Original Paper

Postharvest Shelf-life Extension of Button Mushroom (Agaricus bisporus L.) by Aloe vera Gel Coating Enriched with Basil Essential Oil

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Short postharvest life of button mushroom (Agaricus bisporus L.) is a serious problem in the expansion of marketing and long-distance transportation of this product. Edible coating is an effective way to delay the browning process and mitigate the deterioration of button mushroom. In this study, the impact of Aloe vera gel alone and combined with basil oil as an edible coating on postharvest quality and browning of mushroom has been investigated. Surface morphology of the coated and uncoated mushrooms was studied by scanning electron microscopy (SEM). The results indicated that application of A. vera gel enriched with basil oil significantly alleviated weight loss, softening and respiration rate during the storage. In addition, coated samples delayed browning and color change compared to uncoated samples. Interestingly, total phenolic contents, antioxidant and phenylalanine ammonia lyase activity increased in samples coated by treatment of A. vera and basil oil. Relative electrolyte leakage, malondialdehyde content and polyphenol oxidase activity were also significantly lower in A. vera enriched with basil oil treated samples. These findings suggest that combination of A. vera with basil oil is a promising method to preserve the quality of the button mushrooms during cold storage.

Keywords : antioxidant activity, edible coating, browning, hydrophobic property, phenolic content, polyphenol oxidase

INTRODUCTION

Well-known characteristics of edible mushrooms are their strong nutritional and medicinal properties which help developing the immune system regulation. Mushroom contains low calorie and little fat and offers lots of fiber, amino acid, potassium, vitamins, iron, and even a protein. As a result, dietitians recommend mushroom as an ingredient in a healthy basket food. White button mushroom (Agaricus bisporus L.) are the most common typical example of mushrooms with unique flavor. They exhibit superior free radical scavenging and antioxidant activities (Valverde et al., 2015; Muszynska et al., 2017; Nasiri et al., 2018). However, due to the absence of cuticle which protects them from physical or microbial attacks, mushrooms have a short life span (Gholami et al., 2019). The short shelf life of mushrooms, typically 1–3 days at ambient and 8 days under refrigeration condition, limits their shipping and marketing potential (Qin et al., 2015). Thus, it is trivial that the extension of shelf life of fresh mushrooms, while preserving their quality, is desirable to export/import grocery companies (Jiang et al., 2013). Serious problems contribute to the postharvest deterioration of mushroom such as browning, moisture loss, softening, and high respiration rate (Zhang et al., 2020).

The application of edible coatings has received attention as an effective way to extend the shelf life of fresh products. The edibles coating limit gaseous exchange and moisture loss through fruit and atmosphere by providing an external protective thin layer on the surface and maintain the fruit quality (Thakur et al., 2018; Mohammadi et al., 2021).

A. vera gel as a natural edible coating has been recently developed in food productions and pharmaceutical industries due to antimicrobial activity, biochemical and biodegradability properties. Polysaccharide has been found to be able to control these activities (Sánchez-Machado et al., 2017; Iwanit et al., 2018). A. vera gel contains high polysaccharides and soluble sugars with low lipid contents (0.07–0.42%). It is reported that coating contained both polysaccharide and lipid form more effective barrier to moisture loss and gas permeability compared to polysaccharide-based alone (Hassan et al., 2018; Tzortzakis et al., 2019).

Basil essential oil is well known as a natural antioxidant and antimicrobial additive, which is rich in lipid compound and is a good candidate for composition with A. vera gel to reach the coating with high polysaccharide-lipid composite coating. Basil plant of Lamiaceae family can grow in various regions with different climates around the world and contain in protein, fatty acid, vitamins, and minerals (Hemalatha et al., 2017; Falowo et al., 2019).

The current experiment is carried out to assess the effect of combination of basil oil with A. vera on tissue browning and quality characteristics of button mushroom...
upon 12 days at cold storage.

