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Effects of Potassium Iodide and Potassium Carbonate Treatments on the Postharvest Quality of White Button Mushroom (*Agaricus bisporus*)

Mohammad Haji[1], Akbar Rostami-Vartooni[1]*, Parviz Malekzadeh[2]

[1] *Department of Chemistiry, Faculty of Science, University of Qom, Qom, Iran.*

[2] *Department of Biology, Faculty of Science, University of Qom, Qom, Iran.*

Abstract

White button mushroom (*Agaricus bisporus*) is highly perishable, and rapid cap browning, softening, and moisture loss severely limit its postharvest life. This study investigated the effects of potassium iodide (KI) and potassium carbonate (K_2CO_3) coatings, applied by two methods immersion and spray on the postharvest quality of button mushrooms during 15 days of cold storage. Cap browning, firmness, and physiological weight loss were evaluated at 5-day intervals. Both salts significantly delayed cap browning compared with the control under both application methods; by day 15, browning reached approximately 69–75% in control mushrooms, whereas KI and K_2CO_3 treatments limited it to about 51–56%, with the strongest inhibition observed in spray-treated samples. Firmness declined in all groups during storage, but KI-treated mushrooms retained the highest firmness under both methods. The two application methods differed markedly in weight loss: in immersion, treated mushrooms lost slightly more weight than the control, whereas in spray application, K_2CO_3 substantially reduced weight loss. Overall, spray application of potassium salts provided the best combination of quality preservation, suggesting that potassium salt sprays are a simple, low-cost approach for extending the shelf life of fresh button mushrooms.

Keywords: *Agaricus bisporus, Coating, button mushroom, Potassium carbonate, Potassium iodide, Shelf life*

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1. Introduction

White button mushrooms (*Agaricus bisporus*) are among the most widely cultivated edible fungi worldwide, accounting for roughly 15% of global mushroom production, and are valued for their nutritional profile, including proteins, B-vitamins, minerals, dietary fiber, and bioactive compounds (Royse et al., 2017; Valverde et al., 2015). However, their extremely short shelf life—only 1–3 days at ambient temperature and 5–10 days under refrigeration results in 20–40% postharvest losses and restricts market distribution (Burton & Twyning,.1989; Jiang et al., 2011; Xu et al., 2016).

This rapid deterioration stems from high moisture content (≈85–92%), lack of protective cuticle, elevated respiration rates 5–10 times higher than most vegetables, and mechanical damage that triggers enzymatic browning (Brennan et al., 2000; Villaescusa & Gil, 2003; Jiang, 2013). Enzymatic browning—the most visible quality defect occurs when polyphenol oxidase (PPO) oxidizes phenolic compounds to reactive *o*-quinones, which polymerize into brown melanin-like pigments (Jolivet et al., 1998; Mayer, 2006; Yoruk & Marshall, 2003). Peroxidase (POD), laccase (LAC), and phenylalanine ammonia-lyase (PAL) amplify this cascade (Mayer & Harel, 1979; Dixon & Paiva, 1995). Additional deterioration involves cell wall-degrading enzymes causing softening, proteolysis producing off-flavors, and oxidative stress from reactive oxygen species accelerating senescence (Braaksma et al., 1994; Simontacchi et al., 2015).

Traditional methods include refrigeration (0–4°C), which remains most common but offers limited extension (Jiang, 2013), and controlled/modified atmosphere packaging (CA/MAP) with reduced O_2 (1–5%) and elevated CO_2 (5–15%), extending shelf life by 3–7 days though excessive CO_2 (>20%) causes off-flavors and anaerobic fermentation (Villaescusa & Gil, 2003; Roy et al., 1995). Chemical preservatives, particularly sulfites, historically provided effective PPO inhibition but cause adverse reactions in sensitive individuals and face regulatory restrictions in many countries (Sapers & Miller, 1992; Taylor et al., 1986;).

Research into alternative preservatives has explored multiple approaches. Antibrowning agents such as ascorbic acid and citric acid have been shown to delay browning of fresh produce and mushrooms during storage (Sapers, 1993; Oszmiański & Lee, 1990). Edible coatings have also been investigated: chitosan coatings can extend mushroom shelf life, and subsequent work confirmed similar coating benefits across different formulations (Eissa, 2007; Mohammadi et al., 2015). However, polysaccharide- and protein-based edible coatings require specialized application equipment, can be expensive, and may alter texture or leave visible residues (Baldwin et al., 1995; Lin & Zhao, 2007; Petriccione et al., 2015; Dehghani et al., 2018).

