



Effect of short-term high CO₂ treatment on quality and shelf life of button mushroom (*Agaricus bisporus*) at refrigerated storage

Afsaneh Hosseini¹ and Farid Moradinezhad^{2*}

1, 2 Department of Horticultural Science, University of Birjand, Birjand, Iran, P.O. Box 331

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*Corresponding author:

Department of Horticultural Science,
University of Birjand, Birjand, Iran, P.O.
Box 331.

E-mail: fmoradinezhad@birjand.ac.ir

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ABSTRACT

Button mushroom (*Agaricus bisporus* L.) is marketed for its unique flavor and benefits. The shelf life of fresh button mushroom is limited and its quality decreases rapidly during storage mainly due to high respiration rate. Postharvest changes of browning of the cap, softening of tissues, moisture loss and development of off-flavor lose its marketability. Modified atmosphere rich in CO₂ can modify respiration rate, energy metabolism and physiological changes in postharvest storage of many fresh products. In this study, button mushrooms were treated with high CO₂ concentration (95%) for 0 (control), 6 or 24 h. Thereafter, the mushrooms were ventilated and packed in polyethylene lid containers 500 ml (packed with its lid) (PE-LC) or polyethylene containers cellophane wrapped (PE-CCW) and were then stored in a refrigerator at 4 °C for 14 days. The results showed that high CO₂ treatment for 24 h that were packed in polyethylene container cellophane wrapped significantly affected the shelf life and maintained the flavor of button mushroom during refrigerated storage compared to the control. In addition, after 14 days of cold storage 24 h high CO₂ treated samples that were packed with PE-CCW had better taste and flavor than the control. Color of treated mushrooms especially the BI index in both CO₂ durations was better than control samples. Generally mushroom whiteness, which is an important quality aspect, was also observed the best in 24 h high CO₂ treated samples packed with PE-CCW than other treatments and the control.

INTRODUCTION

Button mushroom (*Agaricus bisporus* L.) is a favorite edible mushroom, which is considered not only as a nutritional vegetable, but also as functional food due to the free radical scavenging and antioxidant activities (Guan et al., 2013; Wu et al., 2016). Mushroom is appreciated, not only for texture and flavor, but also for their nutritional characteristics. They contain not only little fat and digestible carbohydrates, but also have higher protein than most vegetables. They are also rich in vitamins B, D, and K, and sometimes vitamins A and C, making them suitable for low-calorie diets (Kim et al., 2008; Kurtzman, 1997; Manzi et al., 2001). Mushrooms have also been reported as therapeutic foods, useful in preventing diseases such as hypertension, hypercholesterolemia, and cancer (Manzi et al., 2001). However, mushrooms lose their quality rapidly during postharvest storage at ambient temperature because of their high moisture content and overall structure (Oliveira et al., 2012). Loss of the quality of mushrooms includes browning, softening, cap development, off-flavor and secondary mold growth (Kim et al., 2006). Therefore, mushrooms need special care to keep its quality and freshness, especially when they are processed such as slicing (Iqbal et al., 2009). Mushrooms grow on the growing medium which is compost and tend to be still a bit dirty when sold in stores. Effect of washing treatments with different solutions such as citric acid, sodium hypochlorite and even water alone on the visual and microbiological quality of whole mushrooms have been evaluated by many researchers (Lagnika et al., 2014; Sedaghat et al., 2015; Simón et al., 2010). However, usually the mushroom surface color turns creamy and loses their flavor when they are soaking up than samples without any treatment (control). Mushrooms are usually marketed in trays overwrapped with perforated polyvinyl chloride (PVC) stretchable film (Simon et al., 2005). Therefore, the use of modified atmosphere packaging (MAP) as an alternative method accompanied with low-temperature storage can effectively retard the quality changes and extend shelf-life of fresh-cut mushrooms (Parentelli et al., 2007) especially due to the reduction of respiration rate of fresh mushroom that is usually high. It has been reported that modified atmospheres rich in CO₂ can modify respiration rate, energy metabolism, ethylene reaction and physiological changes during postharvest storage or packaging of many fresh products (Blanch et al., 2015; Lumpkin et al., 2015; Yi et al., 2016). However, excessive accumulation of CO₂ in modified atmosphere packages can damage the cell membrane and cause physiological injuries to the product, such as enzymatic browning and loss of firmness (Briones et al., 1992; Burton et al., 1987). Thus, the exact concentration and exposure time should be determined for specific fresh produce during modified atmosphere packaging or storage. The objective of this study, therefore, was to evaluate the effect of short-term high CO₂ pre-packaging treatment in different duration and the type of packaging on quality of button mushroom in the refrigerated condition.

