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Single-to-combined effects of gelatin and aloe vera incorporated with Shirazi thyme essential oil nanoemulsion on shelf-life quality of button mushroom

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RESEARCH ARTICLE

Abstract

Button mushrooms are considered one of the most sensitive agricultural products due to the mechanical damages that can significantly decrease their quality and color. Our study aimed to evaluate the effect of aloe vera and gelatin edible coatings containing Shirazi thyme essential oil nanoemulsion on the shelf life, enzymatic browning, physicochemical, microbiological, textural, and sensorial properties of a button mushroom. Seven samples, including the control (C) and those coated with 1% gelatin (G1), 3% gelatin (G3), 1% aloe vera (A1), 3% aloe vera (A3), 1% gelatin + 2% aloe vera (G1A2), and 2% gelatin + 1% aloe vera (G2A1), were produced. Parameters such as weight loss, pH, firmness, color, microbiological, and sensory attributes were analyzed to evaluate these features. Our results showed that aloe vera and edible gelatin coatings are capable of efficiently maintaining the physicochemical, microbiological, and sensory properties of button mushrooms. The lower microbial counts, including mesophilic bacteria, yeasts, and molds in treated samples during storage, could be due to the coating containing Shirazi thyme essential oil nanoemulsion. Regarding the efficient role of aloe vera coating (3%) in preventing the growth of microorganisms and maintaining the sensory properties of samples, this treatment could be a promising technique for the preservation of button mushrooms and other vegetables and fruits.

Keywords: aloe vera and gelatin; enzymatic browning; mushroom; nanoemulsion

Introduction

Browning, bacterial attack, and water loss are among the most important factors decreasing the commercial value and shelf life of button mushrooms (*Agaricus bisporus*) (Gao *et al.*, 2014). Some gram-negative bacteria, such as *P. fluorescens*, *P. tolaasii*, and yeasts, including *Candida sake*, usually increase with sample decay (Ding *et al.*, 2016; Qin *et al.*, 2015). The limited storage time of the sample is very crucial to the marketing and distribution of a fresh sample. So, increasing the post-harvest shelf life while protecting quality is useful for product value and consumer preference. In this regard, the application of coating with biodegradable protein-carbohydrate based biopolymers has been introduced as a promising technique to overcome these challenges

(Al-Tayyar *et al.*, 2020; Mahajan *et al.*, 2018). Biodegradable coatings can improve the quality of vegetables and fruits by controlling the solute, gas, and vapor barriers (Cazón *et al.*, 2017). They are helpful in slowing respiration, moisture loss, and fruit oxygen uptake (Galgano, 2015). Gelatin is a hydrolyzed animal protein produced from collagen hydrolysis (Zhang *et al.*, 2019). It is a copolymer made from triads of α-amino acids used with glycine and has a limited molar mass distribution (Cao *et al.*, 2019; Mohammad *et al.*, 2015). This biopolymer is usually used for its coating and film properties to increase food quality (Ramos *et al.*, 2016). However, the utilization of gelatin alone as a coating material doesn't have satisfactory water vapor barrier properties. Physicochemical modification is generally used to improve the polymer network to increase the functionality of the coating (Hosseini and Gómez-Guillén, 2018; Tyuftin and Kerry, 2021). Hydrocolloids such as aloe vera are extensively used as a solution since they have suitable emulsification characterization (Geetanjali *et al.*, 2021; Maan *et al.*, 2021). Hydrocolloid is used for coating nuts for an oily and moist appearance, and to provide a low-calorie food. Ali *et al.* (2010) applied an edible coating for tomato preservation using gum arabic (10%). This increased the ripening time and the tomato's shelf life at room temperature was extended by up to 20 days with good flavor. Maqbool *et al.* (2011) also reported the application of 10% gum arabic mixed with cinnamon essential oil (0.4%) as a fungicide for increasing the shelf life in important tropical fruits, including papaya and banana. Essential oils (EOs) are important secondary metabolites usually applied as a flavoring in industry. The antimicrobial effects of EOs on some pathogens and food spoilage microorganisms have been reported by many researchers (Bhavaniramya *et al.*, 2019; Gonfa *et al.*, 2022). However, the EOs interfere with the food matrix's sensory properties, which limits their application at high concentrations. Moreover, the incorporation of EOs as coating materials is limited because of changes in flavor, low water solubility, high volatility, and ingredient interactions (Al-Maqtari *et al.*, 2021; Weisany *et al.*, 2022). *Zataria multiflora* Boiss is an herbal and industrial plant usually grown in Pakistan, Iran, and Afghanistan. The antimicrobial effects of *Z. multiflora* essential oils (ZMEO) against a wide range of microorganisms have been previously reported (Naveen and Bhattacharjee, 2021). ZMEO was used in coating matrices, including carboxymethylcellulose, chitosan, corn starch, and whey protein, to reduce the above-mentioned limitations. EOs are usually emulsified in the coating suspension to produce an antioxidant and antimicrobial coating or film (Akhter *et al.*, 2019). However, to the best of our knowledge, the use of gelatin and aloe vera alone or mixed with ZMEO nanoemulsion has not yet been reported in the coating of button mushrooms. So, this research aimed to evaluate the influence of gelatin and aloe vera coating, used alone and mixed, on the shelf life and quality of button mushrooms.

Materials and Methods

Materials

Button mushrooms were purchased from a local market in Shiraz, Iran. The samples were moved to the laboratory and then kept in darkness at 7 ± 1°C. All chemicals were purchased from Merck (Darmstadt, Germany).

ZMEO extraction and analysis with GC-FID

The main components of the extracted ZMEO were investigated, as reported by Emir Çoban and Tuna Keleştemur (2017). Briefly, 50 g of sample leaves were combined with 500 mL of double distilled water (DDW) and extracted with hydrodistillation for 150 min in Clevenger-type apparatus. ZMEO was dried over Na_2SO_4 and stored at −80°C (Mohtashami *et al.*, 2018). ZMEO was analyzed by a gas chromatograph (SP-3420A, Beifen-Ruili analytical instrument, Beijing, China) equipped with a flame ionization detector (FID).