Mineral salts represent a simpler, more economical approach, and several studies have examined their effect on mushroom postharvest quality. Mignani et al. (1995) and Gonzalez-Aguilar et al. (2005) reported that calcium salts (calcium chloride, calcium lactate) help maintain firmness during storage. Sapers (1993) and Son et al. (2001) investigated a range of mineral salts on browning and quality of fresh produce, noting practical advantages such as water solubility, food safety, low cost, and simple dipping or spraying application. Sapers & Miller (1995) studied sodium chloride treatment of mushrooms. Luo & Xie (2013) reviewed calcium-based postharvest treatments for mushrooms.

K_2CO_3 is Generally Recognized as Safe (GRAS) by the U.S. FDA and is widely permitted internationally as a buffering agent, acidity regulator, and leavening agent (Codex Alimentarius, 2019). Potassium iodide (KI) is an approved food-grade source of dietary iodine, used in fortified salt and supplements, and provides iodine essential for thyroid function and human health (WHO, 2012). Their favorable regulatory status facilitates commercial application without extensive toxicological evaluation.

Given the substantial economic losses from mushroom perishability, the regulatory hurdles and consumer concerns surrounding sulfites, the cost and complexity of film-forming coatings, and the limited comparative data on potassium salt treatments, systematic investigation is warranted. The objective of this study was to evaluate the effects of K_2CO_3 and KI treatments on the postharvest quality of white button mushrooms during refrigerated storage at 4°C for 15 days. Specifically, we aimed to: (1) quantify the effects of K_2CO_3 and KI on weight loss, cap browning, firmness, and sensory quality; and (2) compare the relative efficacy of K_2CO_3 and KI to identify the most promising treatment for commercial application.

2. Materials and Methods

2.1. Mushroom Material and Treatment

Fresh white button mushrooms (*Agaricus bisporus*) were obtained from Shabnam Kosar Mushroom Company, Kosar Greenhouse Complex, Dastjerd, Qom, Iran. Mushrooms were transported immediately to the Biotechnology and Plant Physiology Research Laboratory at Qom University .Samples were carefully selected for uniformity in size (cap diameter 3–4 cm), absence of physical defects, unopened caps (closed veil, no visible gills), and no signs of browning, depressions, scratches, holes, or peeling epidermis.

2.2. Salt Treatment and Concentration

Two potassium salts were evaluated:

- K_2CO_3 (Merck, purity ≥99%)
- KI (Merck, purity ≥99%)

Both salts were prepared as 0.005 M aqueous solutions (1 liter each) using deionized water. The required quantities were:

- 0.69 g K_2CO_3
- 0.83 g KI

The concentration of 0.005 M was selected based on preliminary screening experiments and previous reports indicating effective browning inhibition at millimolar concentrations without adverse sensory effects (Son et al.,2001).

2.3. Treatment Procedure

Selected mushrooms were randomly divided into three groups:

1. Control (untreated, dipped in distilled water)
2. KI treatment
3. K_2CO_3 treatment

Mushrooms were immersed for 15 minutes in the respective solutions at room temperature (22 ± 2°C) with gentle agitation to ensure uniform coating. After immersion, samples were removed and left at room temperature on stainless steel mesh trays to air-dry the surface moisture for approximately 30 minutes. Once surface-dried, mushrooms were vacuum-packed in polyethylene bags. For the spray application, 15 mL of each prepared treatment solution was used to spray the mushroom samples from a distance of 15 cm, ensuring complete coverage of their surfaces. For each treatment, three replicate samples (n = 3) of each were prepared for statistical analysis and calculation of standard deviations.

2.4. Storage Conditions

Packaged samples were stored in a temperature-controlled refrigerator at 4 ± 0.5°C. Quality parameters were evaluated at four storage intervals: 0, 5, 10, and 15 days after treatment.