MATERIALS AND METHODS

Plant material preparation and treatment procedures

Fresh button mushrooms (*Agaricus bisporus* L.) were purchased from a commercial mushroom company (Sepahan Co. Esfahan, Iran). Closed and uniform mushrooms with white color were selected and pre-cooled for 12 h in a cold room at 4 °C. The mushrooms were divided into three lots and then placed in LDPE bags with 0.05 mm thickness, the bags vacuumed and were then filled with CO₂ gas (95%), O₂ (4%) N₂ (1%) and sealed for 6 or 24 hours. Thereafter, the mushrooms were unpacked and repacked (100 g per container) in polyethylene lid containers with 500 ml volume (packed with its lid) (PE-LC) with 0.07 mm

thickness, or the same polyethylene containers cellophane (0.015 mm thickness) wrapped (PE-CCW) to make two different passive modified atmosphere packaging (MAP), and were then stored in a refrigerator at 4±1 °C for 14 days. Evaluations including weight loss, veil opening, percent veil opening, stem elongation, wrinkles, decay percentage, gap cap, total soluble solids, organoleptic assessments (texture, taste, and flavor), overall acceptability, and color attributes (L*, a*, C, h° and BI) in all the treatments were carried out in the fourteenth day of storage under refrigeration.

Quality measurements

Weight loss (WL) percentage

Weight loss was determined by weighing the whole mushroom before and after the storage period. Weight loss was expressed as the percentage of loss of weight with respect to the initial weight in the formula (1).

$$WL = \frac{\text{Initial weight} - \text{Secondary weight}}{\text{Initial weight}} \times 100 \quad (1)$$

Veil opening and percentage veil opening

Veil opening on each package was studied by observing mushroom packages visually and counting the number of opened veils inside the package. The value was taken as the number of opened veils to the total number of mushrooms present inside the package multiplied by 100 to express in percent in the formula (2) (Dhalsamant et al., 2015).

$$\text{Percentage of veil opening} = \frac{\text{Opened veils}}{\text{Total number of mushrooms}} \times 100 \quad (2)$$

Stem elongation

The length of the stems was measured with a digital caliper with a precision of 0.01 mm.

Wrinkles

The amount of wrinkle was graded from 0 to 3 (0 = no, 1 = slightly, 2 = high, 3 = too high).

Decay percentage

The number of decayed samples due to fungal or any microorganism infection was recorded at day 14 and calculated as a percentage (Gol et al., 2013).

Gap cap

At day 14, number of mushrooms with gap cap was counted.

Total soluble solids (TSS)

Carbohydrates are important components of structural materials in plants and exist as free sugar and polysaccharide. The carbohydrate content can be calculated by hydrolyzing the polysaccharides into simple sugars by acid, sulfuric and appraising the resultant monosaccharide. The TSS content of the mushrooms was determined using a handheld refractometer (RF 10, 0-32 °Brix, Extech Co., USA).

Organoleptic evaluations and overall acceptability

The five-point Hedonic method was used to evaluate the panel's test (1 = bad, 2 = weak, 3 = medium, 4 = good, 5 = very good) (Stone et al., 2012). From the mean texture, taste, and flavor, the overall acceptance was achieved.

Color attributes

The surface color of mushroom caps was measured with a colorimeter (TES 135-A, Taiwan). 'L*' (light/dark), 'a*' (red/green) and 'b*' (yellow/blue) values were used to calculate the browning index (BI) according to the following equation (3) (Gao et al., 2014), and hue according to the following equation 4.

$$BI = [100 (x - 0.31)] / 0.172, \text{ where } x = (a^* + 1.75L^*) / (5.645L^* + a^* - 3.012b^*) \quad (3)$$

$$h^\circ = \tan^{-1} \frac{b}{a} \quad (4)$$

Statistical analysis

A completely randomized design was used in this study and consisted of four replicates for each treatment. Data from the components of this design were analyzed using GenStat program (version 12.1, VSN, International, Ltd., UK, 2009).