Sample preparation, treatment, and storage

Mushrooms were harvested from one place to limit the possible variations caused by environmental conditions and cultivation. The samples were then transferred to the Shiraz University laboratory within 1 h of being picked. The gelatin solution (1, 2, 3, and 4%) and aloe vera (1, 2, 3, and 4%) containing glycerol plasticizer (0.3, 0.6, 0.9, and 1.2%) were mixed at 45°C for 60 min for complete homogenization. This concentration was chosen based on the primary experiments. Seven different samples were produced: (1) control (C); (2) 1% gelatin coating (G1), (3) 3% gelatin coating (G3), (4) 1% aloe vera coating (A1), (5) 3% aloe vera coating (A3), (6) 1% gelatin + 2% aloe vera coating (G1A2), and (7) 2% gelatin + 1% aloe vera coating (G2A1), all treatments contained 3% ZMEO nanoemulsion (6 g ZMEO + 4.5 g tween 80 + 89.5 g water). Mushrooms were coated and placed in their prepared suspension for 6 min. The coating samples were selected based on the primary analysis of button mushrooms. The coated mushrooms were placed on a perforated sheet for 15 min to dry using a low-speed air fan. The coated mushrooms were packed in 10–20 cm PE bags (0.1 mm thickness). Mushrooms were kept for 16 days at 5 ± 1°C and 90% RH. Samples were analyzed every 4 days in three replicates.

Weight loss

This parameter was evaluated by weighing the button mushroom during the storage time. This parameter was reported as the weight loss percentage compared to the initial weight (Wang *et al.*, 2015).

Texture

A penetration test was done on the button mushroom cap by a texture analyzer (Santam Systems, STM 20 model, Iran) with a cylindrical probe (0.5 cm diameter). Button mushrooms were penetrated to 0.5 cm. The probe speed during penetration and pretest was 0.2 cm s^{-1}. Firmness was extracted from the force vs. time curves (maximum force) (Nketia *et al.*, 2020).

Color measurement

The color properties of the samples were assessed by the $L^*a^*b^*$ method, according to Duan *et al.* (2016). L^*, a^*, and b^* values were evaluated on the mushroom sample's outer surfaces. A box (0.5 × 0.5 × 0.6 cm^3) with natural daylight (6500 K) and a Canon digital camera were used for evaluating the color parameters. This apparatus was designed and calibrated by the Department of Food Science and Technology, Shiraz University, Shiraz, Iran. CS6 Adobe Photoshop® was used to evaluate the surface color of the samples.

Percent open caps

The percentages of cap opening of mushrooms (umbrella-like shape) during storage were reported (Hu *et al.*, 2015).

Microbiological measurements

The count of mesophiles, yeasts, and molds was evaluated in treatments. Mushrooms (25 g) were chosen from the pack and suspended in 0.1% saline (225 mL). Mushrooms were mixed using a high-speed mixer (IKA, Vortex 1V1, Germany) completely. The sample was diluted between 10^{-1} and 10^{-9} (CFU/g) by adding 1 mL sample to 9 mL saline (0.9% sodium chloride). The number of mesophilic bacteria was evaluated by PCA after incubation at 37°C for 48 h. Yeasts and molds were determined on YGC and incubation was at 29°C for 6 d (Rokayya *et al.*, 2021).

Sensorial properties

The sensorial properties of the samples, such as color, off-odor, cap surface form (appearance), uniformity, and brown zones, were evaluated (Srivastava *et al.*, 2020). Fifteen semi-trained students evaluated the sensory properties. Sensory evaluation was based on a nine-point hedonic scale (9 = very good, 7 = good, 5 = middle, 3 = bad, and 1 = very bad).

Statistical analysis

Findings were evaluated by one-way analysis of variance (ANOVA) at $P < 0.05$ significance level. Duncan's multiple range tests were done by SAS® software (v. 9.1, NC, USA.) to evaluate significant differences.

Results and Discussion

ZMEO composition

Table 1 reported the ZMEO chemical composition, content, and retention times. GC-FID detected 14 ingredients. Carvacrol, thymol, and α-terpinene with 39.57, 25.44, and 11.52% were the main components. The findings reported in our research were consistent with the finding reported by Gahruie *et al.* (2017). In a research by Golmakani and Rezaei (2008), carvacrol (25.5%), thymol (26.8%), *p*-cymene (7.9%), and γ-terpinene (7.1%) were the main ingredients of this EO. The differences observed in various studies may be due to the differences in climatic conditions, cultivation, and extraction techniques (Al-Balushi *et al.*, 2022; Giacometti *et al.*, 2018; Stevanović *et al.*, 2018). The antioxidant activities of carvacrol (de Carvalho *et al.*, 2020) and thymol (Yildiz *et al.*, 2021) and the antimicrobial activity of carvacrol and thymol (Rúa *et al.*, 2019) were previously reported.

Weight loss

The weight loss percentage of button mushrooms is due to water and CO_2 loss during respiration. Besides, the phenomenon of exudation during storage leads to constant water loss from the product to the surrounding environment. Fast deterioration, water loss, and shriveling are due to the thin skin of samples. As reported in Figure 1, the control mushroom had the highest weight loss (%), reaching 5.97% after 16 days of storage. This observation shows that the applied technique has retained a sufficient water-holding. In a research by Bico *et al.* (2009), 4–6% weight loss was accompanied by slow wrinkling or wilting of the sample's surface. The treated samples had a weight loss of less than 2.92%, and the applied coating kept the freshness during the 16 days of storage. There was no significant difference between the coated samples. Our findings show that edible coatings can form a thin barrier on the mushroom's surface, thereby protecting the mushroom epidermis and restricting water transfer from mechanical injuries, as well as delaying dehydration

Table 1. ZMEO chemical ingredients.

