

Effect of postharvest exogenous edible coating treatments on inhibitor browning and maintaining quality of fresh mushroom

Saleh M. ABOU-ELWAF¹, Mona M. HAFEEZ¹, Atef F. AHMED²,
Ahmed ABOU EL-YAZIED³, Khaled ABDELAAL^{4*}

¹Horticulture Research Institute, Agricultural Research Center, Department of Postharvest and Handling of Vegetable Crops, Giza, Egypt; salehmabouelwafa@gmail.com; monamhafeez1@gmail.com

²Taif University, College of Science, Department of Biology, P.O. Box 11099, Taif 21944, Saudi Arabia; atefali@tu.edu.sa

³Ain Shams University, Faculty of Agriculture, Department of Horticulture, Cairo, 11566, Egypt; ahmedabouelyazied@gmail.com

⁴Kafrelsheikh University, EPCRS Excellence Center, Plant Pathology and Biotechnology Laboratory, Faculty of Agriculture, Agricultural Botany Department, 33516, Egypt; khaled.elhaies@gmail.com (*corresponding author)

Abstract

The shelf-life of fresh mushrooms is limited to 1-3 days at ambient conditions and antioxidant characters are reduced and acquire a brown colour during post-harvest storage. Therefore, the present study was conducted to investigate the effect of some postharvest exogenous edible coating treatments of immersed in six different solutions for 5 min of calcium chloride (2%, 4%), chitosan (1%, 2%), CMC (1%, 2%) and control (distilled water) on reducing the browning, microbial load and maintaining quality during storage for 15 days at 4 ± 1 °C and 95% RH, during two successive seasons of 2021 and 2022 in 4th and 6th of January in the first and second seasons respectively. The obtained results revealed that dipping mushroom plants in a solution of chitosan 2% or calcium chloride 4% was the best treatment for reducing weight loss, while chitosan 2% for 5 min was the most effective treatment in reducing browning, PPO activity, total phenolic, flavonoids contents and inhibiting microbial counts for 12 days at 4 ± 1 °C and 95% RH.

Keywords: browning; CaCl₂; chitosan; fresh mushroom; quality attributes; storability

Introduction

Button mushroom is one of the most used mushrooms in the world. It contains essential elements and phytochemicals which have antioxidant abilities and benefits to human health. The short shelf-life is mostly explained by the water loss and high respiration levels. (Zhang *et al.*, 2016). Mushrooms are usually used as food and as functional food as well as for medical purpose due to their high concentrations of minerals, proteins, low cholesterol contents and presence of several bioactive compounds (Wani *et al.*, 2010). Browning is a significant factor that limits consumer mushrooms acceptability. Browning occurs in much vegetables because of the increase in PPO activity, phenolic compounds, lipid peroxidation and membrane integrity (Saba and Sogvar, 2016).

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Calcium chloride is an important treatment for extending the shelf life of fresh fruits is applying edible coating on the surface of the fruit (Luna-Guzman and Barrett, 2000), chitosan (Chong *et al.*, 2015) and carboxymethylcellulose (Sangsuwan *et al.*, 2008), in conjunction with low temperature. Edible coating potentially prolongs the shelf life of fruits due to the formation of a barrier layer blocking the exposure of gas and moisture. The barrier layer can delay the quality deterioration of fruits by reducing respiration, delaying volatile loss, decreasing the broke of moisture migration and thus extending the shelf life of fruits (Rojas – Grau *et al.*, 2009). Treatment with calcium chloride increased the amount of internal calcium in the cell wall, which contributes to the retention of rigidity and inhibition of respiration, ethylene production and aging in mushrooms (Rageh, 2018). Applying CaCl_2 treatment as calcium helps in maintaining cellular organization and regulating enzyme activities, thereby reducing moisture loss associated with senescence (Singh *et al.*, 2016) on the mushroom. The potential of calcium in imparting stability to vacuole membranes and further slowing the enzymatic browning was studied by (Beelman *et al.*, 1987). They also indicated that CaCl_2 inhibited the browning of mushrooms. Calcium dips raise the possibility of producing fruit less susceptible to flesh browning symptoms.

Chitosan has been applied successfully as a coating on the food surface to extend the shelf life effectively without compromising the natural tastes of the product. The chitosan films are used as coating of fresh fruits and vegetables (mushroom, apples, oranges, tomatoes, pepper, cantaloupe ...etc.) because they are flexible, offer valuable properties such as elasticity, selective permeability and act as an antimicrobial barrier against pathogens (Zhelyazkov *et al.*, 2012; Hussein *et al.*, 2015). An additional positive effect of chitosan coating is related to its ability to extend the storage life of fruits and vegetables. Chitosan forms a semipermeable film that regulates the gas exchange and reduces transpiration losses and fruit ripening is slowed down. Also, the respiration rate and hence water loss are reduced (Bautista-Banos *et al.*, 2006). However, chitosan coating partially inhibited enzyme activity and delayed the increase in phenolic content and enzyme activities of fresh-cut mushroom. Thus, it seems that the effect of chitosan coating on anti-browning is not only due to the reduction in oxygen supply but also to the inhibitory effects of enzyme activities (Eissa, 2008) on the fresh-cut mushroom.

Carboxymethyl cellulose (CMC) is one of the polysaccharides used in an edible coating. Carboxymethyl cellulose is flexible and transparent and can act as a barrier to moisture and oxygen. Previous studies reported the application of carboxy methyl cellulose as a suitable coating material for several products. It is a linear, long-chain, water-soluble, anionic polysaccharide that can be used as a fruit coating. Purified CMC is a white to cream-colored, tasteless, odourless, free-flowing powder. Edible coatings can also serve as carriers of food additives, anti-browning and antimicrobial agents, colorants, flavors, nutrients, and spices (Srivastava and Bala, 2016) on button mushroom. Moreover, Haffez (2016) reported that coating fresh-cut cantaloupe with methylcellulose extended the shelf life of the product, and also showed a beneficial effect on reducing decay, weight loss, colour change, loss of firmness and delayed the softening of fruit and texture change. The objective of this study was to investigate the potential of some edible coating such as calcium chloride, chitosan and carboxy methylcellulose individually in different concentrations to extend shelf life and maintain the quality of fresh mushroom during storage at 4 °C and 95% RH.