MATERIALS AND METHODS

Sample preparation

Button mushrooms were harvested from Mitsukura Nourin Inc, Okayama, Japan and transferred to the laboratory. Selection of samples was performed based on the size (10–15 g and 3–5 cm diameter) and uniform shape without any browning symptoms and mechanical damage. The selected 600 homogeneous mushrooms were divided into 4 groups for the following coating treatments in three replicates. Sample groups were immersed in distilled water (control), A. vera gel alone (AV) at 100%, A. vera gel (100%) + 500 µL L⁻¹ leaf basil oil (AVBO1) and A. vera gel (100%) + 1000 µL L⁻¹ leaf basil oil (AVBO2) for 5 minutes at 20℃. All samples were air-dried at 20℃ for 2 hours, then placed in containers (120 mm × 170 mm × 30 mm) and stored at 4℃ with 90% relative humidity.

Coating preparation

A. vera plants were obtained from farmer in Chikugo, Fukuoka, Japan. For preparing the gel of A. vera, mature leaves of A. vera were cut and washed with distilled water. Then, A. vera gel was manually extracted and mixed with a blender (IFM-700 G, Iwatani, Japan) for 2 minutes. Next, it was heated at 70℃ for 15 minutes, and immediately cooled on ice for pasteurization. Leaf basal essential oil (100% purity) obtained from Yuwn Inc., Tokyo with concentrations of 500 and 1,000 µL L⁻¹ were dissolved into Tween-80 (0.001% (v/v)) separately and added to the mixed A. vera gel to achieve AVBO1 and AVBO2, respectively. In the following step, the solutions were homogenized by a rotor-stator homogenizer (Ultra-Turrax T-25, IKA Japan Co.) at a speed of 20,000 rpm for 2 minutes.

The quality of samples was evaluated at 4, 8, and 12 days of storage and compared to the quality of 0 day of untreated samples. A list of quality parameters including weight loss, firmness, respiration rate, total color difference, polyphenol oxidase and phenylalanine ammonia lyase enzymes activities and sensory evaluation were studied at selected days.

Respiration rate

The respiration rate was observed for coated and uncoated mushrooms during cold storage according to the work of Nasrin et al. (2017) with slight modification. Five mushrooms (~50 g fresh weight (FW)) per desiccator (1,000 mL) were selected and incubated for 1 hour at 20℃ (three desiccators per treatments). Desiccators were linked to a gas chromatograph (GC-2014, SHIMADZU, Japan) by tubes. Gas from the headspace of the containers was analyzed automatically by a thermal conductivity detector (TCD) and a flame ionization detector (FID). The concentration of CO₂ gas in the container was detected by TCD. Thus, the results were determined as mgCO₂ kg⁻¹ h⁻¹ (Paladines et al., 2014).

Weight loss

The weight of mushroom in different sample groups was recorded for each replicate (five mushrooms ~50 g for every replicate and 3 replicates per treatments) initial day and at each sampling day during storage by a digital balance (EK-610, A&D, Japan). The weight loss was determined by the following equation:

\[
(WL)(%)=\frac{W_{0} - W_{N}}{W_{0}} \times 100
\]

where, WL is the weight loss, \(W_{0}\) is the weight at \(N = 4, 8, \) and 12 days during storage and \(W_{N}\) is the weight of initial day of storage.

Firmness

The samples were removed from cold storage and held at 20℃ for 15 minutes for textural analysis. Mushroom cap hardness was defined using a creep meter (RE-3305, YAMADEN Co., Ltd., Japan) with a 5 mm diameter cylindrical probe. Samples were penetrated 5 mm in depth at speed of 5 mm s⁻¹. The results were expressed as firmness in N.

Browning index and color change

Surface color transformation of coated and uncoated mushroom was defined by lightness (L*), total color variation (ΔE) and browning index (BI) measurement, where \(L^{*}\) value and \(\Delta E\) present the luminosity and overall color change of products. The browning index (BI) represents the purity of the brown color of samples (Qu et al., 2020).

The value of \(L^{*}\), \(a^{*}\), \(b^{*}\) were monitored using a color reader (CR-20, KONIKAI MINOLTA, Inc., Japan) on sampling days in ambient temperature of 20℃.

