Journal of Food Science and Technology (Iran)

Homepage:www.fsct.modares.ir

Scientific Research

Combined use of sodium alginate and calcium lactate to extend the shelf-life of edible button mushroom.

Hadi Zarini, Orang Khademi* and Shahpour Khangholi

Department of Horticulture, Faculty of Agriculture, Shahed University, Tehran, Iran

ARTICLE INFO

Article History:

Received: 2025/07/31

Review: 2025/12/09

Accepted: 2025/12/14

Keywords:

Agaricus bisporus, browning, cold storage, combined treatment, quality

DOI: 10.48311/fsct.2026.84079.0

*Corresponding Author E-

o.khademi@shahed.ac.ir

ABSTRACT

This study aimed to improve the shelf life and maintain the quality of edible button mushrooms (*Agaricus bisporus*) through edible coating treatments. A factorial experiment was conducted in a completely randomized design with three replications, involving sodium alginate (0, 0.5, and 1%), calcium lactate (0 and 0.5%), and storage durations (0, 7, 14, and 21 days). After applying the treatments, the mushrooms were packaged in cellophane and stored at 4°C. Microbiological, physicochemical, and sensory parameters were evaluated. The results showed that the combined treatment of 0.5% sodium alginate and 0.5% calcium lactate significantly maintained the quality of the mushrooms, reducing weight loss by 50%, inhibiting browning by 38%, decreasing bacterial growth by 38%, preserving optimal texture firmness, and reducing fluctuations in soluble solids compared to the control. Additionally, this treatment significantly preserved the sensory characteristics of the mushrooms. In contrast, the treatment with 1% sodium alginate and 0.5% calcium lactate, despite increasing calcium content to 0.76 mg/g dry weight, showed weaker performance in controlling browning and maintaining sensory attributes. Single treatments were also effective in some parameters but were less effective than the combined treatment in preventing quality deterioration. In conclusion, the simultaneous use of 0.5% sodium alginate and 0.5% calcium lactate is recommended as an effective method to extend the shelf life and preserve the quality of edible button mushroom.

1- Introduction

The button mushroom (*Agaricus bisporus* L.) is one of the major sources of plant-based protein worldwide and has been commercially cultivated and consumed for centuries due to its high nutritional quality and unique functional properties [1]. This mushroom contains numerous bioactive compounds with anti-inflammatory, anticancer, antimicrobial, antidiabetic, antioxidant, and antiviral activities [2]. Additionally, mushrooms are rich in secondary metabolites such as phenolic compounds, terpenes, steroids, and bioactive polysaccharides such as β-glucans, dietary fibers, ergosterol, and various vitamins including B1, B2, C, and folate [3, 4].

Postharvest visual quality of mushrooms is a primary determinant of their marketability and pricing. Unlike many vegetables, mushrooms lack a thick protective cuticle, which makes them highly susceptible to physical damage, microbial contamination, moisture loss, and intense metabolic activity. These characteristics lead to high perishability, enzymatic browning, moisture loss, and accelerated senescence of the mushrooms [5]. The browning mechanism is largely attributed to enzymatic and bacterial activity [6]. Mushrooms are easily contaminated by microorganisms such as *Pseudomonas* mesophilic, *Campylobacter jejuni*, *Listeria monocytogenes*, *Escherichia coli*, and *Salmonella* species [7, 8]. Therefore, developing effective methods to extend the shelf life of mushrooms, with an emphasis on controlling enzymatic browning and suppressing bacterial factors, is of great importance in the mushroom production industry.

Various techniques have been investigated to maintain postharvest quality of mushrooms, including nanocomposite packaging [9], bioactive and edible coatings [10, 11], application of hydrogen peroxide [12], citric acid [5], methyl jasmonate [13], 4-methoxycinnamic acid [14], modified atmosphere packaging [15, 16], cold storage [17, 18], and high carbon dioxide environments in packaging [19]. Despite relative successes, these methods may result in drawbacks such as reduced nutritional value, undesirable color changes, textural degradation, secondary contamination, and sensory quality deterioration, and may not be economically feasible for small-scale producers [20].

Edible coatings and films, as cost-effective and more practical approaches, have been widely applied in food packaging and typically contain antimicrobial agents to prevent bacterial and fungal spoilage. These coatings are considered part of the product and contribute to preserving visual quality and enhancing consumer appeal [21, 22]. Sodium alginate, a linear polysaccharide extracted from brown algae of the *Phaeophyceae* family, is recognized as a promising candidate for food coating due to its favorable cost, biodegradability, non-toxicity, and ability to form stable gels in the presence of divalent metal cations such as calcium [23, 24, 25, 26].

Calcium plays a vital role in regulating physiological processes and maintaining postharvest quality of fruits and vegetables. This element can delay cell wall degradation, increase tissue firmness, and enhance resistance against pathogens by inactivating degradative enzymes and preserving cell membrane integrity [27, 28, 29]. Various calcium salts including calcium lactate, calcium chloride, and calcium gluconate have been applied in postharvest studies [30, 31, 32]. Although calcium chloride is widely used, its undesirable bitter taste limits its application, whereas calcium lactate, due to its lack of unfavorable taste and improvement of textural properties, is considered a suitable alternative [31, 33].

In this study, the combined effect of an edible sodium alginate coating and calcium lactate on extending shelf life and maintaining the visual quality of button mushrooms after harvest was investigated.

2- Materials and Methods

2.1. Mushroom Samples and Treatment Applications

This study was conducted in 2021 in the Postharvest Physiology and Technology Laboratory, Faculty of Agriculture, Shahed University. Button mushroom samples with closed caps and uniform diameters of 40 mm were obtained from a commercial producer located in Eslamshahr and transported to the laboratory at approximately 10 °C. The mushrooms were divided into six treatment groups (each group containing 144 mushrooms) and treated as follows:

Group 1: Distilled water as the control.
Group 2: Sodium alginate at 0.5% (Al-0.5).
Group 3: Sodium alginate at 1% (Al-1).
Group 4: Calcium lactate at 0.5% (CaL-0.5).
Group 5: Sodium alginate 0.5% + Calcium lactate 0.5% (Al-0.5 + CaL-0.5).
Group 6: Sodium alginate 1% + Calcium lactate 0.5% (Al-1 + CaL-0.5).

To prepare the solutions, the required amounts of sodium alginate (10 g and 20 g for the 0.5% and 1% w/v solutions, respectively) and calcium lactate (10 g for the 0.5% w/v solution) were weighed and dissolved in two liters of distilled water. For the combined treatments, the sodium alginate solution was prepared first and then the calcium lactate solution was added to it. Mushrooms in each treatment were immersed in the prepared solutions for two minutes and then dried at room temperature.

The treated samples were packaged in polyethylene containers (each containing 12 mushrooms) and covered with cling film. They were then stored at 4 °C, and on days 0, 7, 14, and 21 of storage, three packages from each treatment group were evaluated as three replicates.

2.2. Evaluated Traits

To calculate the percentage of weight loss, packages were weighed before storage as the initial weight and after the storage period on days 7, 14, and 21 as the final weight using a digital balance (AND, Japan) with an accuracy of 0.01 g. The percentage of weight loss was calculated using the following formula:

Weight Loss (%) = (Initial Weight - Final Weight) / Initial Weight × 100

Color attributes L*, a*, and b* were measured at three random points on the cap of each mushroom using a colorimeter (TEST model, Taiwan). The browning index (BI) was calculated using the following formula based on L*, a*, b* values:

$$BI=\frac{100(X-0.31)}{0.17}$$

$$X=\frac{(1.75\times L^*)+a^*}{(5.645\times L^*)+a^*-(0.3012\times b^*)}$$

The mushrooms' marketability was evaluated visually by three trained panelists on a scale from 0 to 3 (0 = lowest marketability; 3 = highest marketability). The marketability index was calculated using the following formula:

Marketability = (∑(Marketability Score × Number of Samples at Each Score)) / (3 × Total (Number of Samples per Package)

Four mushrooms from each package were randomly selected, and cap firmness was measured using a handheld texture analyzer (FT-011) with a 4 mm diameter probe. Total soluble solids were measured using a refractometer (VBR80, Italy) [34].

