and 2% sodium alginate solution + 0.2% ascorbic acid solution (SA + Vc) stored at 44°C for 16 days. Values are mean with bar indicating standard error of three replicates (n = 3). Means followed by different lowercase letters within a column are significantly different ($p < 0.05$) between treatments for a same storage time. Means followed by different uppercase letters within a column are significantly different ($p < 0.05$) between values measured at different storage times for a same treatment.

Conclusion

The present work demonstrated the use of 2% SA and 0.2% Vc to coat mushrooms. This SA + Vc treatment could suppress the production of climacteric peak, reduce weight loss, maintain firmness, colour, content of Vc, and inhibit the activities of PPO and POD. This suggested that coating with 2% SA and 0.2% Vc could be a useful method for retaining the postharvest characteristics, and prolonging shelf life of fresh button mushrooms. Although SA + Vc coating could maintain the physical properties of mushrooms, consumers' acceptance of mushroom edible coating may present a challenge which needs to be solved. In recent years, most studies on food applications have been conducted at a laboratory scale. However, further research more focused on a commercial scale needs to be conducted so that more realistic information can be used to commercialise edible coating for fresh fruits and vegetables. For example, product packers could provide information on the presence of edible coating, or whether the edible coating material could be allergenic; chitosan is an allergenic shellfish material, but alginate is not. Besides reading labelling information, consumers could overcome their concerns on edible coating by rinsing mushrooms with warm water or scrubbing with a brush prior to consumption.

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