Total color difference (ΔE) compared to color values of an ideal cap (\(L^{*} = 97, a^{*} = -2 \) and \(b^{*} = 0\)) and BI were defined with these relations (Karimirad et al., 2019):

\[
\Delta E = [(L^{*}-L^{*})^2+(a^{*}-a^{*})^2+(b^{*}-b^{*})^2]^{1/2}
\]

\[
BI = [100(X-0.31)]/0.17
\]

\[
X = (a^{*}+1.75 L^{*})/(5.645 L^{*}+a^{*}-3.012 b^{*})
\]

Surface morphology

The mushroom surface morphology with and without coating was studied using a scanning electron microscope (SEM) (SU3500 Hitachi High-Tech, Japan). The microscopic analysis was determined at different magnifications using an accelerating voltage of 15 kV under high vacuum mode (Chu et al., 2017).

Viscosity of coating solutions

To determined viscosity of treatments 100 mL of AV, AVBO1 and AVBO2 solutions were poured in bottle glass with 90% relative humidity. Then, AVBO1 and AVBO2 solutions were poured in bottle glass with 90% relative humidity.
EDIBLE COATING OF MUSHROOM

...method (Singleton and Rossi, 1965) with some modification. In this regard, 5 g of the cap of mushroom and 20 mL of 80% ethanol were homogenized at 2 minutes. This solution was held for 2 hours at 20°C and then filtered through cheesecloth. The filtered solution was centrifuged at 1,725 × g in 10 minutes at 4°C using a centrifuge (5922, KUBOTA, Japan). One mL of ethanol supernatant was mixed with 1 mL of Folin Ciocalteu (10 % (v/v)) and 10 mL of sodium carbonate (7% (v/v)) and filled up with distilled water up to 25 mL. This solution was left to settle in dark condition at 20°C for 50 minutes. Then, the absorbance at 760 nm was recorded.

The capacity of antioxidant activity defined with DPPH (1,1-diphenyl-2-picrylhydrazyl) in all samples described by the method of Mirshekari et al. (2019) with slight modification. Briefly, 2 g of cap mushroom with 10 mL of methanol was homogenized in 2 minutes. Then, the homogenized solution was filtered with cheesecloth and centrifuged at 3,000 × g for 15 minutes at 4°C using the centrifuge. Next, 1 mL of DPPH was added to 1 mL of upper centrifuged methanol and mixed to 1 mL of Tris buffer and left to settle in dark condition for 30 minutes. To measure the absorbance, the spectrophotometer (V-530, JASCO, Japan) at 517 nm was employed. The capacity of antioxidant activity was calculated according to the following formula:

Antioxidant activity (%) = [(Abs control – Abs sample) / Abs control] × 100 (5)

where, Abs is the absorbance.

Polyphenol oxidase (PPO) and phenylalanine ammonia lyase (PAL) activities

Enzymatic activity measurements were carried out by following as a method of Gao et al. (2014) with minor modifications. In brief, 4 g mushroom tissue per replicate were homogenized with 12 mL phosphate buffer (50 mM, pH 7) containing EDTA (1 mM) and DTT (2 mM). The mixture was then centrifuged at 3,500 × g for 30 minutes and 4°C.

PPO activity was determined by the reaction mixture, containing 1 mL of supernatant and 1 mL of sodium phosphate buffer (100 mM, pH 7.0) mixed with 1 mL pyrocatechol (50 mM). Then, absorbance was determined using a spectrophotometer (V-530, JASCO, Japan) at 410 nm (Mirshekari et al., 2019). Specific PPO activity was expressed as Unit gFW⁻¹. For PAL activity measurement, 1 mL of supernatant was added to 2 mL 1-phenylalanine (50 mM) in sodium borate buffer (200 mM, pH = 8.8). The mixture was incubated in a water bath at 37°C for 90 minutes and the reaction was interrupted by ice water. Then, the absorbance of trans-cinnamic acid was measured at 290 nm (Nasiri et al., 2019). The specific PAL activity was expressed as Unit gFW⁻¹.