Materials and Methods

Mushrooms (*Agaricus bisporus*) were obtained from the outlet of the Food Technology Research Institute - Agricultural Research Center in Giza, Egypt, during the two seasons 2021 and 2022 on January 4 in the first season and on January 6 in the second season. Then Button mushrooms were taken to the laboratory of Vegetable Crops Postharvest and Handling Dept., Giza Governorate, Egypt. Button mushrooms were selected with uniformity size, colour and free of blemishes, visual damage or defects for postharvest experiment.

Preparation of edible coating solution:

Chitosan is a commercial product; it includes chitosan in a proportion of 90-95% (2-Amino-2-deoxy-beta-D-glucosamine) (EL-Badawy 2014). Chitosan was bought from El-Gomhouria Company, Egypt. Chitosan coating at (1 or 2%) was prepared by dissolving 10 g or 20 g chitosan powder in 1000 ml of distilled water, respectively and homogenized by a magnetic stirrer. Glycerol (1.5% W/V) was added to the mixture as a plasticizer.

Carboxymethyl cellulose (CMC) was bought from Technogene Company, Egypt. CMC coating at (1 or 2%) was prepared by dissolving 10 g or 20 g of CMC powder in a water ethyl alcohol mixture (2:1) at 75 °C under the high-speed mixer (900 rpm) for 15 min. then, glycerol (1.5% W/V) was added and the solution was stirred for another 10 min under the same conditions. Calcium chloride solution coating at (2 or 4%) was prepared by dissolving 20 g or 40 g CaCl₂ powder in 1000 ml of distilled water respectively and homogenized by a magnetic stirrer. Button mushrooms were washed with tap water and then treated with the following treatments:

- 1-Dipping in calcium chloride solution at 2% for 5 min.
- 2-Dipping in calcium chloride solution at 4% for 5 min.
- 3-Dipping in chitosan solution at 1% for 5 min.
- 4-Dipping in chitosan solution at 2% for 5 min.
- 5-Dipping in carboxy methyl cellulose solution at 1% for 5 min.
- 6-Dipping in carboxy methyl cellulose solution at 2% for 5 min.
- 7-Control (dipping in distilled water).

All treatments were air-dried after being directly dipped in air and packed in polypropylene bags (25 x 30 cm) with a thickness of 20 mm. Each sachet contains 100 g mushrooms represented as an experimental unit (EU). 12 replicates were selected from each treatment and stored at 4 °C and 95% relative humidity for 12 days. Samples were randomly drawn in 3 replicates and samples were organised in a complete randomized design.

Quality attributes:

Studied characters were examined directly after treatment and at 3 days intervals to determine the following:

1- Browning Index (BI): The colour of the mushroom cap was measured using a Minolta Chroma Meter (Model CR-155, Minolta Camera Co., Osaka, Japan), using the Hunter Lab Color Scale. Mushroom colour has been commonly measured using the L* value. Also changes in other parameters of the hunter scale (a* and b*) related to browning (Aguirre *et al.*, 2008). BI was determined by the method of Ruangchakpet and Sajjaanantakul (2007) using the following equation:

Browning Index (BI) = $[100 (x - 0.31)] / 0.17$, where $x = (a^* + 1.75L^*) / (5.645L^* + a^* - 0.3012b^*)$, L* value indicates lightness of the colour, which range from 0 (dark) to 100 (white). The positive value of a* indicates the red colour, while the negative value indicates the green colour. The positive value of b* indicates the yellow colour, while the negative value indicates the blue colour.

2-Polyphenol oxidase (PPO) activity: the activity of PPO was determined in the extract during storage period by the method of Pizzocaro *et al.* (1993).

3-Total phenolic contents: Total phenolic contents were measured according to Singleton and Rossi, (1965).

4-Total bacteria counts (TBC) and total yeast and mold counts (TYMC): The population of total bacteria counts (TBC) and total yeast and mold counts (TYMC) were determined by the method of Gonulalan *et al.* (2003).

5-Weight loss (%) was measured.

6-Flavonoids contents were determined using the method of Barros *et al.* (2008).

Statistical analysis

The experimental design was factorial with two factors in a CRD with three replicates. Duncan's Multiple Range Test at 5% level of significance was used to compare between means according to Sendecor and Cochran (1982).

Results

Browning Index (BI)

Data in Figure (1) showed a significant difference between edible coating treatments in the browning Index of fresh mushrooms during storage. The Browning Index of fresh mushrooms was increased with the prolongation of the storage period. These results were recorded with (Rageh 2018) on button mushrooms and (Eissa 2008) on fresh-cut mushrooms.

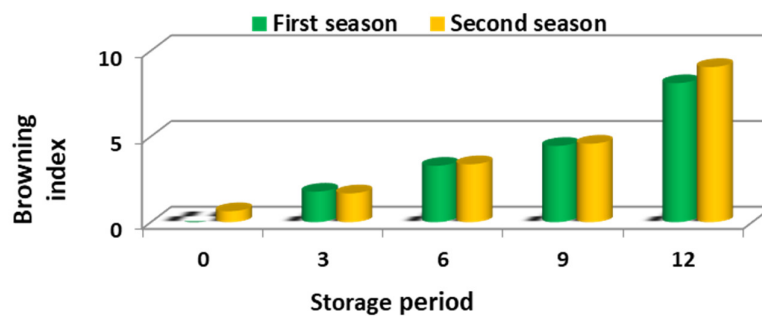


Figure 1. Effect of storage periods on the browning index (BI) of fresh mushroom during cold storage at 4 °C in 2021 and 2022 seasons

Concerning the effect of CaCl₂, chitosan and carboxy methyl cellulose (CMC) on the browning Index, Data in Figure (2) showed a significant difference between edible coating treatments in the browning Index of fresh mushrooms during storage.