No.	Compound	Chemical formula	Retention index	Retention time (min)	Relative peak area (%)
1	α-Thujene	$C_{10}H_{16}$	924	1.56	0.26
2	α-Pinene	$C_{10}H_{16}$	932	4.28	3.69
3	3-Octanone	$C_{8}H_{16}O$	984	5.67	3.33
4	Myrcene	$C_{10}H_{16}$	988	6.55	1.07
5	α-Terpinene	$C_{10}H_{16}$	1014	6.90	11.52
6	p-Cymene	$C_{10}H_{14}$	1020	7.97	3.24
7	γ-Terprinene	$C_{10}H_{16}$	1054	13.12	0.29
8	Linalool	$C_{10}H_{18}O$	1095	15.51	0.53
9	Carvacrol methyl ether	$C_{11}H_{16}O$	1241	17.92	1.21
10	Thymol	$C_{10}H_{14}O$	1289	18.39	25.44
11	Carvacrol	$C_{10}H_{14}O$	1298	18.81	39.57
12	Eugenol	$C_{10}H_{12}O_{2}$	1361	23.13	1.92
13	Carvacrol acetate	$C_{12}H_{16}O_{2}$	1370	29.94	4.26
14	β-Caryophyllene	$C_{15}H_{24}$	1417	40.86	3.11

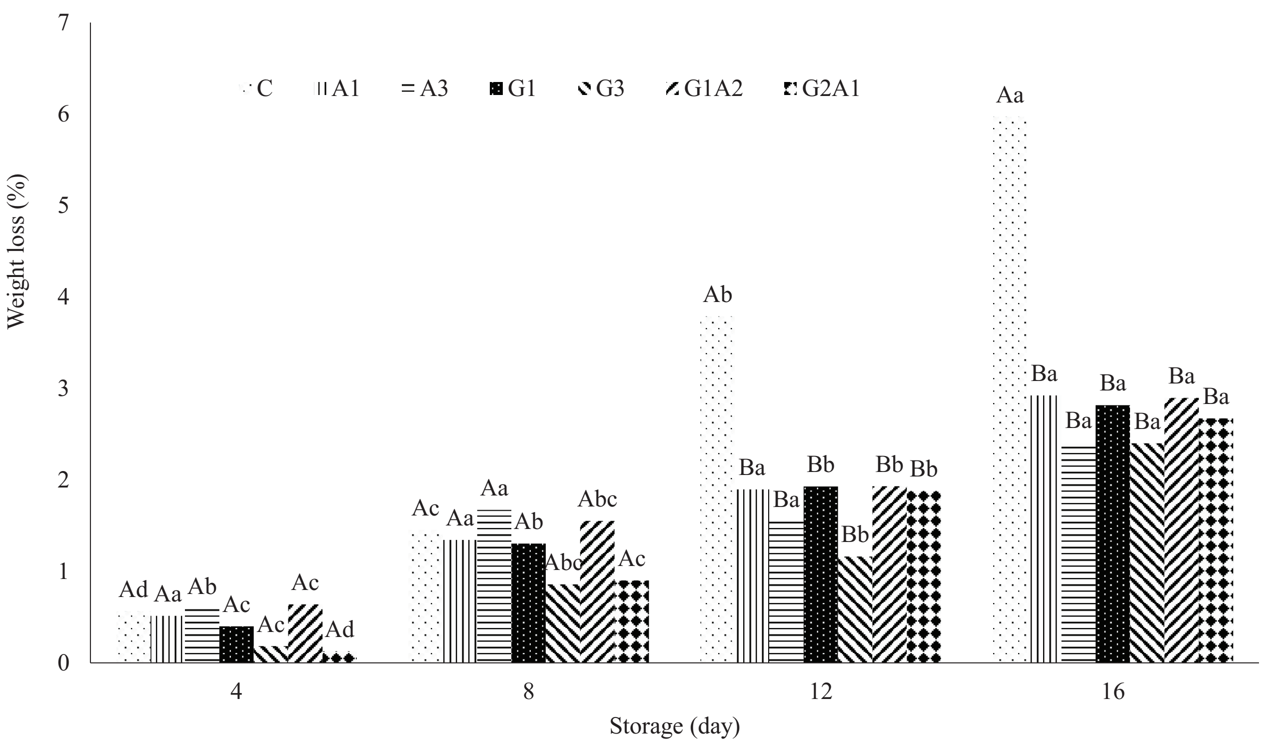


Figure 1. Effect of coating on weight loss change in button mushrooms during shelf life. C (control sample), A1 (1% aloe vera coating), A3 (3% aloe vera coating), G1 (1% gelatin coating), G3 (3% gelatin coating), G1A2 (1% gelatin + 2% aloe vera coating), and G2A1 (2% gelatin + 1% aloe vera coating).

and thus sealing small wounds. The lowest weight loss (%) was observed in the sample coated with aloe vera and gelatin during its 16 days of shelf life. Our results are in accordance with the study of Cavusoglu *et al.* (2021), who evaluated the effects of different coatings on the weight loss (%) of button mushrooms. They reported that sodium alginate was better than other coatings for reducing the weight loss (%) of samples. It's due to the higher capacity of alginate to reduce the respiration rate and evaporation of moisture. Pleșoianu and Nour (2022) studied the effect of sodium alginate, chitosan, CMC, and pectin coatings incorporated with N-acetyl cysteine on the weight-loss (%) of a fresh white button mushroom. They reported that the weight loss (%) of the coated sample was significantly lower than the control sample. It's due to the protective layer of the coating and the role of coating as a barrier to moisture diffusion between the sample and the environment.

At the same time, different capital letters indicate significant differences (P < 0.05) between different samples. For each sample, different small letters indicate significant differences (P < 0.05) during storage.

Firmness

Firmness loss (N) is an important factor in decreasing the quality and shelf-life of a button mushroom. This parameter significantly affects the mushroom's value during marketing. The texture changes in button mushroom in all samples during shelf life were reported in Figure 2. The edible coating protected the texture of the button mushroom during storage. Coating with aloe vera 3% and aloe vera 1% + gelatin 2% had a significant influence on the firmness of mushrooms. Aloe vera 1% + gelatin 2% coated sample, protected firmness during the 16 days of storage time. Reduction in hardness may occur due to the cell wall degradation in samples caused by enzymes of bacterial origin and improved endogenous autolysin activity (Zivanovic *et al.*, 2000). Many organisms, including *pseudomonas*, destroyed button mushrooms by influencing the intracellular matrix and decreasing the central vacuole, as evidenced by less firmness in the control mushroom. However, the coated samples showed better firmness during storage due to the barrier properties of coating materials against microbial contamination. The application of ZMEO in the coating had a good influence on the coated samples by reducing the microbial count and retarding its softening during storage. The same findings were reported by Lee *et al.* (2003), who reported that the addition of 1% NaCl within a whey protein coating improved the ability to maintain apple firmness. The effect of coatings on maintaining the firmness of mushrooms was reported by Gholami *et al.* (2020) after applying chitosan coating and Mohammadi *et al.* (2021) during the application of *aloe vera* gel coating incorporated with Basil EO.