Relative electrolyte leakage (REL) and malondialdehyde (MDA) content

REL and MDA content were assayed according to the method of Li et al. (2019) with minor modifications. For REL measurement, mushrooms were sliced into pieces of 1 cm in diameter and 0.3 cm in depth. Then, the samples were incubated at 40 mL of deionized water and the initial conductivity (C₀) was immediately recorded on a conductivity meter (OAKLON, Singapore). C₁ was determined after shaking the suspension (100 cycles, for 120 minutes). The final conductivity (C₃) was measured after boiling for 10 minutes and cooling to room temperature. The relative electrolyte leakage was determined by the following equation (Li et al., 2019):

Electricity leakage (%) = [(Cᵥ – C₀) / (C₃ – C₀)] × 100 (6)

To determine the MDA, button mushrooms were homogenized in 1 g samples and 7 mL of trichloroacetic acid (10 % (w/v)) and then, centrifuged at 3,500 × g for 30 minutes at 4°C. Two mL of the supernatant was mixed with 2 mL of thiobarbituric acid (0.67% (w/v)) and placed in a water bath at 80°C for 30 minutes. The mixture was cooled and centrifuged at 3,500 × g for 30 minutes at 4°C. Ultimately the absorbance of the supernatant was recorded at 450, 523, and 600 nm. The MDA content was determined in nmol gFW⁻¹ (Huang et al., 2019).

Sensory evaluation

Sensory characteristics of coated and uncoated mushrooms were investigated after 12 days of storage. In order to measure whiteness, hardness, fresh appearance, odor properties and intention to purchase by the method of Nouzro and Sayyari (2020) was followed. In this regard, 10 panelists with different gender and age (22 to 35 years old) assisted to evaluate the quality of mushrooms at the end of storage. The score for sensory evaluation was on 1 to 5 points scale. 1 = very poor, 2 = poor, 3 = middle, 4 = good, 5 = excellent.

Statistical and correlation analysis

This study was conducted in a completely randomized design as factorial arrangement with two factors including treatment and time. To assess normality of the obtained data, Kolmogorov-Smirnov and Shapiro-Wilk tests were used by using SPSS 20.0 software and after making sure the data were normal, analysis of variance was performed by using SAS 9.1 software and the means were compared using the protected least significant difference (PLSD) test at P < 0.01 level. Spearman correlation coefficients between the attributes were calculated using SPSS 20.0 software.

RESULTS AND DISCUSSION

Respiration rate

The respiration rate of coated and uncoated mushrooms during the cold storage is shown in Fig. 1. The results displayed a decreasing trend for all of the samples. While initial respiration rate was measured to be 143.86 mgCO₂ kg⁻¹ h⁻¹ initial day, the respiration rate reached 86.50, 71.56, 62.00 and 55.90 mgCO₂ kg⁻¹ h⁻¹ for control, AV, AVBO1, and AVBO2, respectively, at the end of storage (P < 0.01). Overall reduction pattern of mushroom respiratory after harvest could be related to mushroom texture decay and senescence (Singh et al., 2010). It has been
shown that increased aging of the harvested crops is usually proportional to the respiration rate. Respiration rate is a metabolic process that provides the necessary energy in the presence of O₂ for the plant’s biochemical activity and accelerates fruit and vegetable senescence after harvest. Therefore, maintaining a low level of respiration is essential to prolong the life of crops at postharvest duration (Yang et al., 2014; Han et al., 2017). The application of coating on fruit surface could be used as an alternative way to limit O₂ and CO₂ exchange between internal and external fruit atmosphere and drives reducing O₂ available (Nasiri et al., 2018). The lower values of respiration in AVBO1 and AVBO2 coatings on mushroom than AV alone could be attributed to the presence of basil oil as lipid ameliorated polysaccharide gas barrier properties of A. vera gel coating (Mohammadi et al., 2020). Our finding was in accordance with the study of Martínez-Romero et al. (2017) who reported addition of rosehip oil to A. vera gel delayed respiration rate on plum.

Weight loss
The weight loss of the experimented samples showed increasing tendency during 12 days of the storage at 4°C as shown in Fig. 2. The maximum value for the uncoated and coated samples was observed at the end of the storage and the highest one was for the control samples ~20% compared to the coated samples (P < 0.01). The use of coating reduced loss of the weight and it reached 14.56% in AV, 10.92% in AVBO1 and 10.54% in AVBO2 at the end of the cold storage (P < 0.01). The weight loss is followed by transpiration and respiration. Accordingly, the high weight loss of the uncoated samples could be attributed to the unprotected thin epidermal structure of the mushrooms which causes rapid surface dehydration and mass transfer. However, the lower weight loss of the coated mushrooms related to the semi-permeability coating that acts as barrier against moisture loss, O₂, and CO₂ transition (Sogvar et al., 2016; Nasiri et al., 2018). The suppression of the weight loss was even more pronounced in AVBO1 and AVBO2 treatments. This could be attributed to the hydrophobic properties of coating with the lipid content which increases the barrier efficacy of the A. vera coating (Tzortzakis et al., 2019). This result was in agreement with previous works such as employing a combination of A. vera and seed basil oil on apricot (Nourozi and Sayyari, 2019) and A. vera gel enriched with basil oil on strawberry (Mohammadi et al., 2021).