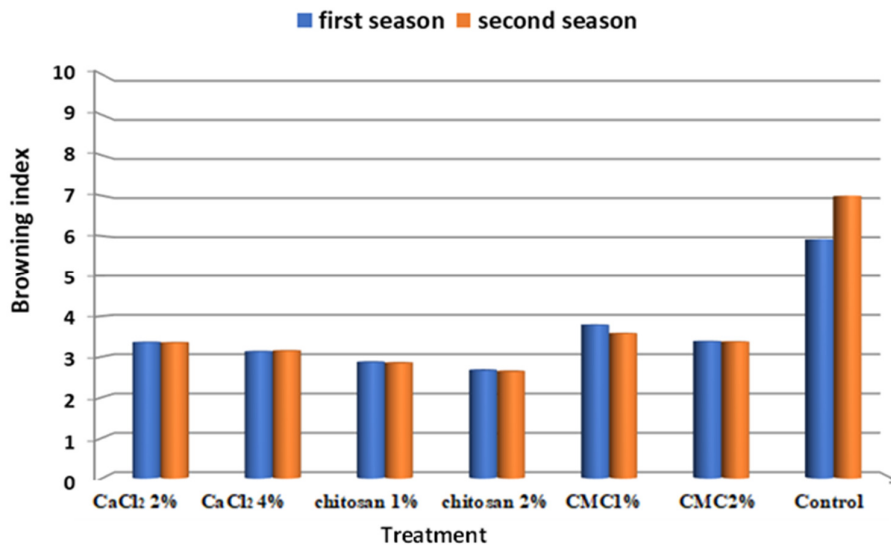


Figure 2. Effect of edible coating treatments on the browning index (BI) of button mushroom during storage at 4 °C during both seasons.

All treatments were better than the control however; fresh mushroom dipped in a solution of chitosan at 2% was the most effective treatment for reducing the browning Index during storage in two seasons. In another word, this treatment gave the lowest value of the browning Index in both seasons, while untreated (control) obtained the highest ones in this concern. Fresh mushroom treated with CMC at 1% was less effective in reducing the browning Index when compared with the other treatments (Table 1). These results were true in the two seasons and agree with Eissa (2008) for chitosan, Anshu and Anju (2018) for CaCl₂, Srivastava and Bala (2016) for CMC and Ban *et al.* (2014) for chitosan and CaCl₂.

Table 1. Effect of edible coating treatments and storage periods on browning index (BI) of button mushroom during storage at 4 °C during both seasons

Treatments	Storage periods (per day)				
	0	3	6	9	12
2021					
CaCl ₂ 2%	0.71 r	1.69 o-q	3.43 kl	4.52 hi	6.40 c
CaCl ₂ 4%	0.71 r	1.58 pq	3.17 lm	4.35 i	5.82 d
chitosan 1%	0.71 r	1.50 pq	2.96 m	4.00 j	5.15 e
chitosan 2%	0.71 r	1.39 q	2.55 n	3.77 j	4.89 e-g
CMC1%	0.71 r	1.95 o	3.69 jk	4.79 f-g	6.74b
CMC 2%	0.71 r	1.81 op	3.23 lm	4.61i	6.47bc
Control	0.71 r	2.55 n	3.99 j	5.08 ef	9.27a
2022					
CaCl ₂ 2%	0.64 s	1.53 q	3.55 l	4.62 hi	6.34 c
CaCl ₂ 4%	0.64 s	1.47 q	3.28 m	4.58 i	5.72 d
chitosan 1%	0.64 s	1.39 qr	3.00 n	4.12 j	5.03 f
chitosan 2%	0.64 s	1.28 r	2.64 o	3.81 k	4.77gh
CMC1%	0.64 s	1.87 p	3.80 k	4.90 fg	6.66 b
CMC 2%	0.64 s	1.74 p	3.32 m	4.71 hi	6.38 c
Control	0.64 s	2.48 o	4.11 j	5.35 e	10.43 a

Values with the same letters are not significantly different at $P \leq 0.05$ level; Tukey's multiple range test.

Concerning the interaction between edible coating treatments and storage period on browning Index, data recorded that fresh mushroom dipped in chitosan at 2% gave the lowest value in browning index till 12 days (end of storage period) at 4 °C, while, untreated control had the highest value in the browning index after 12 days of storage.

Polyphenol oxidase activity (PPO)

The presented data in Figure 3 indicated that PPO activity was increased with the prolongation of the storage period in the two tested seasons. The increase in PPO activity may be due to the activation from latent to fully active form. PPO enzyme activity increased in fruit after harvest and the activity of phenols was closely associated with the development of browning, these results are in an agreement with those reported by Mirshekari *et al.* (2019) on button mushrooms.

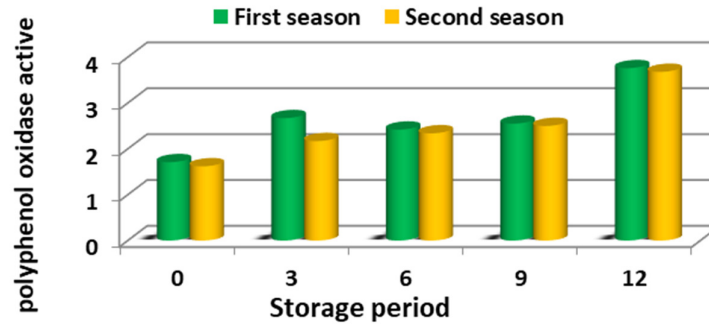


Figure 3. Effect of storage periods on the activity of PPO during both seasons.

Concerning the effect of CaCl_2 , chitosan and carboxy methyl cellulose (CMC), data in Figure 4 revealed that fresh mushroom dipped in chitosan 2% were the most effective treatments in reducing PPO activity with significant differences between this treatment and the others, in both seasons. The highest mean values of PPO activity were obtained from untreated control, in the two seasons. These results are in agreement with those obtained by Eissa (2008) for chitosan.