At the same time, different capital letters indicate significant differences (P < 0.05) between different samples. For each sample, different small letters indicate significant differences (P < 0.05) during storage.

Color properties

Color is one of the most significant indices for determining the freshness and quality of fruit and vegetables during post-harvest. During storage, the color of button mushrooms gradually shifts to brown, possibly due to oxidation processes and microbial growth, resulting in the loss of overall nutritional quality and shelf-life. Surface color changes were evaluated by determining lightness (L^*), redness (a^*), and yellowness (b^*) (Li *et al.*, 2019). Figure 3 reports the color parameters after the application of the

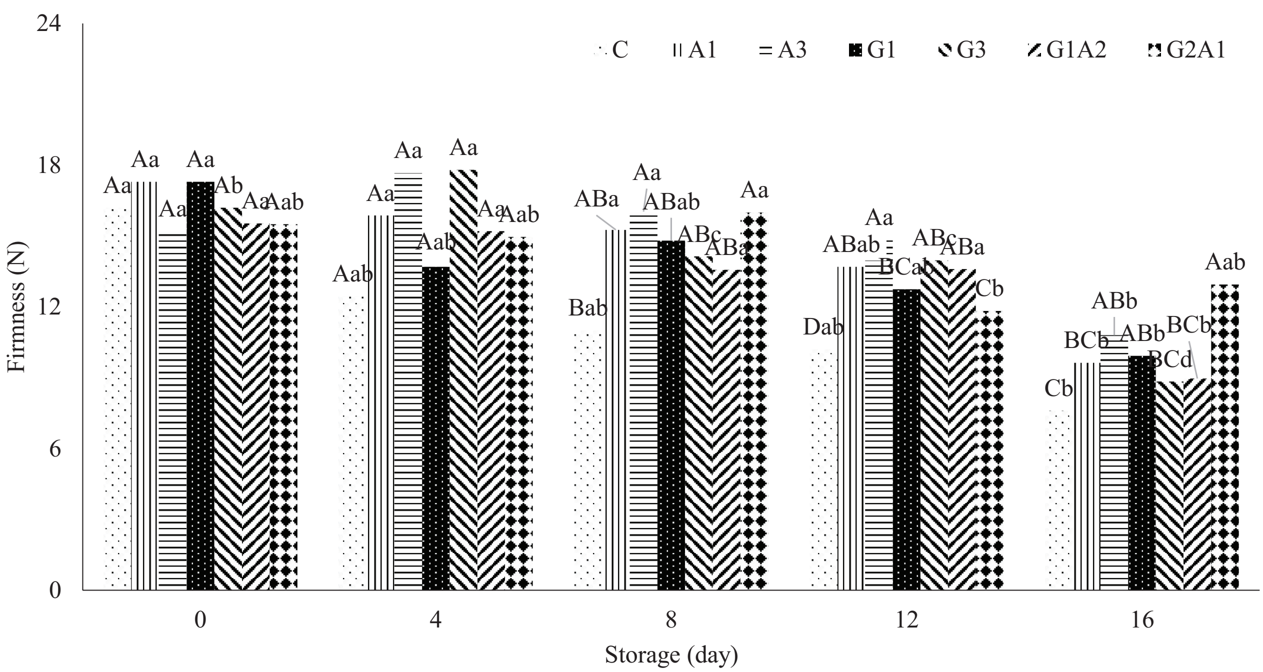
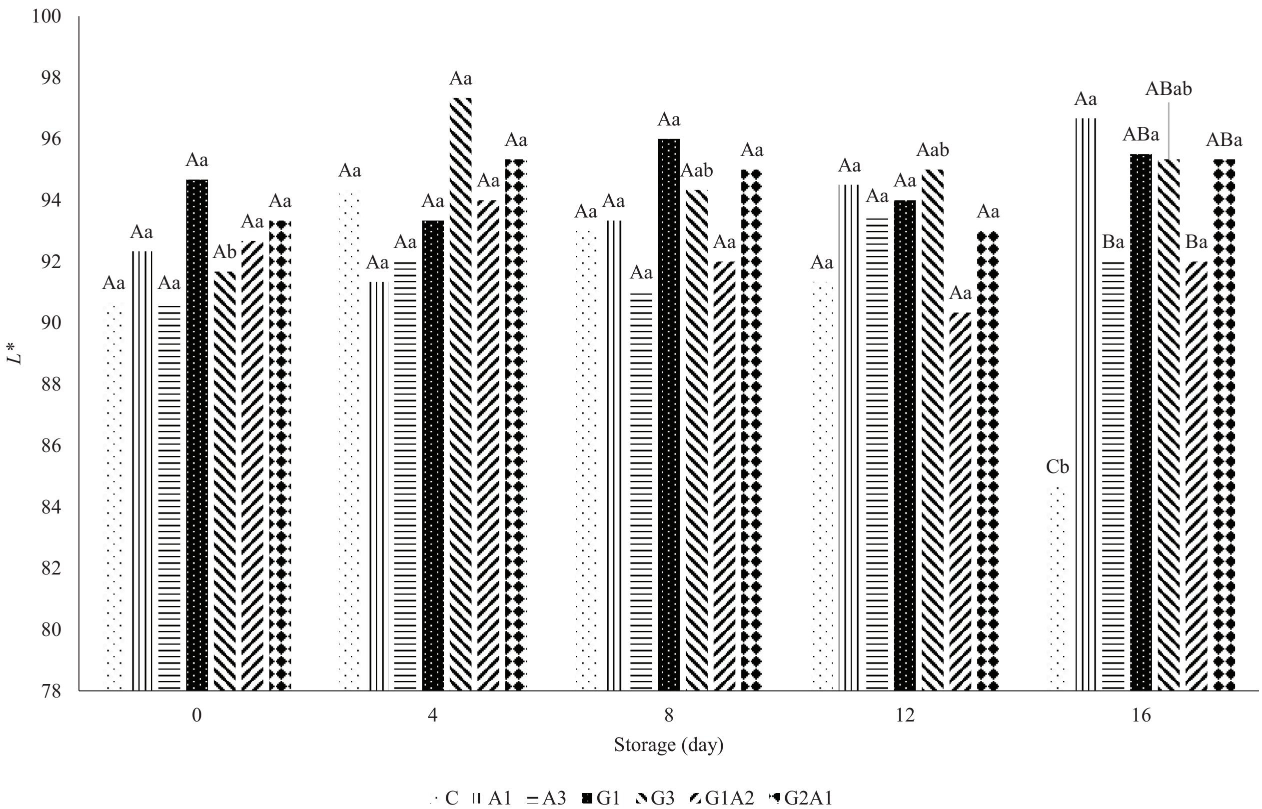