RESULTS AND DISCUSSION

Weight loss percentage

About 90% of fresh mushroom content is water. It was proved that water evaporates from fresh mushroom (whole or cut) at the same rate comparable to that from a free water surface (Nichols, 1985). A major factor in the fresh mushroom deterioration has been water loss and subsequent loss of weight (Nichols, 1985). Dehydration, particularly more than 5% weight of the freshly harvested mushroom, is an important process in quality loss of mushrooms, affecting the appearance, economic value, and texture of mushrooms during postharvest storage (Singh et al., 2010). At day 14, control treatment that was packed with cellophane film (PE-CCW) had greatest (7.37%) weight loss compared to other treatments (Table 1). Weight loss is a normal process over time (Mostofi et al., 2010). The high respiration rate, due to accelerated aging processes, causes the consumption of fruit nutrition (Gao et al., 2013) and this will reduce the weight of the mushrooms during storage. Singh et al. (2010) reported that a loss of 5–6% of harvested mushrooms would lead to a depression of its commercial value because of marked deterioration of quality. When a weight loss of 5–10% of postharvest mushroom happens, the mushrooms begin to wilt and soon become unusable (Antmann et al., 2008). Mass losses can cause significant loss of aroma and flavor, ultimately leading to the rejection by consumers as reported in lettuce (Aguero et al., 2010). In this experiment, use of PE-LC packaging reduced weight loss than cellophane film (PE-CCW) (Table 1).

Veil opening and percentage of veil opening

There was no significant difference among for veil opening after 14 d of cold storage (Table 1). Cap opening of mushrooms is related to dryness as a result of water loss during storage due to of a decrease in cohesive forces of water and other hydrophilic molecules such as proteins, responsible for the intact condition of mushroom caps and veils (Alikhani Koupaie et al., 2014).

Table 1. Effect of short-term high CO₂ pre-storage treatment and packaging type on weight loss (%), veil opening (number), veil opening (%) and stem elongation (mm) of mushroom (*Agaricus bisporus* L.) after 14 days of cold storage at 4 ± 1 °C

Pre-storage treatments	Packaging type	Weight loss (%)	Veil opening (number)	Veil opening (%)	Stem elongation (mm)
Control	PE-LC	4.43 ^{b†}	2.00 ^a	32.14 ^a	27.07 ^a
	PE-CCW	7.37 ^a	2.75 ^a	48.21 ^a	29.94 ^a
CO ₂ 6 h	PE-LC	4.63 ^b	2.50 ^a	36.15 ^a	26.43 ^a
	PE-CCW	6.29 ^{ab}	2.50 ^a	37.37 ^a	26.90 ^a
CO ₂ 24 h	PE-LC	3.98 ^b	1.75 ^a	23.21 ^a	24.99 ^a
	PE-CCW	5.51 ^{ab}	1.25 ^a	19.19 ^a	25.24 ^a

PE-LC: Polyethylene lid container (packed with its lid); PE-CCW: Polyethylene container cellophane wrapped.

†Different letters within columns indicate significant differences among treatments ($P \leq 0.05$).**Table 2.** Effect of short-term high CO₂ pre-storage treatment and packaging type on wrinkles, decay percentage (%), gap cap (number) and TSS of mushroom (*Agaricus bisporus* L.) after 14 days of cold storage at 4 ± 1 °C

Pre-storage treatments	Packaging type	Wrinkles	Decay (%)	Gap cap (number)	TSS (°Brix)
Control	PE-LC	1.00 ^{a†}	79.52 ^{ab}	0.00 ^a	7.1 ^a
	PE-CCW	1.75 ^a	92.26 ^a	0.00 ^a	6.8 ^a
CO ₂ 6 h	PE-LC	1.00 ^a	66.51 ^{ab}	0.00 ^a	6.9 ^a
	PE-CCW	1.25 ^a	58.72 ^{ab}	0.00 ^a	7.8 ^a
CO ₂ 24 h	PE-LC	1.00 ^a	51.33 ^b	0.00 ^a	7.9 ^a
	PE-CCW	1.00 ^a	6.69 ^c	0.00 ^a	8.5 ^a

PE-LC: Polyethylene lid container (packed with its lid); PE-CCW: Polyethylene container cellophane wrapped.

†Different letters within columns indicate significant differences among treatments ($P \leq 0.05$).

Stem elongation

There was no significant difference among treatments at day 14 of refrigerated storage (Table 1), so high CO₂ treatments were not effective on the stem elongation of treated and untreated mushrooms. Presumably, any stem elongation occurring at these stages is due primarily to cell proliferation rather than cell elongation (Hammad et al., 1993).