The bacterial population was evaluated following the method described by Guan [35] using nutrient agar (2.8%). One gram of sample was aseptically taken from the surface of mushrooms in each package with a sterile scalpel and homogenized in 100 mL of sterile distilled water using an electric homogenizer. Serial dilutions of the homogenate were prepared from 10^{-1} to 10^{-4}. A volume of 100 µL from each dilution was spread onto nutrient agar plates, which were then incubated at 25 °C in a growth chamber for 24 hours. After incubation, colonies were counted using a

colony counter, and bacterial counts were expressed as log CFU per gram of fresh weight.

To determine calcium and sodium content, several mushrooms were randomly selected from each package, dried in an oven at 65 °C, ground, and finally passed through a 40‑mesh sieve. Two grams of the ground samples were placed in an electric furnace at 550 °C until ashing. The ashes were dissolved in 2 M HCl, then filtered and brought to a final volume of 50 mL with distilled water. Calcium and sodium contents were determined using a flame photometer (Flame Photometer model: PTFP‑5), and the amounts of sodium and calcium were expressed as milligrams per gram of dry weight [36].

2.3 Experimental Design and Statistical Analysis

The experiment was conducted as a three-factor factorial in a completely randomized design with three replications. The first factor was the sodium alginate edible coating treatment (at three concentrations: 0, 0.5, and 1%), the second factor was the calcium lactate treatment (at two concentrations: 0 and 0.5%), and the third factor was the evaluation times (at three times: 7, 14, and 21 days). Collected data were checked for normality, and analysis of variance (ANOVA) was performed using SAS software (version 9.4). Duncan's multiple range test at a 5% probability level was used to compare differences between means.

3- Results

The results of the analysis of variance of the experiment on the effect of combining sodium alginate edible coating with calcium lactate on the shelf life of button mushrooms during 21 days of cold storage are presented in Table 1.

3.1. Weight Loss

The results showed that in all treatments, the percentage of weight loss increased over time. The highest weight loss throughout the experimental period was observed in the control treatment (water). The calcium lactate treatment alone (without sodium alginate) significantly controlled weight loss compared to the control samples. Also, the use of sodium alginate without calcium lactate effectively prevented weight loss. However, the combination of sodium alginate and calcium lactate was the most effective treatment in controlling weight loss; the lowest percentage of weight loss was observed in the Al‑0.5 + CaL‑0.5 and Al‑1 + CaL‑0.5 treatments. These treatments had approximately 50 % less weight loss compared to the control samples (Figure 1).

3.2. Browning Index

The study of changes in the browning index (Figure 2) showed that this process began on the seventh day of the experiment in all samples and continued to increase until the end of the 21‑day period. Among them, the control samples (treated with distilled water) showed the highest degree of browning throughout the experimental period. Both the calcium lactate and the sodium alginate treatments alone were able to reduce the severity of browning compared to the control

In the end, on day 21, the combined treatment (Al‑0.5 + CaL‑0.5) had the lowest browning index, which was 38 % lower than the control. However, this combined treatment did not show a statistically significant difference compared with the Al‑0.5 treatment.

Table 1. ANOVA results of the effects of calcium lactate, sodium alginate and storage time, and their interaction on studied parameters of button mushrooms (*Agaricus bisporus*)

	Mean of square							
Source of variance	Bacterial population	Browning index	Marketability	Weight loss	Firmness	Total soluble solid	Ca	Na
Storage Time (ST)	*	**	**	**	**	**	--	--
Calcium Lactate (CaL)	**	**	**	**	ns	*	**	ns
Alginate (Al)	**	**	**	ns	**	*	**	**
ST × CaL	**	ns	**	*	*	**	--	--
ST × Al	**	**	**	**	**	*	--	--
CaL × Al	**	**	**	**	*	ns	**	ns
ST × CaL × Al	**	**	**	**	ns	ns	--	--
CV%	7.8	13.76	12.1	23.26	10.42	7.08	4.9	15.02

** ,*and ns represent significance at the 0.01 and 0.05 levels and non-significance respectively

3.3. Marketability

The results of the marketability evaluation showed that on the seventh day of the experiment, none of the treatments containing Al, CaL, or the combination of the two showed a significant decrease in marketability compared with the beginning of the experiment, whereas the control samples experienced a noticeable decrease. Over time, all treated samples showed a gradual but significant decrease in marketability, with the lowest marketability observed in the control samples. Among these, the CaL-0.5, Al-0.5, and their combined treatments effectively prevented the reduction in marketability, with the greatest protective effect observed for the combined Al-0.5 + CaL-0.5 treatment. Although the Al-1 treatment alone did not show a statistically significant difference from the control on day 21, when combined with CaL-0.5 it demonstrated a notable protective effect in maintaining the marketability of the mushrooms (Figure 3 and Image 1).

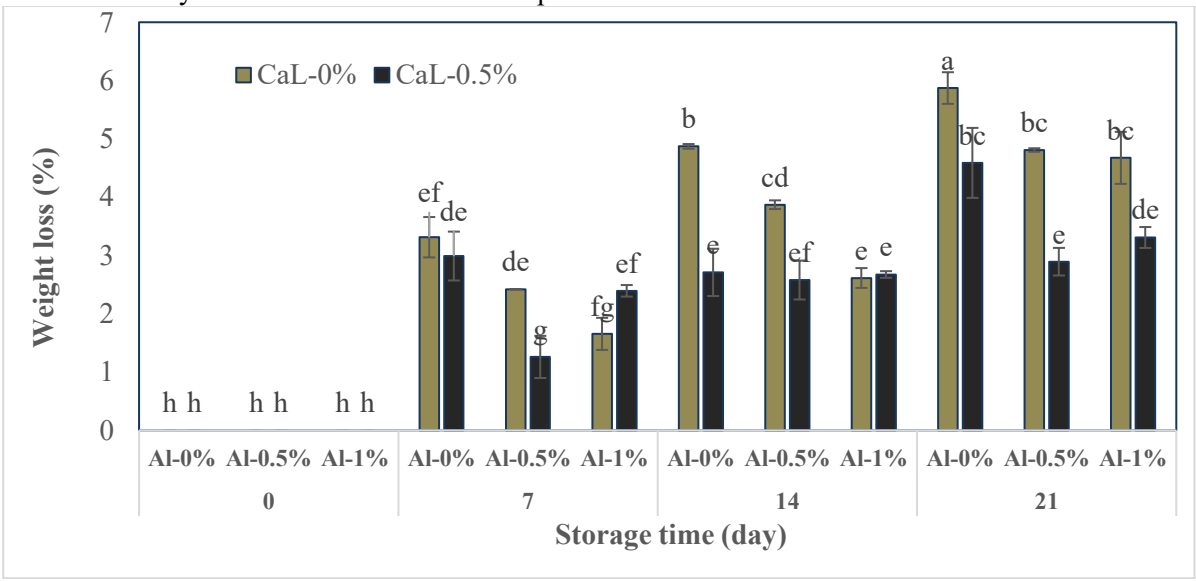

Fig 1. Effect of sodium alginate (Al) and calcium lactate (CaL) on weight loss of button mushrooms during 21 days of cold storage. Means (± standard error) with the same letter are not significantly different by duncan's test ($p \leq 0.05$).