Figure 2. Firmness changes of coated samples during shelf life. C (control sample), A1 (1% aloe vera coating), A3 (3% aloe vera coating), G1 (1% gelatin coating), G3 (3% gelatin coating), G1A2 (1% gelatin + 2% aloe vera coating), and G2A1 (2% gelatin + 1% aloe vera coating).

(A)



(B)

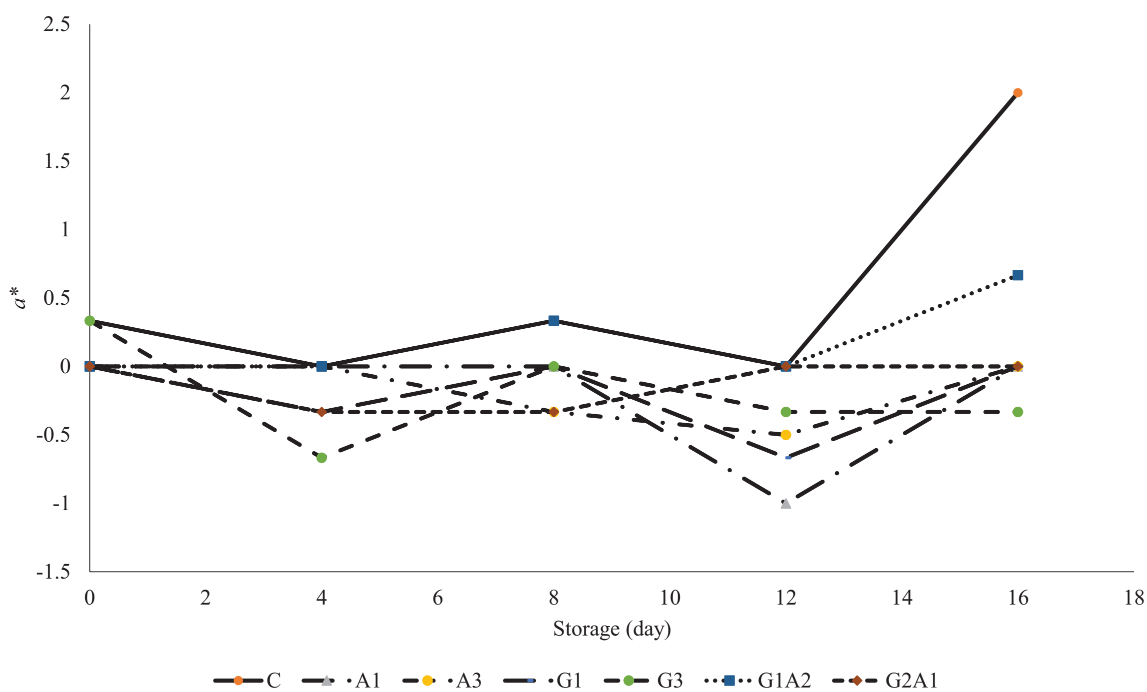


Figure 3. Effect of coating on *L (A), *a** (B), and *b** (C) changes of samples during shelf life. C (control sample), A1 (1% aloe vera coating), A3 (3% aloe vera coating), G1 (1% gelatin coating), G3 (3% gelatin coating), G1A2 (1% gelatin + 2% aloe vera coating), and G2A1 (2% gelatin + 1% aloe vera coating).**

(C)

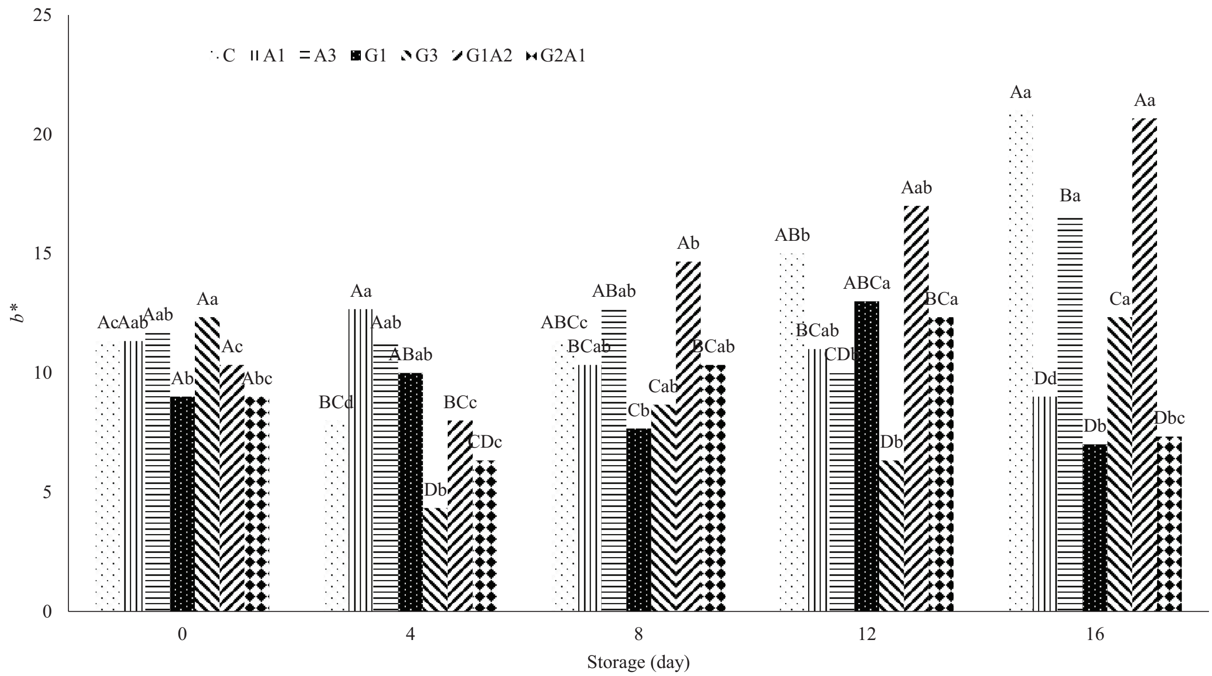


Figure 3. (Continued)