Regarding the interaction between CaCl_2 , chitosan and carboxy methyl cellulose (CMC) treatments and storage periods, data revealed that all treatments reduced PPO activity with significant differences among them compared with the untreated control after 12 days of storage, in the two seasons (Table 2).

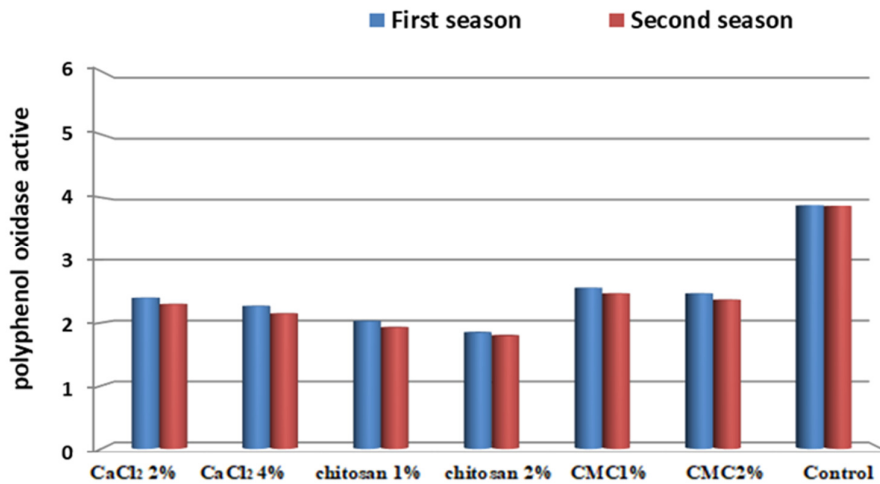


Figure 4. Effect of edible coating treatments on the activity of PPO during both seasons

Table 2. Effect of edible coating treatments and storage periods on the activity of PPO during both seasons

Treatments	Storage periods (per day)				
	0	3	6	9	12
2021					
CaCl ₂ 2%	1.71t	2.34 kl	2.52 hi	2.62 gh	2.74 ef
CaCl ₂ 4%	1.71t	2.16 mn	2.36 k	2.47 ij	2.58 h
Chitosan 1%	1.71t	1.96 p-r	2.05 op	2.13 no	2.25 lm
Chitosan 2%	1.71t	1.77 st	1.86 rs	1.90 qr	1.96 pq
CMC1%	1.71t	2.52 hi	2.71 fg	2.84 de	2.97 c
CMC 2%	1.71t	2.41 jk	2.61 h	2.74 ef	2.85 d
Control	1.71t	2.71 fg	2.86 d	3.18 b	4.95 a
2022					
CaCl ₂ 2%	1.62 u	2.22 mn	2.41 i-k	2.54 f-h	2.67 de
CaCl ₂ 4%	1.62 u	1.98 pq	2.27 lm	2.37 j-l	2.47 h-j
Chitosan 1%	1.62 u	1.84 rs	1.94 qr	2.07 op	2.13 n
Chitosan 2%	1.62 u	1.70 tu	1.80 st	1.88 q-s	1.94 qr
CMC1%	1.62 u	2.48 g-j	2.63 d-f	2.74 cd	2.82 c
CMC 2%	1.62 u	2.33 k-m	2.52 f-i	2.59 e-g	2.74 cd
Control	1.62 u	2.62 ef	2.79 c	3.31 b	5.00a

Values with the same letters are not significantly different at P ≤ 0.05 level; Tukey's multiple range test.

Total phenolic contents:

Data in Figure (5) indicated that the prolongation of the storage period led to decrease total phenolic contents. This decrease could be attributed to the oxidation of the PPO enzyme giving the coloured quinones and quercetin was oxidized directly by PPO. Similar results were obtained by Rageh (2018); Queiroz *et al.* (2008) on button mushroom. Also, the effect of edible coating treatments maintained the total phenolic loss as compared with control, fresh cut mushroom treated with chitosan 2% seems to be most effective in reducing total phenolic loss with significant differences between all treatments in the two seasons, followed by chitosan 1% (Figure 6).

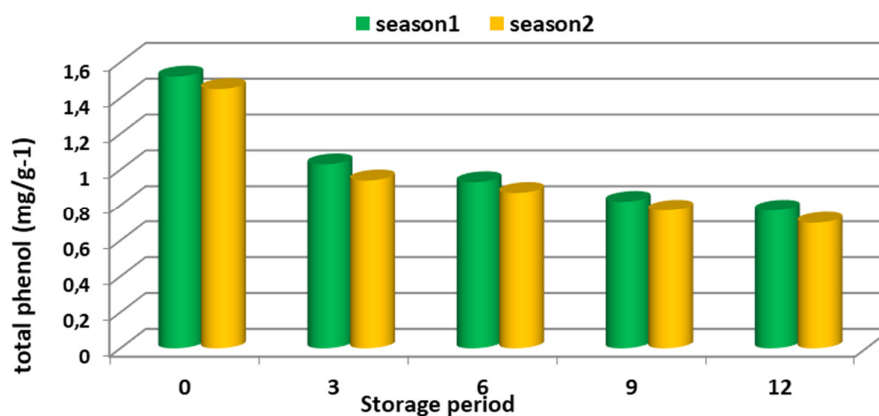


Figure 5. Effect of storage periods on total phenol (mg/g) of fresh mushroom during both seasons