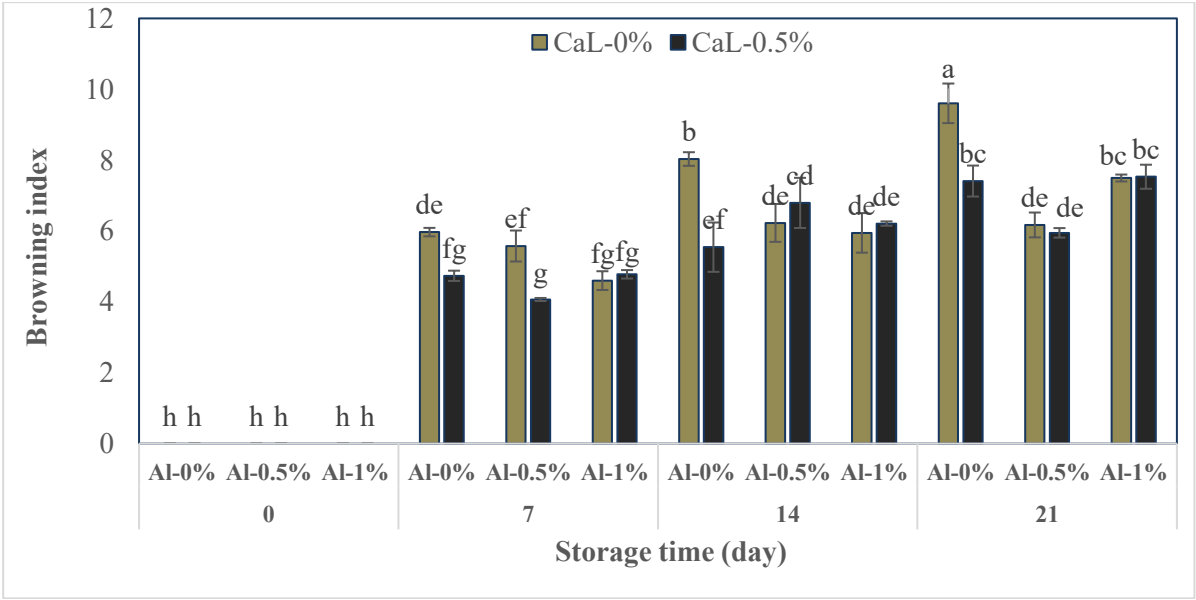

Fig 2. Effect of sodium alginate (Al) and calcium lactate (CaL) on browning index of button mushrooms during 21 days of cold storage. Means (± standard error) with the same letter are not significantly different by duncan's test ($p \leq 0.05$).

3.4. Bacterial Population

The results of this study showed that in mushrooms treated with distilled water (control group), the bacterial population remained at a high level from the beginning of the experiment and this trend was maintained until the end of the 21-day period. In the groups treated with sodium alginate alone (Al-0.5 and Al-1), although a relative decrease in bacterial population was observed in the early stages of the experiment, no significant difference was seen compared to the control group at the end of the period. The calcium lactate treatment alone (CaL-0.5) also initially caused a noticeable reduction in bacterial population, but this effect decreased over time and ultimately did not show a statistically significant difference compared to the control group. In contrast, the combined treatment Al-0.5 + CaL-0.5 consistently maintained the lowest bacterial population throughout the experiment and on the final day of the study showed a 38 % reduction compared to the control group. Notably, the combined treatment with the higher sodium alginate concentration (Al-1 + CaL-0.5), although effective, was not as effective as the combined treatment with the lower sodium alginate concentration (Figure 4).

3.5. Firmness

The results of the interaction between sodium alginate treatments and time, and also between calcium lactate treatments and time, showed that on the seventh day, tissue firmness increased compared to day zero and then decreased as the experiment continued, such that mushrooms treated with CaL-0.5 on the seventh day showed higher firmness than samples without calcium, but no significant differences were observed at other times. The Al-0.5 treatment showed the least changes in firmness throughout the experiment and at the end of the period retained higher tissue firmness compared to the control and the Al-1 treatment, while the greatest fluctuations in firmness were observed in the control group. The investigation of the interaction effects of sodium alginate and calcium lactate treatments showed that the combined Al-0.5 + CaL-0.5 treatment produced the highest firmness, whereas the lowest firmness belonged to the Al-1 + CaL-0.5 treatment (Figure 5).

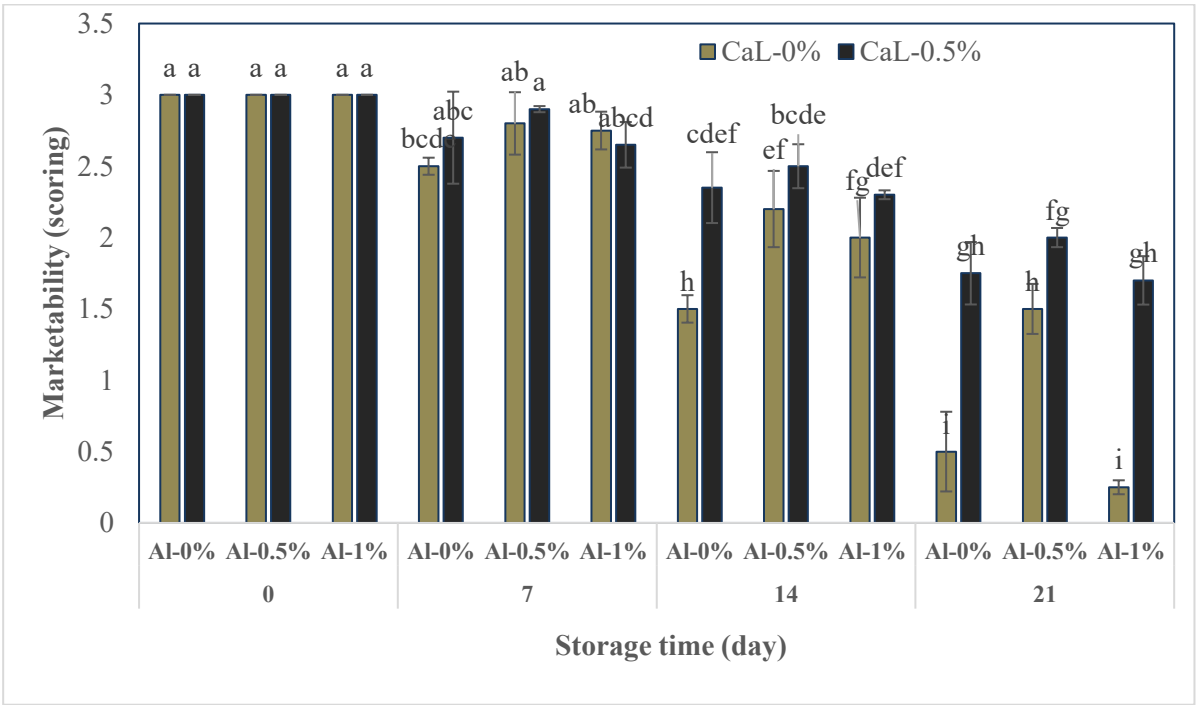

Fig 3. Effect of sodium alginate (Al) and calcium lactate (CaL) on marketability of button mushrooms during 21 days of cold storage. Means (± standard error) with the same letter are not significantly different by duncan's test ($p \leq 0.05$).