Firmness
The senescence of mushroom leads to softening of the...
mushroom tissue which appears in the spongy and soft texture. Figure 3 shows the firmness of the coated and uncoated mushrooms. Results indicated the continuous reduction during the storage in all samples from the initial value of 18 N. The control mushrooms reached to the lowest value of 7.7 N at the end of the storage (P < 0.01). However, the coated samples with lower loss of firmness exhibited larger values i.e. 12.7, 15.3 and 15.7 N for AV, AVBO1, and AVBO2 coated mushrooms, respectively (P < 0.01). The quick reduction of the control treatment during storage could be due to the biochemical reactions including loss of water, cell wall degradation and secondary microbial growth. The coatings by inhibiting moisture loss maintained higher pressure of mushroom cells resisted to firmness reduction (Mohammadi et al., 2020). Furthermore, retention of firmness in coating samples could arise from limitation of microbial activity of ingredients presented in A. vera such as aloein and aloe-emodin (Rasouli et al., 2019) and finalool and eugenol in basil oil (Abbas et al., 2018). According to the results, higher efficacy of treatments with basil oil compared to A. vera alone in firmness could be originated from the higher hydrophobic property of barrier for transpiration and antimicrobial activity of basil oil. These results were compatible with those of previous studies in application of A. vera and rosehip essential oil on several stone fruits (Paladins et al., 2014) and tragacanth gum combined with Satureja hlasitana essential oil on mushroom (Nasiri et al., 2018). Additionally, the significant correlation between firmness and weight loss (−0.570**) was observed (Table 1), which is consistent with the finding of Khorram et al. (2017) on orange fruit.

Microstructure analysis

The microstructure changes of surface cap of button mushroom were studied by scanning electron microscopy (SEM). Figure 4 shows the comparison of surface morphology of initial and final days for uncoated and AVBO2 samples. In Fig. 4a the cap tissue of control samples was observed at the initial day of storage. The interiors of cap are composed of turgid hyphae. It is noteworthy that unlike fruit and vegetables, mushrooms do not possess rigid cell wall support. The orientations of cap tissue hyphae are heterogeneous without any ordering in directions and angles within the cell. The connection of cells was observable between hyphae including wide intercellular space in the absence of water. A similar observation was also reported by Zivanonic et al. (2000) and García-Segovia et al. (2011). Therefore, high delicacy of hyphae tissue could be one of the reasons of mushroom deterioration. Unlike the initial day, the hyphae structure lost its turgidity and appearance caused by moisture loss. As a result, shrinkage and collapse of cell wall were observed at the end of storage as presented in Fig. 4b. By contrast, the AVBO2 treatment covered the surface of mushroom homogenously as a protective barrier at initial day of storage (Fig. 4c) and maintained its integrity without any degraded and fracture until the end of storage (Fig. 4d). Figure 5 visualizes a set of SEM images of cap mushroom surface of uncoated and coated samples at the end of storage. In Fig. 5a the cell shrinkage was observed in the control sample. SEM images of coated samples confirmed that coatings had firmly covered surface of mushrooms as shown for AV (Fig. 5b), AVBO1 (Fig. 5c) and AVBO2 (Fig. 5d). Combination of basil oil and A. vera gel created dense protection membrane which distributed uniformly without any fracture on mushroom cap while AV could not cover the surface as uniformly as the other treatments as indicated by yellow arrow. These morphological observations agreed with the viscosity value of AV solution lower than AVBO1 and AVBO2 (Table 2). In summary, these observations confirmed results of the respiration rate, weight loss and firmness as described by details.