2.5. Weight Loss Measurement

Initial weight of each vacuum-packed sample was recorded immediately after packaging and before refrigeration using a digital balance (precision ±0.001 g). Samples were reweighed at each evaluation interval (days 5, 10, and 15) under identical conditions. Weight loss percentage was calculated as:

$$\text{Weight Loss (\%)} = \frac{\text{Initial Weight} - \text{Current Weight}}{\text{Initial Weight}} \times 100$$

2.6. Cap Browning Assessment

The surface color of the mushroom caps was evaluated at five-day intervals during storage at 4 °C by examining nine mushrooms per replicate using a Minolta spectrophotometer (CR-400). To obtain the L* (lightness/darkness), a* (red/green), and b* (yellow/blue) values, each mushroom was measured at three evenly spaced points on the cap. The percentage of cap browning, which reflects the intensity of the brown color, was determined according to the method described by Malekzadeh et al. (2025).

2.7. Firmness Measurement

Cap firmness was measured on days 0, 5, 10, and 15 of storage using a hand-held fruit penetrometer (FR-5120, Lutron Electronic Enterprise Co., Ltd., Taiwan) fitted with a 3-mm cylindrical probe. For each mushroom, the probe was pressed vertically into the center of the cap surface until a slight, visually detectable indentation (approximately 3 mm in depth) was formed, and firmness was recorded as the maximum penetration force expressed in newtons (N). Three mushrooms were assessed per replicate, with one measurement per mushroom and three replicates per treatment (n = 3, nine mushrooms in total), and the results were expressed as mean ± standard deviation.

2.8. Sensory Evaluation

Sensory quality was evaluated by a trained panel of 5 assessors using a 9-point hedonic scale (9 = excellent, 1 = extremely poor). Panelists evaluated mushroom samples for appearance, color, odor, and

overall acceptability. Sensory evaluations were conducted under standardized conditions (white fluorescent light, room temperature 22°C) in individual booths.

2.9. Statistical Analysis

The data analysis was performed using SPSS version 26.0. Two-way analysis of variance (ANOVA) was performed on the data, after confirming normality and homogeneity of variance. Subsequent post-hoc multiple comparisons were carried out using Tukey's test. The threshold for determining statistical significance was established at a significance level of $P < 0.05$. The results were presented as the mean ± standard error of triplicate experiments. Data manipulation was performed using Microsoft Excel, while GraphPad Prism (version 9) software was used for graphing the results.

3. Results

3.1. Weight Loss

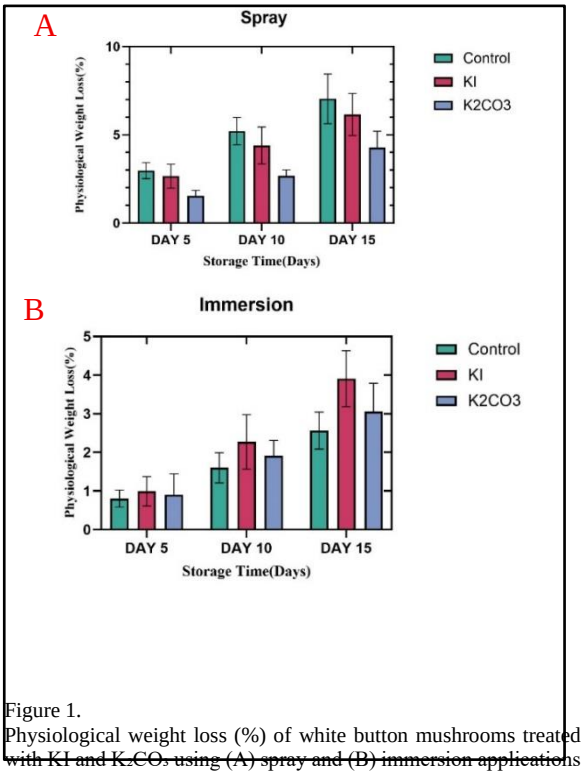
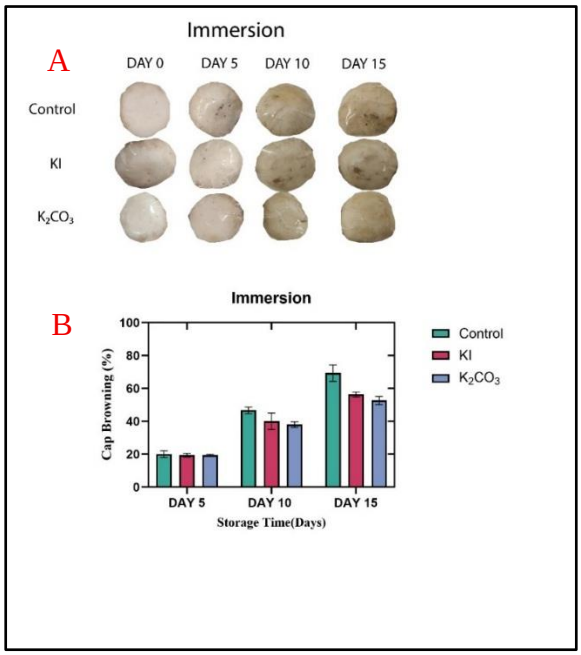