Wrinkles

No significant difference was observed among treatments at day 14 of storage (Table 2). The direct consequences of excessive water loss from fresh mushrooms are symptoms of desiccation such as wrinkles, toughness, and contract of pileus and stipe (Xiong, 2000). They are also associated with loss of freshness. Lopez-Briones et al. (1992) considered the cause of softening and wrinkles of the mushroom tissue during the storage period as a result of cellular growth and also water withdrawal from the cell.

Decay percentage

High CO₂ treatment and packaging significantly affected mushroom decay. After 14 d of storage, control samples that were packed with PE-CCW had the highest decay (92.26%) and 24 h high CO₂ treatment with PE-CCW had the lowest decay (6.69%) (Table 2, Fig. 1). It was found that the deterioration of fresh mushroom is related to bacterial growth (Beelman et al., 1989; Doores et al., 1987). Tomkins (1966) reported that bacterial growth appeared to be responsible for the yellowing of caps and also for pitting of the cap that was followed by blackening of the tissue. Thus, treatments that reduce the initial microbial population or suppress the bacterial growth during storage could have a significant effect on the postharvest quality and shelf life. The use of CO₂ enriched atmospheres can reduce decay, due to its direct antimicrobial activity (Phillips, 1996), but the excessive accumulation of CO₂ can cause physiological injuries in mushrooms (Ares et al., 2006; Parentelli et al., 2007). On the other hand, previous studies showed that the absence of CO₂ within mushrooms package caused by the use of CO₂ scavenger can also cause the growth of aerobic bacteria, yeast and molds (Masson et al., 2002; Oliveira et al., 2012).

Gap cap

As shown on the [Table 2](#) there was no gap cap in all the treatments after 14 days of cold storage.

Total soluble solids (TSS)

Soluble sugar content in harvested fruits and vegetables is also considered as an important index of postharvest deterioration. Because of after-ripening, soluble sugar content in all treatments increased at beginning and then decreased during storage. Differences in the total soluble solids (TSS) among the various packaging during storage are shown in [Table 2](#). The content of soluble solids was increased after 14 d of storage that was slightly different among the treatments. The reason for this gradual increase of Brix is highly likely the gradual decrease in the amount of water present in the mushrooms, which occurs over time and during storage, and hence the Brix shows higher value.

Organoleptic evaluation (texture, taste, and flavor)

The reason for the reduction of tissue firmness may be enzyme activities and the destruction of the cell wall, the destruction of parenchyma tissue and dissolve the pectin in the intracellular fluid ([Shahiri Tabarestani et al., 2013](#)). All samples showed a reduction in firmness throughout the storage period, the changes in the texture of mushroom during storage for the untreated and treated samples are shown in [Table 3](#). After 14 days of storage, that was slightly different in consumer acceptance of the untreated and treated samples. Aging of mushrooms results in a soft and spongy texture characterized by softening of mushroom tissue ([Guillaume et al., 2010](#)). A decrease in firmness was observed for all investigated packaging materials. This trend could be because of protein and polysaccharide degradation, high shrinkage, and central vacuole disruption ([Antmann et al., 2008](#)).

Taste is the detection of nonvolatile compounds by different receptors in the tongue ([Rico et al., 2007](#)). Aroma compounds are detected by olfactory nerve endings in the nose ([Rico et al., 2007](#)). Based on the results of [Table 3](#), at day 14 of storage, treated samples with high CO₂ for 24 h that were packed with PE-CCW had better taste and aroma than the control as reported by [Lin et al. \(2017\)](#). Likely, the lack or reduction of oxygen inside the package under threshold level leads to an unhealthy metabolism that causes the bad taste or an unpleasant aroma. This may also intensify the condition for the production of botulinum. The poisonous bacterium produced by *Clostridium botulinum* is on the face. Therefore, it is necessary to keep the package at the refrigerator temperature ([Brennan et al., 1998](#)).