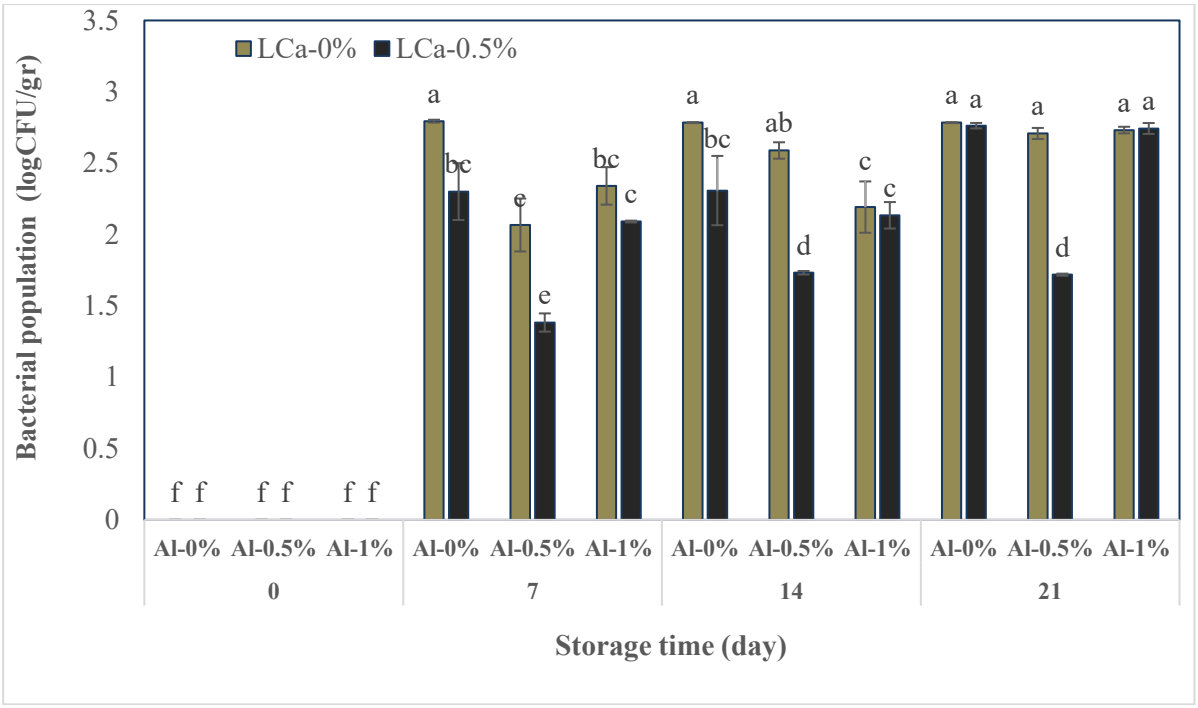

Fig 4. Effect of sodium alginate (Al) and calcium lactate (CaL) on bacterial population of button mushrooms during 21 days of cold storage. Means (± standard error) with the same letter are not significantly different by duncan's test ($p \leq 0.05$)..

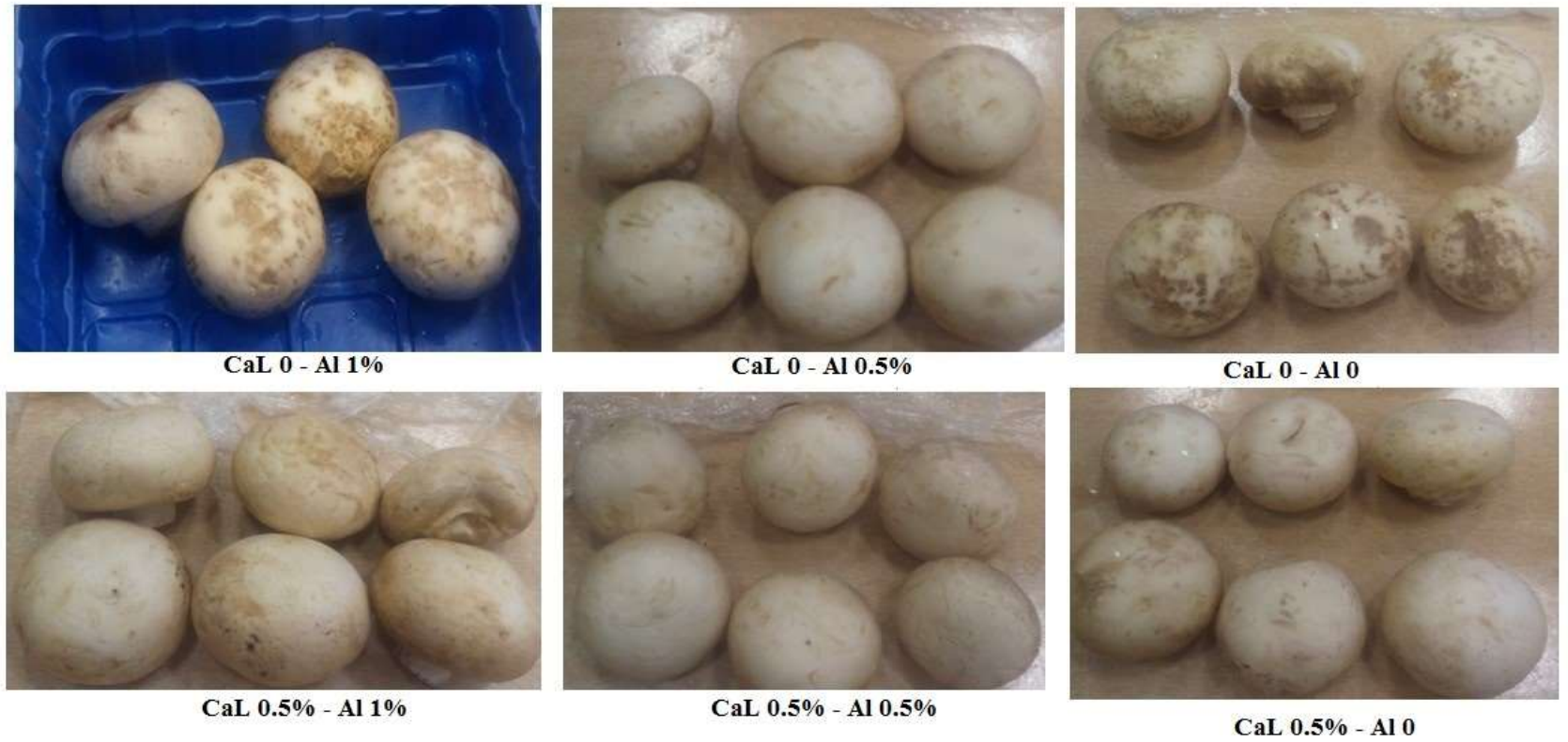

Image 1. Samples showing the effect of calcium lactate (CaL) and sodium alginate (Al) treatments on the appearance quality of button mushrooms.