Figure 1.
Physiological weight loss (%) of white button mushrooms treated with KI and K_2CO_3 using (A) spray and (B) immersion applications during storage at 4°C for 15 days.

Physiological weight loss increased gradually in all samples over the 15-day storage period, In all cases (Figure.1). Under immersion application, the potassium-treated samples exhibited a somewhat higher weight loss than the untreated control, indicating that the deposited salts promoted additional water loss from the cap surface. Between the two salts, KI-treated mushrooms lost slightly more weight than those treated with K_2CO_3. Although these differences were modest in magnitude and not strongly pronounced, they were consistently observable and distinguishable throughout the storage period.

Under spray application, a different pattern was observed: the weight-loss values of all groups remained relatively close to one another; nevertheless, the untreated control exhibited the highest weight loss at all sampling points, whereas both salt-treated groups retained their moisture more effectively. Considering the results of both application methods together, K_2CO_3 showed the most favorable overall performance, as it caused the smaller additional weight loss among the salt treatments under immersion and effectively restricted water loss under spray application.

3.2. Cap Browning



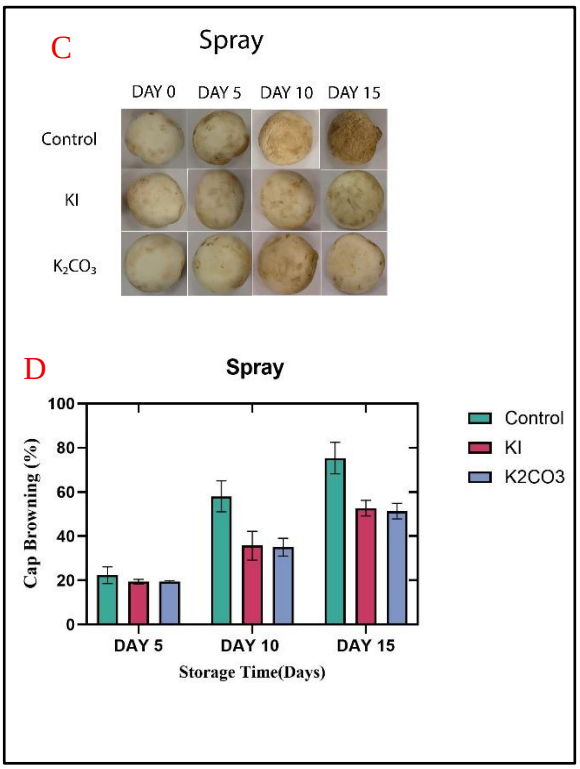


Figure 2.
Visual appearance and cap browning index (%) of white button mushrooms treated with KI,K_2CO_3 and control during 15 days of storage at 4°C: (A) representative images of immersion-treated mushrooms, (B) cap browning index of immersion-treated mushrooms, (C) representative images of spray-treated mushrooms, and (D) cap browning index of spray-treated mushrooms.

Cap browning increased progressively in all samples during the 15-day storage period, under both application methods (Figure. 2). This trend is consistent with the natural senescence of Agaricus bisporus, in which enzymatic browning intensifies as storage advances. However, the extent of browning differed markedly among the treatment groups.

Under immersion application, the untreated control exhibited the highest browning percentage at all sampling points, while both potassium-treated groups maintained visibly lighter cap surfaces throughout storage. A similar pattern was observed under spray application, where the control again showed the greatest browning and both KI- and K_2CO_3-treated mushrooms retained a lower browning percentage until the end of the storage period.

The visual appearance of the samples (Figure.2 (A),(C)) corroborated these measurements: by day 15, the control mushrooms displayed extensive surface discoloration under both methods, whereas the salt-treated samples preserved a comparatively brighter and more acceptable appearance. Taken together, these observations indicate that both potassium salts, irrespective of the application method, were effective in delaying cap browning compared with the untreated control.