Overall acceptability

Overall acceptability was based on firmness, taste, and flavor of the mushrooms treated with high CO₂. The changes of the overall acceptability are shown in [Table 3](#). The overall acceptability of mushrooms decreased as the storage period advanced in all of the groups, compared with the control. At day 14, high CO₂ treated mushroom for 24 h that was packed with PE-CCW had an acceptable score. Modified atmospheres richer in CO₂ and poorer in O₂ than air, can potentially reduce respiration rate, ethylene production and sensitivity, decay and physiological change ([Gorris et al., 1999](#); [Kade et al., 1986](#); [Saltveit, 1997](#)). [Ares et al. \(2006\)](#) reported that physiological damage caused by high CO₂ concentration had a more significant effect than respiration rate in determining sensory mushroom deterioration rates.

Color attributes

Mushroom has a very short shelf-life because it turns brown and loses its quality within a few days ([Lagnika et al., 2013](#)). The most important parameter for consumer acceptance is color.

The L* value decreased with storage time, consequently, the BI increased. The results showed that (Table 4) at day 14 of storage for L*, a*, and C color parameters. Control samples that packed in PE-CCW had the highest h°. The browning index is one of the main quality features for measuring the extent of deterioration on the surface of white mushrooms. As shown in Table 4, the browning index values increased with storage time. Interestingly, at day 14 treated mushrooms with high CO₂ for 24 h that were packed either in PE-LC or PE-CCW significantly decreased the BI compared to the control and other treatments.

Parameter L*, depending on the reflectivity of the surface of mushrooms, is used to express luminosity of the sample (Fernandes et al., 2012). The lower L* value indicates darkening of the mushroom. The quality of mushroom can be classified as good quality for L* value higher than 86 and fair quality for L* value between 85 and 80 (Gormley, 1975). Browning of the cap of mushrooms, indicated by a decreasing L* value. Lin et al. (2017) results showed that 12 h high CO₂ treatment can decrease the browning index and samples treated for 48 hours had greater browning index. Thus, it was concluded that high CO₂ could cause damage to the mushroom cap surface tissue, but it also suppressed browning of button mushrooms during cold storage, which was similar to the effect of UV-C treatment on button mushroom (Guan et al., 2012). Therefore, the increase in browning becomes a recognizable signal and an indicator of freshness. In modified atmosphere packages, the excessive accumulation of CO₂ can cause cell membrane damage and physiological injuries to the product, such as severe enzymatic browning (Briones et al., 1992; Burton et al., 1987; Varoquaux et al., 1999). Modified atmosphere packaging has the potential to slow down the rate of browning in mushroom (Ares et al., 2007). Although levels of O₂ and CO₂ outside the optimum range can have an opposite effect and induce severe browning (Ares et al., 2007; Briones et al., 1992).

Table 3. Effect of short-term high CO₂ pre-storage treatment and packaging type on organoleptic evaluation and overall acceptability of mushroom (*Agaricus bisporus* L.) after 14 days of cold storage at 4 ± 1 °C

Pre-storage treatments	Packaging type	Texture ^z	Taste	Flavor	Overall acceptability
Control	PE-LC	3.25 ^{a†}	3.75 ^{bc}	3.00 ^{cd}	3.33 ^{cd}
	PE-CCW	3.00 ^a	3.25 ^c	2.50 ^d	2.91 ^d
CO ₂ 6 h	PE-LC	3.25 ^a	4.00 ^{ab}	3.50 ^{bc}	3.58 ^{bc}
	PE-CCW	3.00 ^a	3.75 ^{bc}	3.25 ^{cd}	3.33 ^{cd}
CO ₂ 24 h	PE-LC	3.50 ^a	4.00 ^{ab}	4.25 ^{ab}	3.91 ^b
	PE-CCW	3.75 ^a	4.50 ^a	5.00 ^a	4.41 ^a

PE-LC: Polyethylene lid container (packed with its lid); PE-CCW: Polyethylene container cellophane wrapped.

^z Scores 3 and more mean acceptable organoleptic quality.

†Different letters within columns indicate significant differences among treatments ($P \leq 0.05$).

Table 4. Effect of short-term high CO₂ pre-storage treatment and packaging type on L*, a*, chroma, hue and BI of mushroom (*Agaricus bisporus* L.) after 14 days of cold storage at 4 ± 1 °C

Pre-storage treatments	Packaging type	L*	a*	Chroma	Hue	BI
Control	PE-LC	77.25 ^{a†}	8.86 ^a	25.71 ^a	10.00 ^a	45.22 ^b
	PE-CCW	74.68 ^a	8.79 ^a	24.34 ^a	10.28 ^a	44.96 ^b
CO ₂ 6 h	PE-LC	73.97 ^a	9.93 ^a	27.22 ^a	9.50 ^a	50.92 ^b
	PE-CCW	80.86 ^a	8.76 ^a	25.98 ^a	10.10 ^a	43.71 ^b
CO ₂ 24 h	PE-LC	88.82 ^a	7.51 ^a	25.28 ^a	11.80 ^a	36.95 ^a
	PE-CCW	89.54 ^a	7.89 ^a	26.16 ^a	11.30 ^a	38.30 ^a

PE-LC: Polyethylene lid container (packed with its lid); PE-CCW: Polyethylene container cellophane wrapped.