| Table 1 | Pearson’s correlation coefficients between measured factors of mushrooms during cold storage |
|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
|                 | RR   | WL   | FM   | L  | ΔE   | BI   | TPC  | AOA  | PPO  | PAL  | REL  | MDA  |
| RR               | 1    | 0.249| 1    | 0.570**| 1    | 0.330| 0.298| 0.517**| 0.548**| 0.589**| 0.670**| 0.774**|
| WL               | 0.203| 1    | 0.570**| 0.747**| 1    | 0.560**| 0.537**| 0.657**| 0.632**| 0.517**| 0.298| 0.509**|
| FM               | 0.012| 1    | 0.870**| 1    | 0.859**| 0.974**| 0.974**| 0.974**| 0.974**| 0.974**| 0.329| 0.329|
| L               | 0.330| 0.560**| 0.377**| 0.974**| 1    | 0.974**| 0.974**| 0.974**| 0.974**| 0.974**| 0.329| 0.329|
| ΔE              | 0.570**| 0.517**| 0.320| 0.298| 0.560**| 0.974**| 0.974**| 0.974**| 0.974**| 0.974**| 0.298| 0.298|
| BI              | 0.330| 0.560**| 0.377**| 0.974**| 1    | 0.974**| 0.974**| 0.974**| 0.974**| 0.974**| 0.329| 0.329|
| TPC            | 0.298| 0.298| 0.298| 0.298| 0.298| 0.298| 0.298| 0.298| 0.298| 0.298| 0.298| 0.298|
| AOA            | 0.320| 0.320| 0.320| 0.320| 0.320| 0.320| 0.320| 0.320| 0.320| 0.320| 0.320| 0.320|
| PPO          | 0.570**| 0.570**| 0.570**| 0.570**| 0.570**| 0.570**| 0.570**| 0.570**| 0.570**| 0.570**| 0.570**| 0.570**|
| PAL          | 0.330| 0.330| 0.330| 0.330| 0.330| 0.330| 0.330| 0.330| 0.330| 0.330| 0.330| 0.330|
| REL        | 0.298| 0.298| 0.298| 0.298| 0.298| 0.298| 0.298| 0.298| 0.298| 0.298| 0.298| 0.298|
| MDA         | 0.203| 0.203| 0.203| 0.203| 0.203| 0.203| 0.203| 0.203| 0.203| 0.203| 0.203| 0.203|

*, ** Correlation is significant at P < 0.05 and P < 0.01, respectively. Where RR is respiration rate, WL is weight loss, FM is firmness, TPC is total phenolic contents and AOA is antioxidant activity.
Figure 7 displays the gradual decrease of $L^*$ value during cold storage. The control sample reached the lowest $L^*$ value (62.56) from the initial value (91.6) compared with coated samples of AV (76.43), AVBO1 (83.90) and...
AVBO2 (83.70) at the end of storage ($P < 0.01$).

The average of $L^*$ between 80 and 85 values observes acceptable quality, between 69 and 79 values means inferior quality and lower than 69 value exhibits unacceptable quality in button mushroom color (Taghizadeh et al., 2009).

Figure 8 shows the trend of $D_E$ in all samples during the storage. A rapid increase of $D_E$ observed in control sample (40.51) from initial value (14.74) compared to AVBO1, AVBO (24.11) and AVBO2 (22.94) at day 12 of storage ($P < 0.01$). These results indicated that covering the mushrooms with $A. vera$ based coatings could preserve the color of samples. In addition, presence of basil oil in the treatments decelerated mushroom darkening and discoloration more than $A. vera$ alone which leads to better preservation of mushroom quality and prolongs its life after harvest.

The BI values of uncoated and coated samples during the cold storage are shown in Fig. 9. The results indicated the increasing tendency of BI values in all samples. The increase was more pronounced for the control sample. On the other hand, the AVBO1 and AVBO2 treatments retarded the spreading of mushrooms’ browning compare to AV alone and highly maintained visual quality of

**Table 2**  Viscosity (Pa s) of the treatments

| Speed (rpm) | AV | AVBO1 | AVBO2 |
|-------------|----|-------|-------|
| 10          | 1.383 | 1.530 | 1.593 |
| 30          | 0.651 | 0.707 | 0.729 |
| 60          | 0.395 | 0.443 | 0.455 |