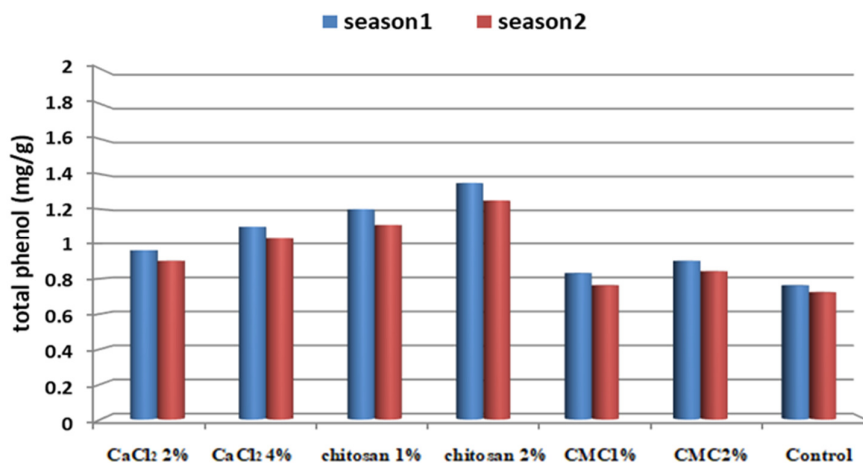


Figure 6. Effect of edible coating treatments on total phenol (mg/g) during both seasons

Regarding the interaction between CaCl₂, chitosan and carboxy methyl cellulose (CMC) treatments and storage periods, data in Table 3 showed that, the interaction between edible coating treatments revealed that all treatments reduced total phenolic loss with significant differences among them compared with the untreated control after 12 days of storage and the lowest value was obtained from untreated control, in the two seasons. In general, the interaction between edible coating treatments and storage period was significant in the two seasons. After 9 days of storage, fresh-cut mushrooms treated with chitosan 2% gave the highest total phenolic content, while untreated control gave the lowest ones at the same period (Table 3).

Table 3. Effect of edible coating treatments and storage periods on total phenol (mg/g) of fresh mushroom during both seasons

Treatments	Storage periods (per day)				
	0	3	6	9	12
	2021				
CaCl ₂ 2%	1.52 a	0.97 hi	0.86 jk	0.75 lm	0.69 mn
CaCl ₂ 4%	1.52 a	1.13 f	1.04 g	0.96 hi	0.91ij
Chitosan 1%	1.52 a	1.27 d	1.15 F	1.05 g	1.00 gh
Chitosan 2%	1.52 a	1.45 b	1.35 c	1.23 de	1.18 ef
CMC1%	1.52 a	0.81 kl	0.68 mn	0.60 op	0.56 pq
CMC 2%	1.52 a	0.88 j	0.80 kl	0.69 m	0.63 no
Control	1.52 a	0.72 m	0.61 op	0.52 q	0.43 r
2022					
CaCl ₂ 2%	1.45 a	0.89 h	0.82 i	0.70 k-m	0.65 m-o
CaCl ₂ 4%	1.45 a	1.03 fg	0.98 g	0.86 hi	0.80 ij
Chitosan 1%	1.45 a	1.15 d	1.05 f	0.99 g	0.88 h
Chitosan 2%	1.45 a	1.32 b	1.25 c	1.15 de	1.08 ef
CMC1%	1.45 a	0.74 jk	0.64 m-o	0.55 pq	0.50 q
CMC 2%	1.45 a	0.80 ij	0.73 kl	0.63no	0.60 op
Control	1.45 a	0.67 l-n	0.59 op	0.49 q	0.41 r

Values with the same letters are not significantly different at P ≤ 0.05 level; Tukey's multiple range test.

Total bacterial count (TBC)

Data in Figure (7) indicated that bacterial growing in fresh mushrooms increased with increasing storage period, mainly in the control in both seasons. These results were similar to the results of Rageh (2018) on button mushroom and (Eissa 2008) on the fresh cut mushroom.

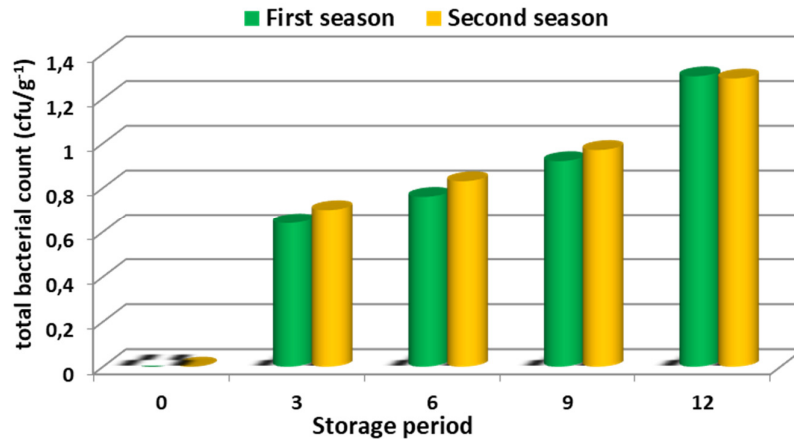


Figure 7. Effect of storage periods on total bacterial count (cfu/g) of fresh mushroom during both seasons

The results in Figure (8) showed significant differences in bacterial growth between edible coating treatments and control. Fresh mushrooms treated with all studied treatments had lower levels of bacterial load in comparison to untreated control treatment, while, dipped in chitosan coating at 2% provided the lowest count in bacterial count followed by chitosan coating at 1% in the two seasons, while the other treatments gave less effective in reducing bacterial growth in both seasons and agree with Jiang *et al.* (2011). Data in Table 4 showed that the interaction between edible coating treatments and storage period was significant during storage periods. After 9 days of storage showed that fresh mushroom treated with chitosan at 2% and chitosan at 1% were effective in inhibition bacterial growth with significant differences between them ,these were true in two seasons and agree with (Rageh, 2018) on button mushroom and (Eissa, 2008) on the fresh cut mushroom.