3.3. Firmness

Tissue firmness declined progressively in all treatments during the 15-day storage period, reflecting the natural softening associated with postharvest senescence in *Agaricus bisporus* (Figure.3). Throughout the storage, control samples exhibited the most rapid loss of firmness in both immersion and spray methods, indicating a greater rate of textural deterioration compared to the treated mushrooms.

Both KI and K_2CO_3coatings slightly retained firmness more effectively than the control, with their values remaining consistently higher. Although both potassium-based treatments showed a similar trend in preserving the mushrooms structure, the KI treatment performed slightly better than K_2CO_3in both application methods (immersion and spray) by the end of the storage period. These findings suggest that the application of potassium-based coatings, particularly KI, can successfully delay the softening of white button mushrooms.

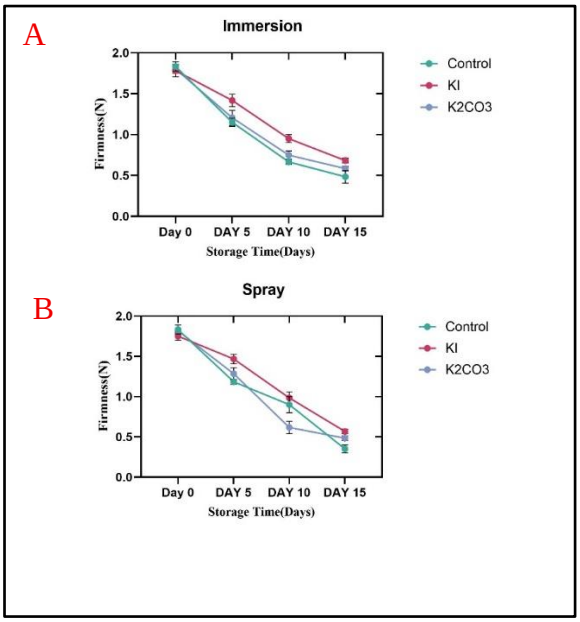


Figure 3.
Changes in the firmness (N) of white button mushrooms treated with KI, K_2CO_3 and control using (A) immersion and (B) spray methods during 15 days of storage at 4°C.

3.4. Overall Quality and Sensory Evaluation

Sensory evaluation was performed by a trained panel (n=5) on three replicates of each treatment. Parameters including appearance, color, odor, and overall acceptability were assessed using a 9-point hedonic scale. KI and K_2CO_3 treatments significantly ($P < 0.05$) maintained sensory quality compared to control. On day 15, overall acceptability of control samples reached 5.0, while KI and K_2CO_3 scored 5.8 and 6, respectively. Observed differences in all sensory parameters were clearly distinguishable.

4. Discussion

The present study demonstrated that postharvest application of potassium salts (KI and K_2CO_3), whether by immersion or spray, significantly delayed the quality deterioration of button mushroom (*Agaricus bisporus*) during 15 days of cold storage, as reflected in higher firmness retention, lower physiological weight loss, and reduced cap browning compared with the untreated control. Since both salts share the potassium cation but differ in their accompanying anion, the consistent improvements observed with both treatments point to a substantial contribution of K^+ itself, whereas the differences in the magnitude of their effects can reasonably be ascribed to anion-specific mechanisms. This cation/anion dissection provides a useful framework for interpreting the results.

Regarding the cationic component, potassium is the most abundant inorganic cation in fungal and plant cells and plays a central role in osmoregulation, turgor maintenance, and the stabilization of membrane potential (Rodríguez-Navarro, 2000; Wang et al., 2013). Postharvest firmness loss in mushrooms is driven largely by water loss, turgor decline, and progressive membrane deterioration; an exogenous supply of K+ may therefore help sustain cellular water relations and delay the collapse of hyphal tissue. In addition, adequate potassium status has been associated with reduced accumulation of reactive oxygen species (ROS) and enhanced stress tolerance in plant tissues (Hasanuzzaman et al., 2018; Sardans & Peñuelas, 2021). The lower weight loss recorded in spray KI- and K_2CO_3-treated mushrooms in the present work is consistent with such a turgor- and membrane-stabilizing role of the potassium cation.