edible coatings and their comparison with the control sample. Regarding Figure 3, at the beginning of storage, higher *L** and lower *a** values were found in the coated samples compared with the control. The *L** value of the control mushroom was reduced after the 12th day of storage. This parameter was 91.33 and 84.66 on the 8th and 12th days of storage, respectively. The final accepted *L** value based on commercially acceptable value is higher than 80 (Briones *et al.*, 1992). The *b** value of control and G1A2 samples was high during storage time. After 16 days of storage, the color of mushrooms coated with A1, G1, and G2A1 shifted to brownish. Although, they were still edible and had commercial value. In comparison with the control, in some coated treatments less browning was observed. Applying a coating to these samples can significantly influence the color properties because of changes in shriveling and browning. There are no differences in *a** value of all samples. Also, the protective effect of edible coatings such as gum, agar, sodium alginate, egg white protein, and lecithin (Cavusoglu *et al.*, 2021), chitosan (Sami *et al.*, 2021), pectin, chitosan, sodium alginate, and CMC (Pleșoianu and Nour, 2022) against color changes were reported previously. Our results demonstrated that the applied coating may be a potential approach to maintaining the freshness and extending the shelf life of the button mushroom during storage.

At the same time, different capital letters indicate significant differences ($P < 0.05$) between different samples. For each sample, different small letters indicate significant differences ($P < 0.05$) during storage.

Percent open caps

The results showed that the open-cap percentage of samples increased during storage, and the highest percentage was observed for the control. Figure 4 shows that this parameter significantly increased (66.6%) during storage. The average open caps percentage in coated samples with aloe vera and gelatin was between 0.00 and 33.3% during storage. The lowest amount (0.00%) of this parameter was determined for the A1- and G1-treated samples. The open-cap percentage of samples is due to the mushroom dryness and water loss during storage. The increase in water loss during storage is due to the decreasing water cohesion and some molecules, including proteins. Between coated samples, the lowest open-cap percentage was found in A1 and G1. Sami *et al.* (2021) studied the effects of chitosan coating on the open-cap percentage of mushrooms. They reported that chitosan is a good treatment for reducing the open-cap percentage of samples. It is due to controlling the respiration rate, moisture evaporation, and firmness of samples.

At the same time, different capital letters indicate significant differences ($P < 0.05$) between different samples. For each sample, different small letters indicate significant differences ($P < 0.05$) during storage.

Microbiological properties

The effect of various coatings on the mesophile count, yeasts, and mold of samples and their comparison with

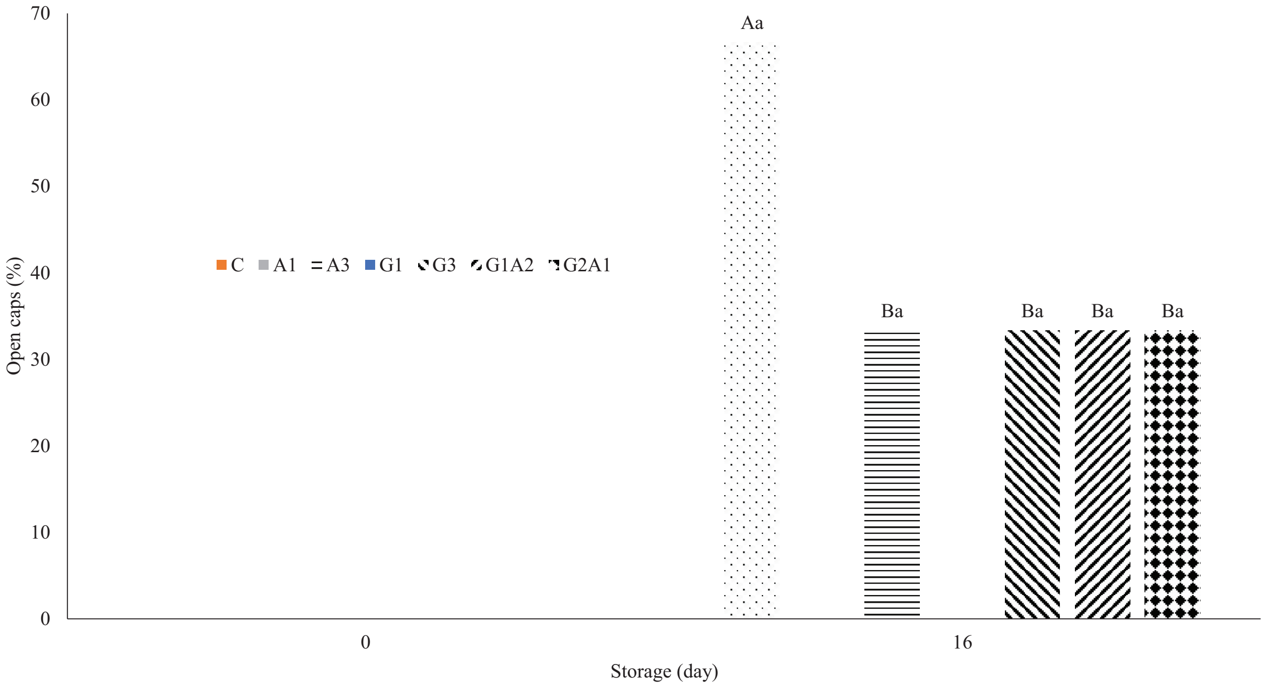


Figure 4. Effect of coating on open cap changes of samples during shelf life. C (control sample), A1 (1% aloe vera coating), A3 (3% aloe vera coating), G1 (1% gelatin coating), G3 (3% gelatin coating), G1A2 (1% gelatin + 2% aloe vera coating), and G2A1 (2% gelatin + 1% aloe vera coating).