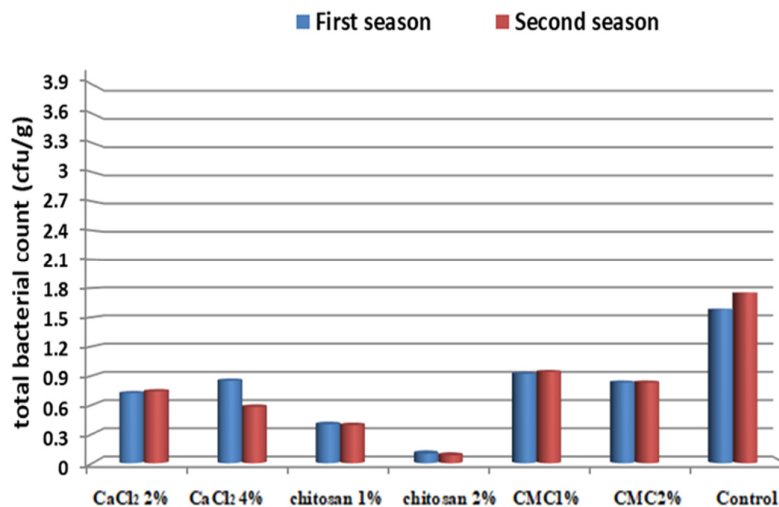


Figure 8. Effect of edible coating treatments on total bacterial count (cfu/g) of button mushroom during both seasons

Table 4. Effect of edible coating treatments and storage periods on total bacterial count (cfu/g) of fresh mushroom during both seasons

Treatments	Storage periods (per day)				
	0	3	6	9	12
	2021				
CaCl ₂ 2%	0.00 n	0.67 i-k	0.78 hi	0.87 h	1.27 ef
CaCl ₂ 4%	0.00 n	0.55 kl	0.65 i-k	0.77 hi	0.93 gh
Chitosan 1%	0.00 n	0.27 m	0.40 lm	0.57 j-l	0.77 hi
Chitosan 2%	0.00 n	0.00 n	0.00 n	0.22 m	0.27 m
CMC1%	0.00 n	0.82 hi	0.93 gh	1.27 ef	1.60 cd
CMC 2%	0.00 n	0.75 h-j	0.87 h	1.10 fg	1.43 de
Control	0.00 n	1.40 e	1.70 c	1.95 b	2.87 a
2022					
CaCl ₂ 2%	0.00 q	0.70 k-m	0.87 i-k	0.90 h-j	1.23 fg
CaCl ₂ 4%	0.00 q	0.57 mn	0.70 k-m	0.77 j-l	0.87 i-k
Chitosan 1%	0.00 q	0.30 op	0.43 no	0.53 mn	0.67 lm
Chitosan 2%	0.00 q	0.00 q	0.00 q	0.17 pq	0.23 p
CMC1%	0.00 q	0.90 h-j	1.07 gh	1.20 fg	1.53 df
CMC 2%	0.00 q	0.83i-l	0.93 u-j	1.00 hi	1.37 ef
Control	0.00 q	1.58 d	1.87 c	2.20 b	3.10 a

Values with the same letters are not significantly different at P ≤ 0.05 level; Tukey's multiple range test.

Total yeast and mold counts (TYMC)

Data in Figure (9) indicated that TYMC mushrooms augmented with the extension of the storage period, mainly in the control in both seasons. The same trend was recorded with Rageh (2018).

Recording the effect of edible coating treatments, data in Figure (10) showed significant differences in TYMC between all treatments and the control. Fresh mushrooms dipped in chitosan at 2% and chitosan at 1% treatments gave the lowest significant number in TMYC treatment with no significant differences between them, followed by CaCl₂ at 4%, however the other treatments were less effective in decreasing this character. The high levels of TYMC were recorded with untreated control during storage in both seasons. These results are in accordance with Eissa (2008) for chitosan and Chikthimmah *et al.* (2005) for CaCl₂.

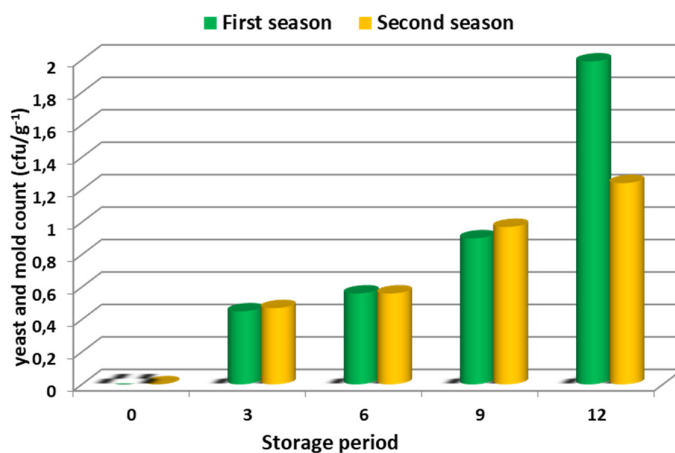


Figure 9. Effect of storage periods on yeast and mold count (cfu/g) of button mushrooms during both seasons

Data given in Table 5 indicated that TYMC of fresh cut mushroom were decreased with increasing chitosan concentration. The untreated fresh-cut mushroom was contaminated with yeasts and molds (TYMC) of untreated mushroom after 12 days stored at 4 °C was 3.13 and 3 log colony-forming units (cfu/g) in the tow season, whereas the TYMC reduced by 1 log value at mushroom coated with 2% chitosan, 1% chitosan and 4% CaCl₂ respectively. This rate is accepted as a maximal count of decontaminated fruit desired by the fruit trade (Lee *et al.*, 2004). Furthermore, no growth of yeasts, bacteria and molds was noticed after 6 days stored at 4 °C in mushroom coated with 1% and 2% chitosan. Our result showed that 2% chitosan was effective for decreasing the harmful microorganisms (TYMC) in mushroom. Concerning the interaction data in Table 6 exhibited that after 12 days of storage fresh mushrooms dipped in chitosan at %2 was the most effective treatment in reducing TYMC in both seasons.