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mushrooms. Since the surface coating reduces the enzymatic browning activities by suppression of oxygen absorption, it can maintain the color of mushroom during storage (Nasiri et al., 2018). Moreover, color change is attributed to the loss of moisture (Mirshekari et al., 2019) and growth of *Pseudomonas* (Park et al., 2020). Thus, application of *A. vera* mixed with basil oil has improved the barrier properties and inhibited the *Pseudomonas* growth. A similar conclusion was achieved in a study on mushroom employing a combination of chitosan nano-particles film and *Cuminum cyminum* oil as a coating (Karimirad et al., 2019). In the current study, BI had positive correlation to weight loss (0.859*) (*P* < 0.01). Similar correlation between BI and weight loss was reported in litchi fruit (Jiang et al., 2018).

Total phenolic contents and antioxidant activity

Mushroom is considered as a rich source of phenolic compounds with antioxidant activity which is effective on prevention the chronic diseases such as cancer and cardiovascular (Gao et al., 2014). The total phenolic contents of all samples during cold storage are depicted in Fig. 10. Total phenolic contents of control samples decreased from 0.867 to 0.699 (mg gFW⁻¹) during the storage. By contrast, coated mushrooms experienced rise in their values. Moreover, maximum phenolic contents of AVBO1 (1.065) and AVBO2 (1.130) were greater than maximum phenolic contents of AV (0.944) at the end of storage. The lower total phenolic contents during storage is related to the higher consumption of polyphenols content utilized in the synthesis of brown pigment and discoloration action in product (Nasiri et al., 2018).

Antioxidant activity in all samples was proportional to the total phenolic contents as shown in Fig. 11. Like phenolic contents in control samples, the capacity of antioxidant was also showed reduction tendency during storage from 38.6% to 28.8%. However, application of AVBO1 and AVBO2 increased antioxidant activity to 46.5% and 46.9 %, respectively, at the end of storage (*P* < 0.01). These increments could be attributed to the presence of phenolic compounds in basil oil especially eugenol (Hemalatha et al., 2017).

Besides, the increment of phenolic contents in AVBO1 and AVBO2 samples than AV could be due to the fact of self-defense reaction of mushroom with increasing the total phenolic and antioxidant activities against external stress induced by basil oil. The role of the basil oil is as slight stress, which creates defensive reaction by increasing total phenolic consequently antioxidant activities on mushroom (Gao et al., 2014). A similar observation is reported on application of *A. vera* gel with basil seed mucilagino-
lager treatment on apricot (Nourozi and Sayyari, 2020). Interestingly, strong correlation was observed between total phenolic and antioxidant activity (0.614**) based on correlation analysis (Table 1).

**Polyphenol oxidase (PPO) and phenylalanine ammonia lyase (PAL) activity**

Activities of PPO enzyme in coated and uncoated mushrooms increased during the cold storage (Fig. 12). This increase is more pronounced in control samples and reached the maximum value of 1.127 at the end of storage from the initial value of 0.296 Unit gFW⁻¹.

The coating suppressed the PPO activities effectively and these activities reached the values of 0.803, 0.629, and 0.645 Unit gFW⁻¹ for AV, AVBO1, and AVBO2, respectively, at the end of storage (P < 0.01). Browning in mushrooms mainly occurs through the oxidation of phenols into quinones by enzymes activities such as PPO, afterward polymerization and browning (Li et al., 2019). Therefore, suppression of enzymes activities serves as an efficacious method to preserve the color of mushroom. Edible coatings such as A. vera play the role of semi-permeable barrier to gases exchanges particularly oxygen, as explained in respiration rate in section 3.1. Furthermore, A. vera gel protects cell membrane integrity which leads to reduction contact of phenols with PPO (Ali et al., 2019a). The fewer enzymes activities in AVBO1 and AVBO2 might be due to the promotion of antioxidant activity related to the presence of basil oil in the treatments (Karimirad et al., 2019). Our finding is similar to the previous studies of Tragacanth gum coating enriched with *Satureja khuzistanica* and *Zaturla malto* essential oil (Nasiri et al., 2019) and pepper min oil on mushrooms (Qu et al., 2020). It was also realized by the positive correlation (0.830**) between PPO and BI and negative correlation (−0.832**) between PPO and L* (P < 0.01) (Table 1).