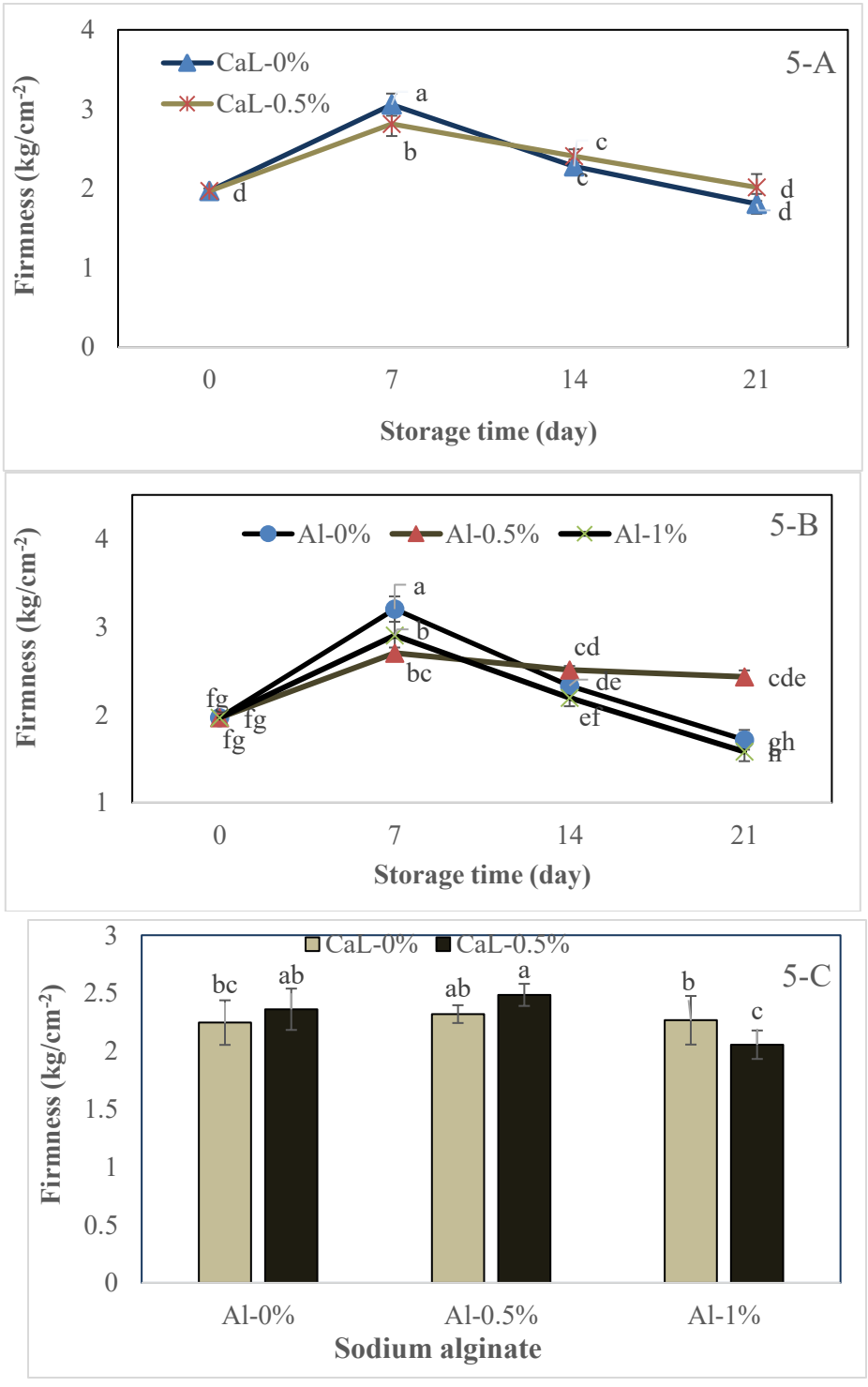

Fig 5. Interaction effects between calcium lactate (CaL) and storage time (5-A), between sodium alginate (Al) and storage time (5-B), and between sodium alginate and calcium lactate (5-C) on the firmness of button mushrooms.. Means (± standard error) with the same letter are not significantly different by duncan's test ($p \leq 0.05$).

3.6. Total Soluble Solids (TSS)

The results showed that the interaction between sodium alginate treatment and evaluation time, and also between calcium lactate treatment and evaluation time, led to a gradual decrease in TSS during the experiment. Samples treated with CaL-0.5 had higher TSS compared to samples without calcium. Additionally, samples treated with Al-0.5 showed smaller fluctuations in TSS, whereas the Al-1 and control samples showed greater decreases, which were not statistically different from each other (Figure 6).

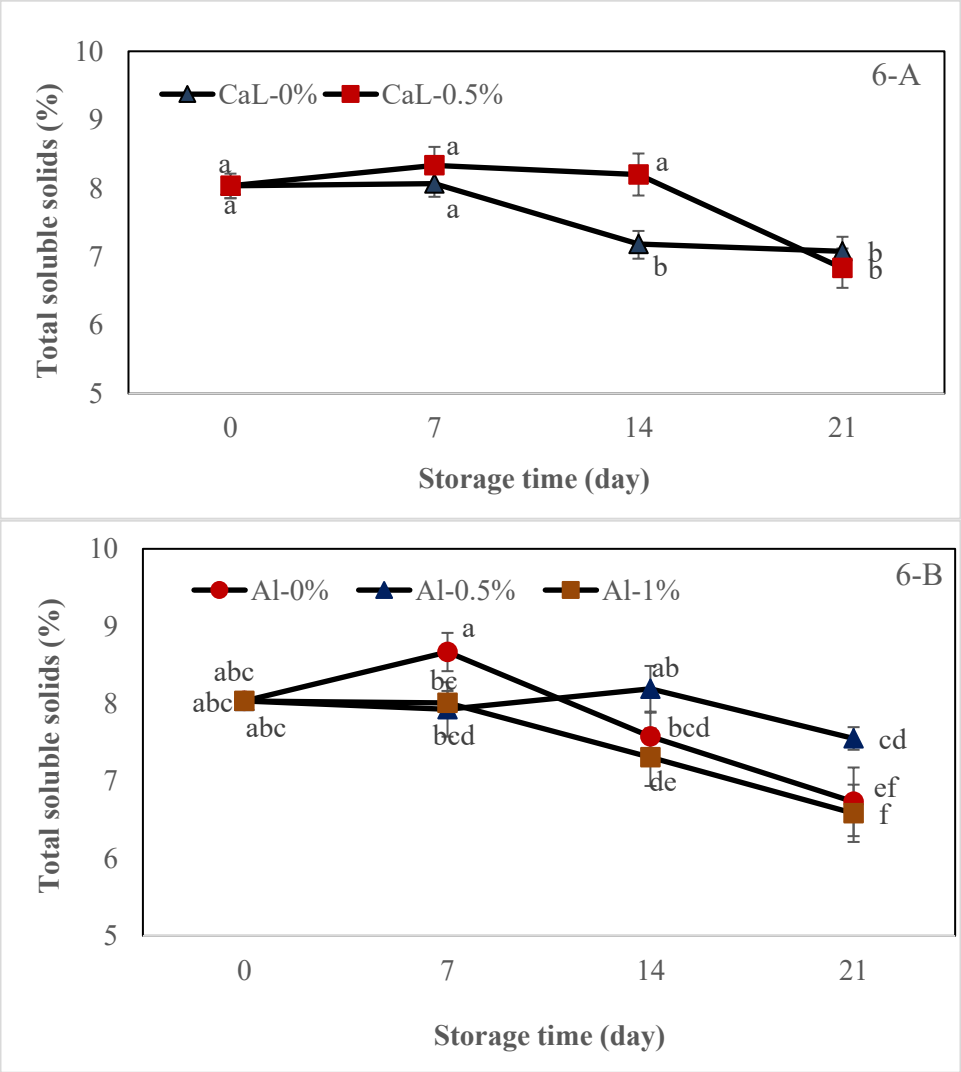

Fig 6. Interaction effects between calcium lactate (CaL) and storage time (6-A), and between sodium alginate (Al) and storage time (6-B) on the total soluble solids of button mushrooms. Means (± standard error) with the same letter are not significantly different by duncan's test ($p \leq 0.05$).

3.7. Calcium and Sodium contents

The results of the study showed that the CaL-0.5 treatment alone, compared with the control samples (without calcium), caused a significant increase in the calcium content of the mushrooms (66 % higher). However, the simultaneous application of this treatment

with sodium alginate had a notable synergistic effect, such that the combination CaL-0.5 + Al-1 resulted in the greatest increase in calcium (with a value of 0.76 mg g^{-1} dry weight) and performed better than the combination CaL-0.5 + Al-0.5 (Figure 7). The results showed that the highest sodium content in mushrooms was observed in the samples treated with Al-1 (0.12 mg g^{-1} dry weight). The Al-0.5 samples also had higher sodium content compared with the samples without sodium alginate treatment (Figure 8).