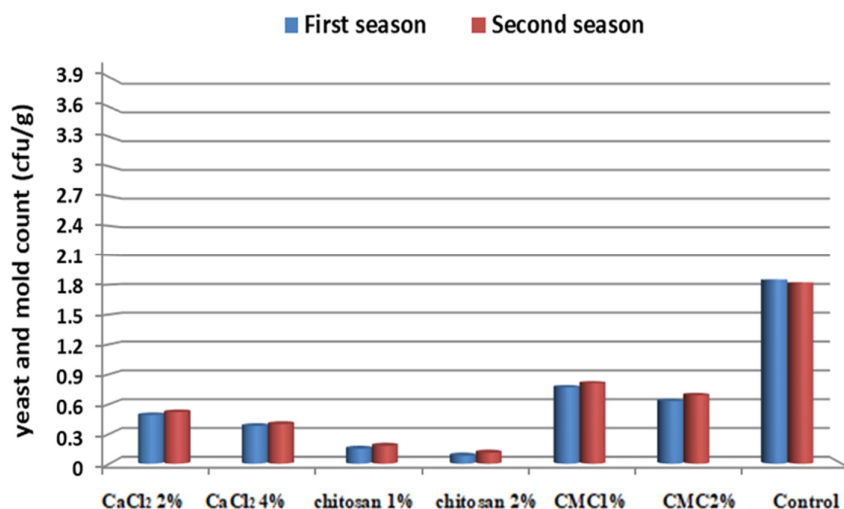


Figure 10. Effect of edible coating treatments on yeast and mold count (cfu/g) of button mushrooms during both seasons

Table 5. Effect of edible coating treatments and storage periods on yeast and mold count (cfu g⁻¹) of fresh mushrooms during cold storage at 4 °C in 2021 and 2022 seasons

Treatments	Storage periods (per day)				
	0	3	6	9	12
	2021				
CaCl ₂ 2%	0.00 o	0.30 mn	0.47 j-m	0.70 hi	0.97 g
CaCl ₂ 4%	0.00 o	0.17 no	0.33 l-n	0.57 i-k	0.83 gh
Chitosan 1%	0.00 o	0.00 o	0.00 o	0.20 no	0.53 i-l
Chitosan 2%	0.00 o	0.00 o	0.00 o	0.13 no	0.27 mn
CMC1%	0.00 o	0.57 i-k	0.67 h-j	1.20 ef	1.40 e
CMC 2%	0.00 o	0.43 k-m	0.53 i-l	1.00 fg	1.20 ef
Control	0.00 o	1.70 d	1.93 c	2.47 b	3.13 a
2022					
CaCl ₂ 2%	0.00 o	0.37 k-n	0.43 j-n	0.73 hi	1.03 fg
CaCl ₂ 4%	0.00 o	0.20 no	0.30 mn	0.60 i-l	0.90 gh
Chitosan 1%	0.00 o	0.00 o	0.00 o	0.27 no	0.63 h-k
Chitosan 2%	0.00 o	0.00 o	0.00 o	0.20 no	0.33 l-n
CMC1%	0.00 o	0.63 h-k	0.70 h-j	1.27 ef	1.47 de
CMC 2%	0.00 o	0.47 i-n	0.57 i-m	1.10 fg	1.30 ef
Control	0.00 o	1.60 d	1.90 c	2.60 b	3.00 a

Values with the same letters are not significantly different at P ≤ 0.05 level; Tukey's multiple range test.

Weight loss percentage

Data in Figure (11) show the impact of chitosan (CH), CaCl₂ and carboxy methyl cellulose (CMC) treatments on the weight loss percentage of fresh mushroom during cold storage. Results indicated that there were significant increases in weight loss of fresh cut mushroom during the storage period in the two seasons.

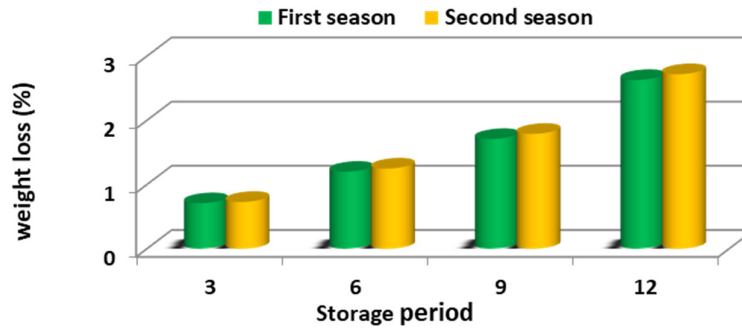


Figure 11. Effect of storage periods on weight loss percentage of fresh mushroom during both seasons

Similar results were obtained by Rageh (2018) and Chong *et al.* (2015). Concerning the effect of postharvest treatments on weight loss percentage, data shown in Figure 12 revealed that there were significant differences between all treatments and untreated control in weight loss percentage during storage, however, all treatments retained their weight during storage as compared with control. Moreover, fresh-cut mushroom treated with CaCl₂ at the two concentrations, resulted in a prominent reduction in weight loss percentage with significant differences between them in the two seasons, followed by chitosan at 1% and CMC at 2% with no significant differences between them in the two seasons. The highest value of weight loss percentage was recorded with untreated control. These results were in agreement with Artia (2014) for CaCl₂ Chong *et al.* (2015) for CaCl₂ or chitosan and Nadim *et al.* (2015) for methylcellulose. Concerning the interaction between postharvest treatments and storage period, data in Table 6 indicated that fresh-cut mushroom treated with CaCl₂ at 4% was the most obvious in reducing the loss of weight loss percentage during all storage period in the two seasons while the highest value of weight loss percentage was recorded with untreated control in both seasons.