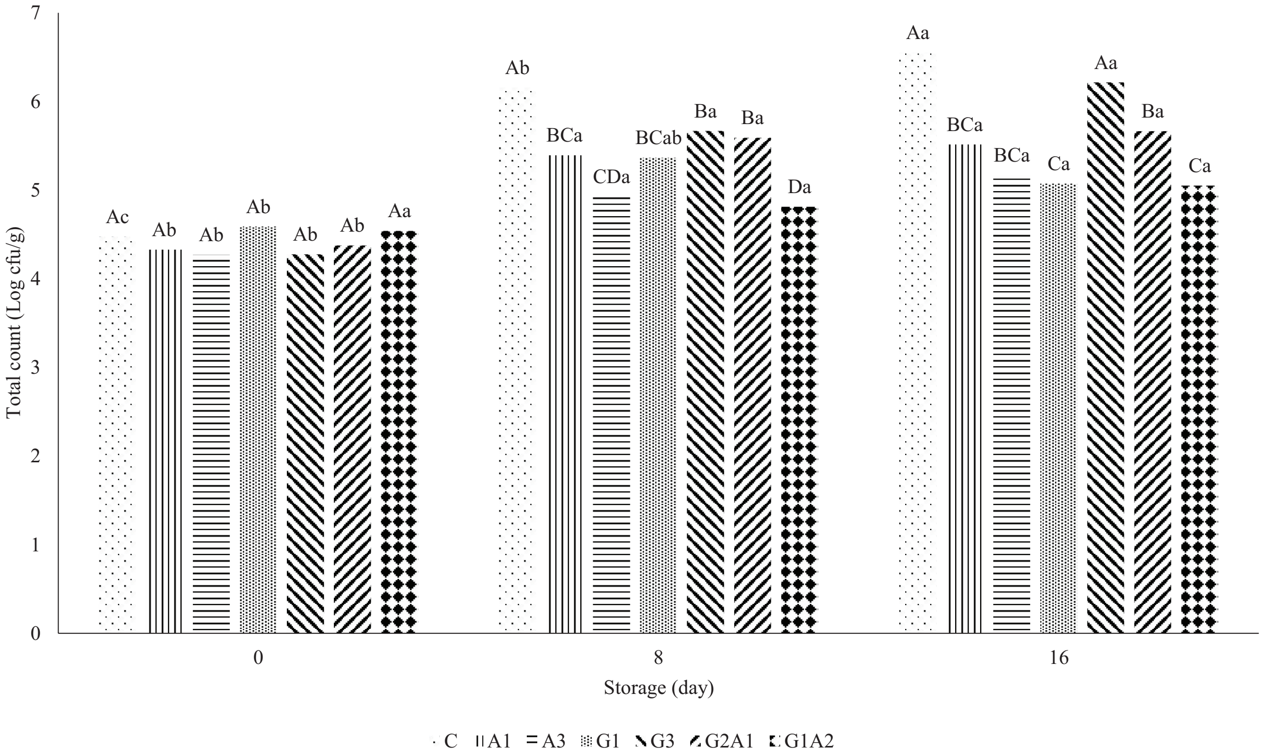
the control are reported in Figure 5. Our results showed that treated samples with A3 and G1A2 had the lowest yeasts and mold counts compared to the control. A3 and G1A2 treatments had counts of yeasts and molds under 6 log CFU/g during 16 days of storage. It can be due to the antimicrobial properties of ingredients in aloe vera and the suitable oxygen barrier properties of the prepared coating. According to Zhang *et al.* (2019), gram-negative and psychrotrophic are the main spoilage organisms in mushrooms. Due to the compost contamination by pseudomonas, higher spoilage of mushrooms was also reported by this strain. Control mushrooms showed tiny brown spots after 4 days that extended into brown zones. The formation of these brown zones in samples during storage was due to microbial spoilage. So, microbiological spoilage affects the softening and browning, and these changes were postponed in A3 and G1A2 treatments. Also, G2A1, A1, A3, and G1 treatments could significantly limit the mesophilic count. The application of coating with good barrier properties for preventing microbial contamination was also reported previously (Rokayya *et al.*, 2021; Sami *et al.*, 2021).

At the same time, different capital letters indicate significant differences ($P < 0.05$) between different samples. For each sample, different small letters indicate significant differences ($P < 0.05$) during storage.

Sensory attributes

The sensory characteristics are the most important parameters when suggesting any new bioactive coatings to consumers for evaluation. The sensorial properties of coated button mushrooms and control after 8 and 16 days of storage are reported in Table 2. Odor, color, texture, appearance, and overall acceptability significantly ($P < 0.05$) decreased during storage. These findings show button mushroom deterioration. The off-odor significantly increased during storage of control mushrooms. The color of button mushroom samples significantly changed to brown and uniformity decreased with storage. The control sample gills had a color intensity of 8.11 on the 8th day and uniformity of 7.33 on the 16th day of shelf life. However, the A1G2 and G2A1 gills were under these intensities even at the end of storage. The cap surface uniformity and dark stains in A1G2 and G2A1 samples were increased during storage. The sample browning is due to the phenol ingredient oxidation, the polyphenol oxidase enzyme activity, and the bacteria and mold growth on the button samples. The lowest spoilage organisms and oxidation of phenolic ingredients were observed in A1G2 and G2A. Therefore, the lowest changes in color and odor were observed for these two samples. These findings propose that the A1G2 sample was highly capable of preventing the sensorial characteristics of the coated button mushroom and increasing the panelists willingness.