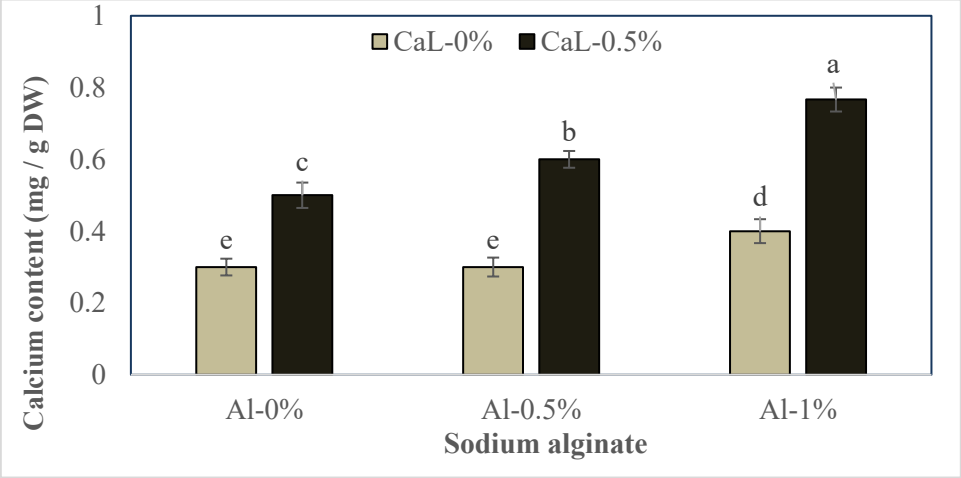

Fig 7. Interaction effect between calcium lactate (CaL) and sodium alginate (Al) on the calcium content of button mushrooms. Means (± standard error) with the same letter are not significantly different by duncan's test ($p \leq 0.05$).

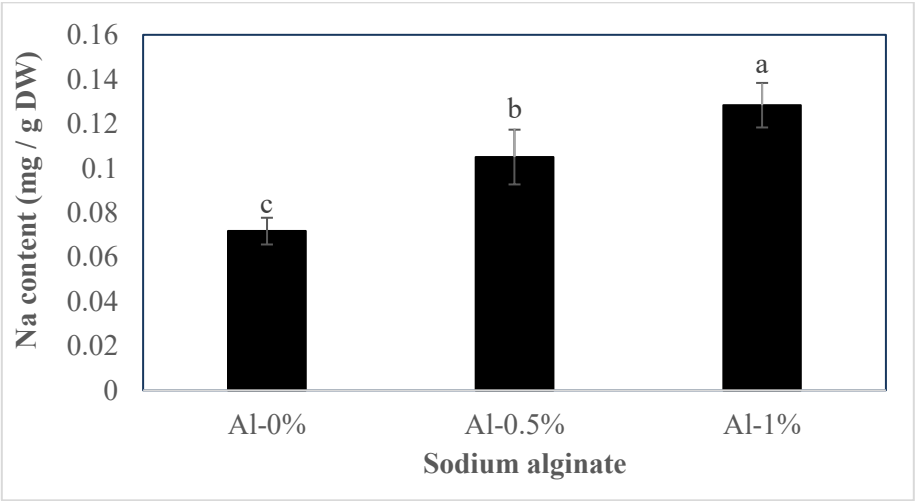

Fig 8. The effect of sodium alginate (Al) on the Na content of button mushrooms. Means (± (standard error) with the same letter are not significantly different by duncan's test ($p \leq 0.05$).

4- Discussion

Button mushrooms have a high rate of transpiration and respiration due to the absence of a thick protective layer, which

leads to significant weight loss after harvest [5, 23]. This phenomenon, which is part of the natural senescence process, directly affects product quality and marketability [20]. In this regard, the use of edible coatings, particularly formulations containing calcium and sodium alginate, has been proposed as an effective strategy to improve quality and extend shelf life.

Calcium, by playing a role in strengthening the structure of the cell wall and membrane, prevents the leakage of ions and cellular materials and, by reducing the rates of respiration and transpiration, delays the senescence process [28, 31]. In addition, various studies have shown that these positive effects are not limited to button mushrooms but have also been observed in other horticultural products such as strawberries and peaches [37, 38]. On the other hand, alginate coatings, despite lacking lipids, are able to partially prevent product weight loss. However, due to the hydrophilic and hygroscopic nature of alginates, their performance as a moisture barrier in products with high water activity, such as mushrooms, is limited [26, 39]. Therefore, the combined use of sodium alginate and calcium can improve the protective performance of these coatings as a synergistic approach.

One of the important quality indices in button mushrooms is the white color of the cap, the loss of which due to browning greatly reduces product marketability [20, 34, 36]. Browning occurs as a result of the activity of polyphenol oxidase (PPO) family enzymes, especially tyrosinase, which leads to the oxidation of phenolic compounds and the production of melanin pigments [40]. Calcium, by maintaining cell membrane integrity and preventing the efflux of phenolic compounds, and also by inhibiting PPO activity, plays an effective role in reducing browning [41]. In addition, sodium alginate coating, by reducing oxygen permeability into the tissue, limits the activity of oxidative enzymes [39].

Compared with fruits, button mushrooms lack a pectic layer and their tissue is exposed to more rapid softening. This process is particularly influenced by the activity of microbial and endogenous autolytic enzymes that degrade the cell wall and lead to a reduction in turgidity due to water loss [20]. Calcium treatment, by creating cross-links between carboxyl groups in the cell wall, increases tissue firmness and resistance to destructive enzymes [29]. Alginate coating also helps delay senescence and maintain tissue firmness by reducing the rate of cellular metabolism [25].

From a microbial perspective, button mushrooms are strongly affected by bacterial pathogens, especially *Pseudomonas tolaasii*, which secretes the toxin tolaasin causing membrane disruption and enzymatic browning [5]. The use of calcium, particularly in the form of calcium lactate, can inhibit the growth of these bacteria by strengthening the cell wall and also through the antibacterial properties of organic acids; these acids, after entering the bacterial cell, change the internal pH, cause damage to DNA and RNA, disrupt energy metabolism, and degrade bacterial protein structures [36, 42].

In addition, alginate coatings can be used as carriers of active substances including antibacterial and antioxidant compounds [39]. The effectiveness of these coatings can depend on the concentration used, such that in some studies higher concentrations (e.g., 2 %) and in others lower concentrations (0.5 % to 1 %) have shown more favorable results, a difference that is likely related to the tissue type and physiological characteristics of the product under study.

The combination of calcium and sodium alginate has been introduced as the most effective treatment for controlling weight loss, browning, softening, and microbial growth in button mushrooms. These effects are due to the synergy between the physical and chemical properties of alginate as a protective barrier and the biological and antibacterial

role of calcium in the cellular structure of the mushrooms.

On the other hand, the senescence process and cellular breakdown lead to the degradation of cell wall polysaccharides and an increase in total soluble solids in mushroom tissue [34]. By reducing the rate of cell wall degradation through coating treatments, this increase can be prevented and internal quality can be preserved [40]. Additionally, the application of calcium lactate leads to a significant increase in the calcium content in mushroom tissue, which is due to the gradual penetration of calcium and its binding to the cell wall structure and, in products containing pectin, pectic compounds [30].

In summary, scientific evidence indicates that the use of combined calcium and sodium alginate coatings can be an effective strategy for maintaining the physical, chemical, and microbial quality of button mushrooms during the postharvest period.

5-Conclusion

The results of this research showed that the use of edible coatings containing calcium lactate and sodium alginate, especially in combination, had a significant effect on preserving the quality of button mushrooms after harvest. These treatments enhanced shelf life and marketability by reducing weight loss, browning, tissue softening, and microbial growth. The positive effects of these compounds were achieved through mechanisms such as strengthening the cell wall, reducing oxygen penetration, decreasing enzymatic activity, and increasing tissue integrity. Based on these findings, the use of a combined calcium and sodium alginate coating can be recommended as a practical and effective approach in postharvest quality management of button mushrooms.