The activity of PAL enzyme of all samples during the cold storage is shown in Fig. 13. The PAL activity of the control samples is significantly reduced, and mushrooms subjected to the AV treatment exhibited a slight reduction during the storage. In contrast, the PAL activity of AVBO1 and AVBO2 samples showed up trend tendency and reached to the ~1.5-fold higher than the initial day. PAL is the essential enzyme in biosynthesis of phenolic compounds (Benol et al., 2000). Previous studies indicated that the pile up of phenols is proportional to the increment of PAL activity (Eissa, 2007; Nasiri et al., 2019). It is reported that essential oils have a potential effect on secondary metabolites of plants and causing biosynthesis of phenolic compounds by motivating activity of PAL (Gao et al., 2014). Our results are agreement with study of Gheyesarbigh et al. (2020) in fresh pistachios by nitric oxide and Li et al. (2019) on mushroom by L-Arginine. In current study we also observed the activity of PAL in samples had positive correlation with total phenolic contents (0.714**) and negative correlation to BI (−0.537**) (P < 0.01) (Table 1).

**Relative electrolyte leakage (REL) and malondialdehyde (MDA) content**

REL content of coated and uncoated samples indicated a continuous increase during cold storage Fig. 14. REL in the control mushrooms sharply increased and was noticeably higher than that in the samples subjected to AV, AVBO1, and AVBO2 treatments (P < 0.01). Likewise, MDA contents of coated and uncoated mushrooms enhanced continually, and control samples had great rise and application of AV, AVBO1 and AVBO2 treatments effectively suppressed generation of MDA during cold storage as shown in Fig. 15. REL was associated with the cell membrane structure by allowing transfer of intracellular material which results in increment of electrolyte leakage intensity (Li et al., 2019).

MDA is an important outcome of membrane lipid per-
oxidation and increases with membrane integrity injuries and senescence (Zhang et al., 2020). Ali et al. (2019b) reported that A. vera gel coating inhibited increment of REL and MDA content in litchi fruit by delaying senescence and maintained membrane integrity with higher antioxidant activities. The minimum values of REL and MDA content of AVBO1 and AVBO2 samples could be related to the higher efficacy of treatments to protect cell membrane structure. In this regard, the results of REL and MDA are in a line with studies of Ali et al. (2019c) on lotus root by application of ascorbic acid and A. vera gel and Huang et al. (2019) on mushroom by chitosan and guar gum coating. In current research we found considerable correlation (0.860**), between REL and MDA. Moreover, REL and MDA had significant correlations (H11002 0.751** and H11002 0.670**, respectively) with firmness (H11021 0.01) (Table 1).

Sensory evaluation

Application of coatings affected the sensorial quality of button mushroom (Fig. 12). According to the panelists’ scores, the lowest quality was attributed to the control sample as a result of rapid senescence process. Meanwhile, due to the lower water loss, all of the coated mushrooms were received comparable scores in whiteness, fresh appearance, texture firmness and odor compared to uncoated samples (H11021 0.01). The results showed addition of basil oil to Aloe vera gel coating in particular with high concentration (1,000 mL L⁻¹) presented significant effect on overall acceptability and intention purchase of mushrooms compare to A. vera gel alone. It could be ascribed to efficacy of basil oil quantity led to retarding microbial activity and decay.

CONCLUSION

This study investigated the effect of application of a mixed A. vera gel and basil essential oil coating as an incorporation of polysaccharide and lipid on senescence process of button mushroom. This treatment decelerated respiration rate and weight loss and preserved firmness by inhibition of relative electrolyte leakage and malondialdehyde accumulation. Furthermore, browning index were delayed through inflation of phenolic contents, antioxidant and phenylalanine ammonia lyase activities and reduction of polyphenol oxidase activity. A. vera gel and basil oil prevented enzymatic browning through inhibition the activities of polyphenol oxidase and increasing phen-
ylalanine ammonia lyase activity during the storage time. In addition, sensory evaluation presented the high score for mushrooms treated with A. vera gel and 1,000 μL L⁻¹ concentrations of basil oil treatment. Due to absence of significant difference between incorporation of 500 and 1,000 concentrations of basil oil to A. vera gel and based on the cost advantage of the treatment with less concentration, A. vera gel and 500 μL L⁻¹ concentrations of basil oil treatment can be recommended.

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