(A)



(B)

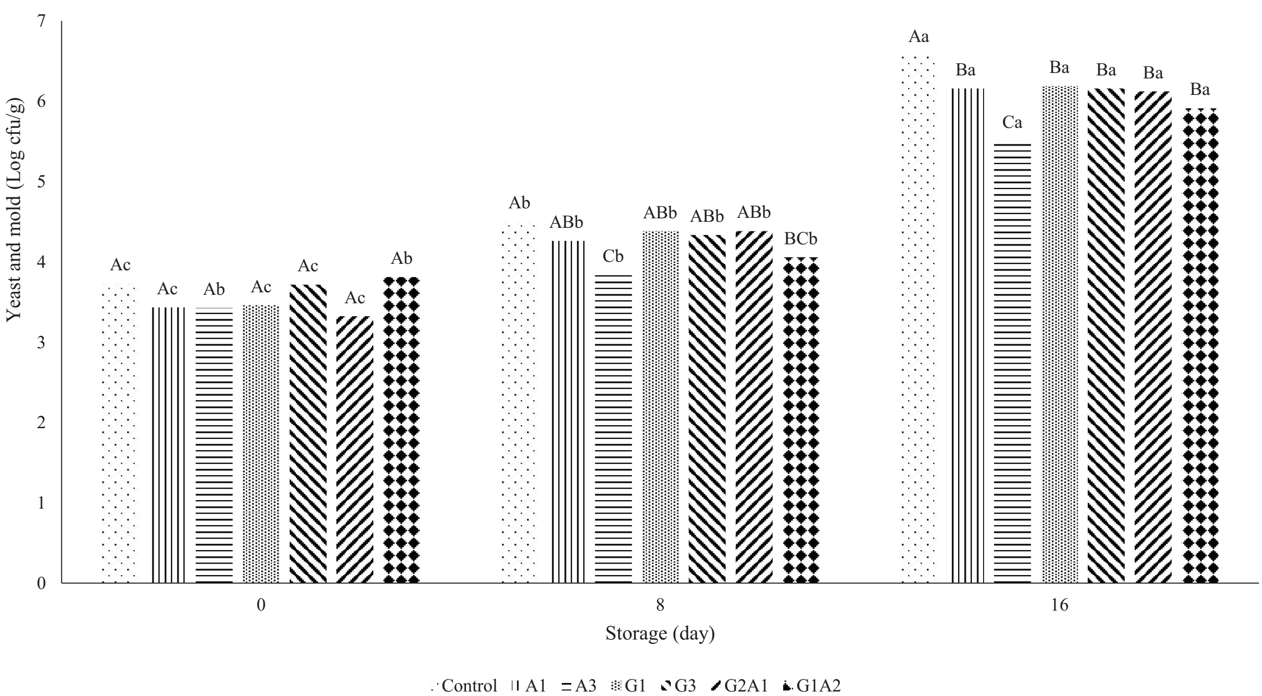


Figure 5. Influence of coating on mesophilic count (A) and yeast and mold (B) of samples during shelf life. C (control sample), A1 (1% aloe vera coating), A3 (3% aloe vera coating), G1 (1% gelatin coating), G3 (3% gelatin coating), G1A2 (1% gelatin + 2% aloe vera coating), and G2A1 (2% gelatin + 1% aloe vera coating).

Table 2. Sensorial properties of samples during shelf life.

	Color		Texture		Odor		Appearance		Acceptability	
Sample	8	16	8	16	8	16	8	16	8	16
C	8.11 ± 0.78Aa	7.33 ± 1.03Aa	8.33 ± 0.71Aa	5.00 ± 1.28Ab	8.00 ± 1.12Aa	5.67 ± 1.75Ab	8.44 ± 0.88Aa	7.17 ± 1.17Ab	8.44 ± 0.53Aa	6.00 ± 2.10Ab
A1	7.44 ± 0.73Aa	6.67 ± 1.03Aa	7.67 ± 1.22ABa	6.83 ± 1.17Aa	7.33 ± 1.22Aa	7.67 ± 1.03Aa	7.78 ± 0.83ABCa	6.00 ± 1.26Ab	7.56 ± 0.53ABa	6.50 ± 1.22Ab
A3	7.11 ± 1.36Aa	6.50 ± 0.55ABa	7.89 ± 1.17Aa	6.17 ± 1.17Ab	7.89 ± 0.78Aa	6.00 ± 1.26Ab	7.44 ± 0.73BCa	5.83 ± 1.33Ab	7.56 ± 0.73AABa	6.17 ± 1.33Ab
G1	7.22 ± 1.86Aa	6.83 ± 1.17Aa	7.89 ± 0.93Aa	6.50 ± 1.22Ab	7.67 ± 0.87Aa	5.67 ± 1.75Ab	7.56 ± 1.01ABCa	6.50 ± 1.22Aa	7.78 ± 0.83ABa	6.00 ± 1.79Ab
G3	5.78 ± 2.12Ba	5.33 ± 1.37Ba	6.11 ± 1.54Ca	6.33 ± 1.51Aa	6.11 ± 1.27Aa	6.50 ± 0.55Aa	6.56 ± 1.53Ca	6.00 ± 1.26Aa	6.44 ± 1.45Ca	5.83 ± 1.17Aa
A1G2	6.67 ± 1.50Aa	6.67 ± 1.21Aa	7.44 ± 1.01ABa	6.67 ± 1.51Aa	6.44 ± 1.27Aa	6.83 ± 1.33Aa	7.89 ± 1.27ABa	7.17 ± 1.83Aa	7.22 ± 1.39Ba	6.67 ± 1.75Aa
G1A2	6.89 ± 1.45Aa	6.83 ± 0.75Aa	6.56 ± 1.74BCa	6.00 ± 1.41Aa	6.78 ± 1.48Aa	6.67 ± 1.03Aa	7.56 ± 0.88ABCa	6.67 ± 0.52Ab	7.22 ± 1.09Ba	6.33 ± 1.03Aa

At the same time, different capital letters indicate significant differences (P < 0.05) between different samples. For each sample, different small letters indicate significant differences (P < 0.05) during storage.

Conclusion

In our research, novel edible coating materials were used to preserve the quality of button mushrooms during cold storage. Our findings showed that the aloe vera and gelatin samples had a suitable influence on the physiological and physicochemical properties of button mushrooms in comparison with the control sample. G1A2 was the best sample to maintain the quality and increase the shelf life of samples during the 16 days of storage. New research on the production of aloe vera and gelatin-coating complexes with nanoemulsion and microemulsion EOs (especially based on the different particle sizes of nanoemulsion) improved the application of this coating in the future for fruits and vegetables.

Data Availability

The data used to support the study are included within the article. Any more information can be obtained by contacting the corresponding author.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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