The beneficial effects of KI observed in this study may be partly attributed to the antioxidant capacity of the iodide anion. Iodide has been identified as the first inorganic antioxidant described in a living system, directly scavenging a broad range of reactive oxygen species (ROS) via the iodide/iodine redox couple (Küpper et al., 2008). In terrestrial plants, low-dose iodide application has also been shown to enhance endogenous antioxidant defenses, including catalase activity and the ascorbate–glutathione pool (Blasco et al., 2011; Medrano-Macías et al., 2016;). Although these mechanisms have been documented mainly in pre-harvest biofortification contexts, it is plausible that a similar ROS-mitigating action contributed to the delayed browning and reduced membrane deterioration observed here. To our knowledge, this is among the first reports evaluating KI as a direct postharvest treatment, and the present findings therefore warrant targeted studies quantifying ROS levels and antioxidant enzyme activities under such conditions. It should also be noted that iodide effects are dose-dependent, as elevated concentrations may induce oxidative or phytotoxic responses (Blasco et al., 2011).

In the case of K_2CO_3, the carbonate anion most likely acted through a different route. Carbonate is a mild alkalizing agent, and its buffering action at the tissue surface may modulate the local pH away from the optimum of browning-related enzymatic activity, thereby slowing melanin formation without requiring direct enzyme inhibition. Carbonate and bicarbonate salts are, moreover, well documented as generally recognized as safe (GRAS) antimicrobial agents against postharvest spoilage fungi and bacteria, and a reduction in microbial load on the mushroom surface would be expected to limit both enzymatic browning triggered by microbial damage and tissue softening. The pronounced reduction in cap browning observed with K_2CO_3, particularly under immersion, is compatible with this combined pH-modulating and sanitizing action (Palou et al.,2001).

Both application methods improved postharvest quality compared with the control. Immersion fully covered the cap surface and its pores, allowing more uniform contact with the salts; however, prolonged

contact with water may itself affect the delicate, porous cap tissue. Spraying left a thinner layer but was faster, easier to apply, and required less solution, making it more practical for commercial handling. Overall, spraying was slightly more effective, and since both methods clearly outperformed the control, the beneficial effects can be attributed mainly to the mineral salts themselves rather than the mode of application.

It should be emphasized that the mechanisms proposed here are inferred from quality indices rather than measured directly, and this constitutes the main limitation of the study. Future work should quantify the activities of browning-related enzymes (PPO, POD, PAL, and laccase) instead of inferring their behavior from color changes, assess ROS levels and the endogenous antioxidant status of treated tissue, examine membrane integrity by electron microscopy, and determine iodine residues in KI-treated mushrooms to evaluate both food safety margins and the potential for iodine biofortification as an added nutritional benefit.

In conclusion, low-cost, food-compatible potassium salts applied as simple postharvest dips or sprays effectively extended the shelf life of A. bisporus. The results support a dual mechanism in which the potassium cation sustains turgor and membrane stability, while the iodide and carbonate anions contribute antioxidant and pH-modulating/antimicrobial actions, respectively. These findings introduce KI and K_2CO_3 as promising and practical candidates for postharvest quality management of button mushroom.

5. Conclusion

Mineral-salt treatments based on KI and K_2CO_3 at 0.005 M, applied either by 15-min immersion or by surface spraying, significantly extended the postharvest shelf life of white button mushrooms (*Agaricus bisporus*) during 15 days of storage at 4 °C. Both salts reduced cap browning, limited firmness decline, and maintained sensory acceptability relative to untreated controls, indicating that both application methods were effective and that the mushrooms retained their quality markedly better than the untreated samples. Overall, spraying was slightly more effective and can be regarded as the preferred delivery method.

The protective effect is probably best explained by a complementary action of the cation and the anion: K^+ may contribute to turgor maintenance and membrane stabilization, while iodide may act as an inorganic reducing species capable of scavenging reactive oxygen species, and carbonate may function as a mild pH-modulating and antimicrobial agent that lowers browning-related enzymatic activity. Reduced cap browning was the most consistent indicator of improved storage stability. Given its comparable efficacy, low cost, and GRAS status, K2CO3 is recommended as the more practical candidate for commercial use, and potassium-salt treatments overall offer a simple and economical alternative to synthetic preservatives. Further work on browning-related enzyme kinetics (PPO, POD, PAL, and laccase) and on optimizing salt concentration and application parameters for each delivery method is needed for reliable industrial implementation.

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