6- Recommendations

Considering the findings of this study, it is recommended that future research investigate the effect of the combined sodium alginate and calcium lactate treatment at the optimal concentration obtained from this study in combination with physical methods such as ultraviolet light, ultrasonic waves, or modified atmosphere packaging, and biological compounds such as plant essential oils or antimicrobial peptides, to assess the potential synergistic effects in controlling browning of edible mushrooms. In addition, examining the physiological mechanisms underlying the performance of these coatings, including their impact on the activity of enzymes involved in decay such as polyphenol oxidase and peroxidase, regulation of respiration, and ethylene metabolism, could lead to a deeper understanding of the role of these compounds in quality preservation.

Funding

The author declares that he / she has not received any funding.

Author Contributions

All activities were carried out by the author.

Competing Interests

The author confirms that he / she has no financial conflicts of interest or competing interests in this study.

Acknowledgements

The authors would like to express their sincere gratitude to the Vice-chancellor for Research and Technology of Agricultural Sciences and Natural Resources University of Khuzestan for supporting this study (1403.38).

7-References

[1] Rathore, H., Prasad, S., and Sharma, S. (2017). Mushroom nutraceuticals for improved nutrition and better human health: A review. *PharmaNutrition, 5*(2), 35-46.

[2] Wu, X., Guan, W., Yan, R., Lei, J., Xu, L., and Wang, Z. (2016). Effects of UV-C on antioxidant activity, total phenolics and main

phenolic compounds of the melanin biosynthesis pathway in different tissues of button mushroom. *Postharvest Biology and Technology, 118*, 51-58.

[3] Valverde, M. E., Hernández-Pérez, T., and Paredes-López, O. (2015). Edible mushrooms: improving human health and promoting quality life. *International Journal of Microbiology, 2015*, 1-14.

[4] Cardwell, G., Bornman, J. F., James, A. P., and Black, L. J. (2018). A review of mushrooms as a potential source of dietary vitamin D. *Nutrients, 10*(10), 1498.

[5] Brennan, M., Le Port, G., and Gormley, R. (2000). Post-harvest treatment with citric acid or hydrogen peroxide to extend the shelf life of fresh sliced mushrooms. LWT-Food Science and Technology, 33 (4), 285-289.

[6] Liang, Y., Luo, K., Wang, B., Huang, B., Fei, P., and Zhang, G. (2024). Inhibition of polyphenol oxidase for preventing browning in edible mushrooms: A review. Journal of Food Science, 89(11), 6796-6817.

[7] Lagnika, C., Zhang, M., and Mothibe, K. J. (2013). Effects of ultrasound and high pressure argon on physico-chemical properties of white mushrooms (*Agaricus bisporus*) during postharvest storage. *Postharvest Biology and Technology, 82*, 87-94.

[8] Carrasco, J., and Preston, G. M. (2020). Growing edible mushrooms: A conversation between bacteria and fungi. *Environmental Microbiology, 22*(3), 858-872.

[9] Donglu, F., Wenjian, Y., Kimatu, B. M., Xinxin, A., Qiuhui, H., and Liyan, Z. (2016). Effect of nanocomposite packaging on postharvest quality and reactive oxygen species metabolism of mushrooms (*Flammulina velutipes*). *Postharvest Biology and Technology, 119*, 49-57.

[10] Guillaume, C., Schwab, I., Gastaldi, E., and Gontard, N. (2010). Biobased packaging for improving preservation of fresh common mushrooms (*Agaricus bisporus* L.). *Innovative Food Science and Emerging Technologies, 11*(4), 690-696.

[11] Han, L., Qin, Y., Liu, D., Chen, H., Li, H., and Yuan, M. (2015). Evaluation of biodegradable film packaging to improve the shelf-life of *Boletus edulis* wild edible mushrooms. *Innovative Food Science and Emerging Technologies, 29*, 288-294.

[12] Kale, S. J., Nath, P., Kannaujia, P., and Dukare, A. (2021). Hydrogen peroxide washing induced changes in postharvest quality of button mushrooms (*Agaricus bisporus*) during storage. Journal of Agriculture and Food Research, 1(1), 119-130.

[13] Meng, D., Song, T., Shen, L., Zhang, X., and Sheng, J. (2012). Postharvest application of methyl jasmonate for improving quality retention of *Agaricus bisporus* fruit bodies. *Journal of Agricultural and Food Chemistry, 60*(23), 6056-6062.

[14] Hu, Y. H., Chen, C. M., Xu, L., Cui, Y., Yu, X. Y., Gao, H. J., and Chen, Q. X. (2015). Postharvest application of 4-methoxy cinnamic acid for extending the shelf life of mushroom (*Agaricus bisporus*). *Postharvest Biology and Technology, 104*, 33-41.

[15] NeysariFam, V., Golmohammadi, A., Tabatabaekoloor, R., Tahmasebi, M., Nematollahzadeh, A., Razavi, M. S., ... and Ghaani, M. (2025). Preservation of button mushrooms using modified atmosphere and bio-nanocomposite film: A combined approach. Applied Food Research, 101043.

[16] Oz, A. T., Ulukanli, Z., Bozok, F., and Baktemur, G. (2015). The postharvest quality, sensory and shelf life of *Agaricus bisporus* in active map. *Journal of Food Processing and Preservation, 39*(1), 100-106.

[17] Dama, C. L., Kumar, S., Mishra, B. K., Shukla, K. B., Mathur, S., and Doshi, A. (2010). Antioxidative enzymatic profile of mushrooms stored at low temperature. *Journal of Food Science and Technology, 47*, 650-655.

[18] Li, D., Qin, X., Tian, P., and Wang, J. (2016). Toughening and its association with the postharvest quality of king oyster mushroom (*Pleurotus eryngii*) stored at low temperature. *Food Chemistry, 196*, 1092-1100.

[19] Lin, Q., Lu, Y., Zhang, J., Liu, W., Guan, W., and Wang, Z. (2017). Effects of high CO_2 in-package treatment on flavor, quality and antioxidant activity of button mushroom (*Agaricus bisporus*) during postharvest storage. *Postharvest Biology and Technology, 123*, 112-118.

[20] Lagnika, C., Zhang, M., Nsor-Atindana, J., and Bashari, M. (2014). Effects of ultrasound and chemical treatments on white mushroom (*Agaricus bisporus*) prior to modified atmosphere packaging in extending shelf-life.

Journal of Food Science and Technology, 51, 3749-3757.

[21] Mohebbi, M., Ansarifar, E., Hasanpour, N., and Amiryousefi, M. R. (2012). Suitability of aloe vera and gum tragacanth as edible coatings for extending the shelf life of button mushroom. *Food and Bioprocess Technology, 5*, 3193-3202.

[22] Sharma, P., Shehin, V. P., Kaur, N., and Vyas, P. (2019). Application of edible coatings on fresh and minimally processed vegetables: A review. *International Journal of Vegetable Science, 25*(3), 295-314.

[23] Jiang, T. (2013). Effect of alginate coating on physicochemical and sensory qualities of button mushrooms (*Agaricus bisporus*) under a high oxygen modified atmosphere. *Postharvest Biology and Technology, 76*, 91-97.

[24] Aguilar, K. C., Tello, F., Bierhalz, A. C., Romo, M. G. G., Flores, H. E. M., and Grosso, C. R. (2015). Protein adsorption onto alginate-pectin microparticles and films produced by ionic gelation. *Journal of Food Engineering, 154*, 17-24.

[25] Sow, L. C., Toh, N. Z. Y., Wong, C. W., and Yang, H. (2019). Combination of sodium alginate with tilapia fish gelatin for improved texture properties and nanostructure modification. *Food Hydrocolloids, 94*, 459-467.