†Different letters within columns indicate significant differences among treatments ($P \leq 0.05$).

Fig. 1. Effect of short-term high CO₂ pre-storage treatment and packaging type on appearance quality of button mushroom (*Agaricus bisporus* L.) after 14 days of cold storage at 4 ± 1 °C

Pre-storage treatments	Packaging type	
	PE-LC	PE-CCW
Control		
CO ₂ 6 h		
CO ₂ 24 h		

CONCLUSION

The findings of the present study have shown that a 24 h high CO₂ treatment followed by PE-CCW has a positive effect on reducing browning index and maintaining flavor quality in button mushroom. Treated mushrooms maintained higher levels of firmness, taste, flavor and overall acceptability. These results indicated that short-term high CO₂ treatment for 24 h could be used as a favorable treatment to extend the shelf life of button mushroom and represent a promising alternative as an environment-friendly application to be used in the complementation of low-temperature storage in mushrooms.

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تأثیر تیمار کوتاه مدت دی اکسید کربن بالا بر کیفیت و ماندگاری قارچ دکمه‌ای (*Agaricus bisporus* L.) در شرایط نگهداری یخچال

افسانه حسینی و فرید مرادی نژاد

چکیده:

قارچ دکمه‌ای (*Agaricus bisporus* L.) با طعم و مزه ویژه و فواید آن به بازار عرضه می‌شود. عمر مفید قارچ تازه محدود است و کیفیت آن در طول نگهداری به سرعت کاهش می‌یابد، این عمدتاً به علت میزان تنفس بالا است. تغییرات پس از برداشت قارچ‌ها شامل قهوه‌ای شدن کلاهک، نرم شدن بافت‌ها، از دست دادن رطوبت و از دست دادن قابلیت فروش آن‌ها است. اتمسفر کنترل شده غنی از CO_2 میزان تنفس، متابولیسم انرژی و تغییرات فیزیولوژیکی بسیاری از محصولات تازه را پس از برداشت تعدیل بخشید. در این مطالعه، قارچ‌های دکمه‌ای با غلظت بالای CO_2 (۹۵ درصد) صفر (شاهد)، شش یا ۲۴ ساعت تحت تیمار قرار گرفتند. پس از آن، تهویه انجام شد و قارچ‌ها در ظروف پلی‌اتیلنی ۵۰۰ میلی‌لیتر درب‌دار (PE-LC) یا ظروف پلی‌اتیلنی با پوشش سلوفان (PE-CCW) بسته بندی شدند و سپس در یخچال با دمای ۴ درجه سانتی‌گراد به مدت ۱۴ روز قرار گرفتند. نتایج نشان داد که تیمار با CO_2 بالا به مدت ۲۴ ساعت در ظروف پلی‌اتیلن بسته بندی شده با سلوفان به‌طور قابل توجهی باعث افزایش ماندگاری و حفظ طعم قارچ دکمه‌ای در هنگام نگهداری در یخچال در مقایسه با شاهد شد. علاوه بر این، پس از ۱۴ روز انبارمانی نمونه‌های تیمار شده با ۲۴ ساعت CO_2 با بسته‌بندی سلوفان، طعم و مزه بهتری نسبت به شاهد داشتند. رنگ قارچ‌های تیمار شده (به ویژه شاخص قهوه‌ای شدگی) با CO_2 در هر دو مدت نیز بهتر از نمونه‌های شاهد بودند. به‌طور کلی، سفیدی قارچ که یک جنبه کیفی مهم است در نمونه‌های تیمار شده با ۲۴ ساعت CO_2 با بسته‌بندی سلوفان در مقایسه با سایر تیمارها و شاهد بهترین بود.

کلمات کلیدی: رنگ، بسته بندی با اتمسفر تغییر یافته، قارچ خوراکی، ماندگاری