[26] Sharma, A., and Singh, A. K. (2025). Sodium alginate: A green biopolymer resource-based antimicrobial edible coating to enhance fruit shelf-life: A review. Colloids and Interfaces*,* 9(3), 32.

[27] Naser, F., Rabiei, V., Razavi, F., and Khademi, O. (2018). Effect of calcium lactate in combination with hot water treatment on the nutritional quality of persimmon fruit during cold storage. *Scientia Horticulturae, 233*, 114-123.

[28] Chaudhary, B., Azam, M., Khan, A. S., & Abbas, H. (2025). Effect of pre-harvest calcium chloride applications on physicochemical quality traits and postharvest life of grapes during cold storage. Journal of Food Measurement and Characterization, 19, 9032–9051.

[29] Nasri, E., Khademi, O., Saba, M. K., and Ebrahimi, R. (2022). Extension of button mushroom storability by ultrasound treatment in combination with calcium lactate. *Journal of Food Measurement and Characterization, 16*(1), 1-9.

[30] Aguayo, E., Escalona, V. H., and Artés, F. (2008). Effect of hot water treatment and various calcium salts on quality of fresh-cut 'Amarillo' melon. *Postharvest Biology and Technology, 47*(3), 397-406.

[31] Manganaris, G. A., Vasilakakis, M., Diamantidis, G., and Mignani, I. (2005). Effect of calcium additives on physicochemical aspects of cell wall pectin and sensory attributes of canned peach (*Prunus persica* (L) Batsch cv Andross). *Journal of the Science of Food and Agriculture, 85*(10), 1773-1778.

[32] Silveira, A. C., Aguayo, E., Chisari, M., and Artés, F. (2011). Calcium salts and heat treatment for quality retention of fresh-cut 'Galia' melon. *Postharvest Biology and Technology, 62*(1), 77-84.

[33] Luna-Guzmán, I., and Barrett, D. M. (2000). Comparison of calcium chloride and calcium lactate effectiveness in maintaining shelf stability and quality of fresh-cut cantaloupes. *Postharvest Biology and Technology, 19*(1), 61-72.

[34] Hassani, F., and Khademi, O. (2018). Effect of calcium chloride and salicylic acid treatments on quality characteristics and shelf life of fresh-cut kiwifruit. *Journal of Food Measurement and Characterization, 12*(1), 658-666.

[35] Guan, W. (2012). Effects of UV-C treatment on inactivation of *Escherichia coli* O157: H7, microbial loads, and quality of button mushrooms. *Postharvest Biology and Technology, 64*(1), 119-125.

[36] Khovitari, S., and Khademi, O. (2022). Determination the best source of calcium for button mushroom conservation. *Journal of Horticulture and Postharvest Research, 5*(2), 177-186.

[37] Eroğul, D., Gundogdu, M., Sen, F., and Tas, A. (2024). Impact of postharvest calcium chloride treatments on decay rate and physicochemical quality properties in strawberry fruit. BMC Plant Biology, 24(1), 1088.

[38] Sohail, M., Ayub, M., Khalil, S. A., Zeb, A., Ullah, F., Afridi, S. R., and Ullah, R. (2015). Effect of calcium chloride treatment on postharvest quality of peach fruit during cold

storage. *International Food Research Journal, 22*(6), 2387-2393.

[39] Kalita, P., Roy, P. K., Bhattacharjee, B., Goswami, A., Pachuau, L., and Roy, S. (2025). Alginate-based coating in post-harvest fruits preservation: A comprehensive review. International Journal of Biological Macromolecules, 145799.

[40] Mirshekari, A., Madani, B., and Golding, J. B. (2019). Aloe vera gel treatment delays postharvest browning of white button mushroom (*Agaricus bisporus*). *Journal of Food Measurement and Characterization, 13*(2), 1250-1256.

[41] Ahmad, F., Muhammad, A., Hashmi, M. S., Ahmad, A., Alam, S., Din, K. U., and Siyab, A. (2024). Pre-storage calcium chloride and aloe vera gel coatings mitigate internal browning and senescence scald in 'Conference'pears. Scientia Horticulturae, 325, 112684.

[42] Aguayo, E., Requejo-Jackman, C., Stanley, R., and Woolf, A. (2015). Hot water treatment in combination with calcium ascorbate dips increases bioactive compounds and helps to maintain fresh-cut apple quality. Postharvest Biology and Technology, 110, 158-165.

مجله علوم و صنایع غذایی ایران

سایت مجله: www.fsct.modares.ac.ir

مقاله علمی_پژوهشی

استفاده تلفیقی از آلژینات سدیم و لاکتات کلسیم به منظور افزایش ماندگاری قارچ خوراکی تکمه‌ای

هادی زرینی، اورنگ خادمی* و شاهپور خانقلی

گروه باغبانی، دانشکده کشاورزی، دانشگاه شاهد تهران

اطلاعات مقاله

تاریخ های مقاله :

تاریخ دریافت: ۱۴۰۴/۰۵/۰۹

تاریخ داوری: ۱۴۰۴/۰۹/۱۸

تاریخ پذیرش: ۱۴۰۴/۰۹/۲۳

کلمات کلیدی:

تیمار تلفیقی،

دمای سرد،

قهوه‌ای شدن،

کیفیت

Agaricus bisporus

DOI: 10.48311/fsct.2026.84079.0

* مسئول مکاتبات:

o.khademi@shahed.ac.ir

چکیده

این مطالعه با هدف بهبود عمر انبارمانی و حفظ کیفیت قارچ خوراکی تکمه‌ای از طریق پوشش‌دهی با ترکیبات خوراکی انجام گرفت. پژوهش به صورت فاکتوریل و در قالب طرح کاملاً تصادفی با سه تکرار شامل فاکتورهای آلژینات سدیم (۰، ۰/۵ و ۱٪)، لاکتات کلسیم (۰ و ۰/۵٪) و زمان نگهداری (۰، ۷، ۱۴ و ۲۱ روز) طراحی و اجرا شد. پس از اعمال تیمارها، قارچ‌ها در بسته‌بندی سلوفان و در دمای ٤ درجه سانتی‌گراد نگهداری شده و پارامترهای میکروبی، فیزیکوشیمیایی و حسی مورد ارزیابی قرار گرفتند. نتایج نشان داد که تیمار ترکیبی آلژینات سدیم ۰/۵٪ و لاکتات کلسیم ۰/۵٪ به طور معنی‌داری در حفظ کیفیت قارچ‌ها مؤثر بوده و موجب کاهش ۵۰ درصدی افت وزن، مهار ۳۸ درصدی شاخص قهوه‌ای شدن، کاهش ۳۸ درصدی رشد باکتری، حفظ مطلوب سفتی بافت و کاهش نوسانات مواد جامد محلول نسبت به شاهد گردید. همچنین، این تیمار ویژگی‌های حسی قارچ را به‌طور قابل توجهی حفظ نمود. در مقابل، تیمار آلژینات سدیم ۱٪ همراه با لاکتات کلسیم ۰/۵٪ علی‌رغم افزایش قابل ملاحظه محتوای کلسیم (۰/۷٦ میلی‌گرم بر گرم وزن خشک)، در کنترل قهوه‌ای شدن و حفظ ویژگی‌های حسی عملکرد ضعیف‌تری از خود نشان داد. تیمارهای منفرد نیز در برخی شاخص‌ها مؤثر بودند، اما نتوانستند به اندازه تیمار ترکیبی از کاهش کیفیت جلوگیری نمایند. در نهایت، نتایج این مطالعه استفاده همزمان از آلژینات سدیم و لاکتات کلسیم هر دو در غلظت ۰/۵٪ را به عنوان روشی مؤثر جهت افزایش عمر ماندگاری و حفظ کیفیت قارچ‌های خوراکی تکمه‌ای پیشنهاد می‌نماید.