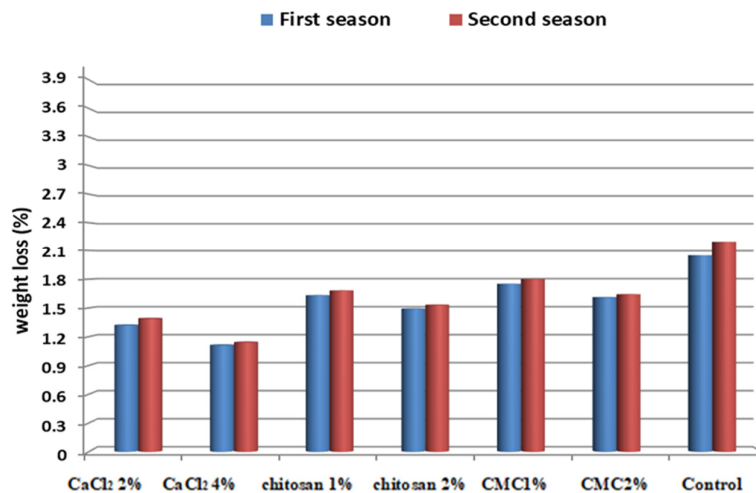


Figure 12. Effect of edible coating treatments on weight loss percentage of fresh mushroom during both seasons

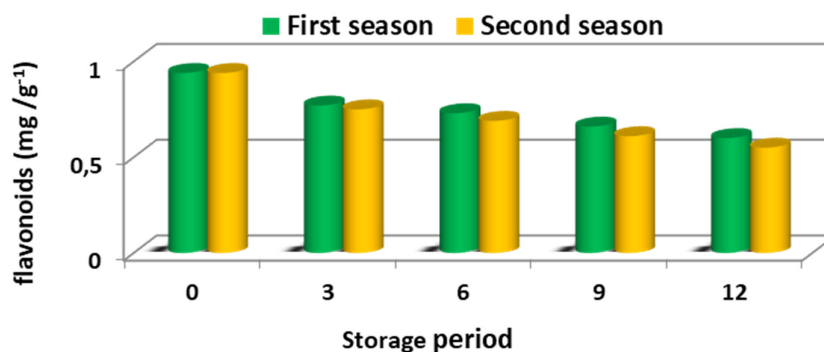
Table 6. Effect of edible coating treatments and storage periods on weight loss percentage of fresh mushroom during cold storage at 4 °C in 2021 and 2022 seasons

Treatments	Storage periods (per day)			
	3	6	9	12
2021				
CaCl ₂ 2%	0.53q	0.99 n	1.48i-k	2.30e
CaCl ₂ 4%	0.36r	0.87 no	1.34kl	1.86f
Chitosan 1%	0.73op	1.23 lm	1.77fg	2.79bc
Chitosan 2%	0.67pq	1.16 m	1.56hi	2.57d
CMC 1%	0.86no	1.37 j-l	1.88f	2.89b
CMC 2%	0.80op	1.28lm	1.68gh	2.69cd
Control	0.99n	1.50ij	2.30e	3.40a
2022				
CaCl ₂ 2%	0.58q	1.06 m	1.54 i	2.37 f
CaCl ₂ 4%	0.38r	0.90 n	1.38 jk	1.92 g
Chitosan 1%	0.77op	1.29 kl	1.80 h	2.84 c
Chitosan 2%	0.69pq	1.20 l	1.60 i	2.62 de
CMC 1%	0.89 n	1.41 j	1.94 g	2.97 b
CMC 2%	0.83 no	1.33 jk	1.72 h	2.70 d
Control	1.03 m	1.59 i	2.53 e	3.65 a

Values with the same letters are not significantly different at $P \leq 0.05$ level; Tukey's multiple range test.

Total flavonoids contents

Data in Figure 13 showed that total flavonoid contents decreased with the prolongation of the storage period. Concerning the effect of postharvest treatments, data in Figure 14 revealed that all treatments were effective in maintaining total flavonoid contents during storage compared with untreated control. Moreover, fresh mushrooms dipped in chitosan 2% were the most effective treatments in reducing the loss of total flavonoid contents in the two seasons, followed by chitosan 1% in the two seasons however, the other treatments were less effective in this concern. The lowest value was obtained from untreated control in the two seasons. These results in agreement with Rageh (2018) for calcium chloride and Jiang *et al.* (2012) for chitosan.

**Figure 13.** Effect of storage periods on flavonoids (mg/g) of button mushroom during both seasons

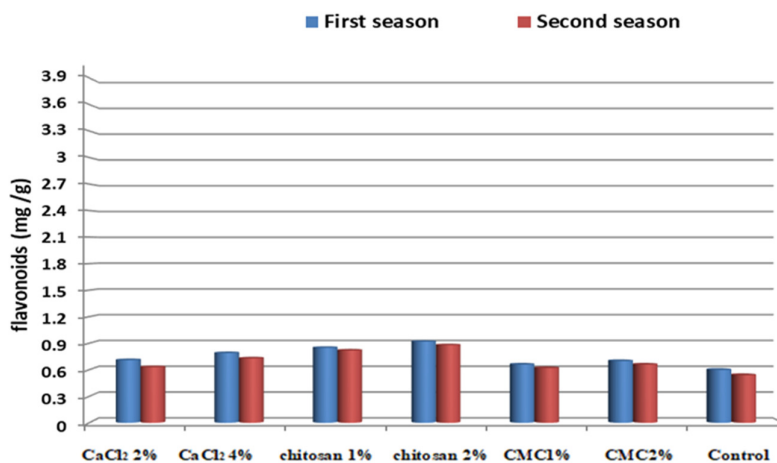


Figure 14. Effect of edible coating treatments on flavonoids (mg/g) of button mushroom during both seasons

For the interaction between postharvest treatments and storage period, after 12 days of storage, results in Table 7 indicated that fresh-cut mushrooms dipped in chitosan 2% had significantly higher values of total flavonoid content compared with other treatments, followed by chitosan 1%. These results were true in the two seasons, while the lowest total flavonoid content was obtained with control in both seasons.

Table 7. Effect of edible coating treatments and storage periods on flavonoids (mg/g) of fresh mushroom during both seasons

Treatments	Storage periods (per day)				
	0	3	6	9	12
2021					
Cacl2 2%	0.98a	0.75gh	0.69ij	0.60l	0.55m
Cacl2 4%	0.98a	0.83c	0.78fg	0.71i	0.65k
Chitosan 1%	0.98a	0.90bc	0.85de	0.80f	0.74h
Chitosan 2%	0.98a	0.96a	0.92b	0.88cd	0.84e
CMC 1%	0.98a	0.66jk	0.62l	0.55m	0.50n
CMC 2%	0.98a	0.71i	0.66jk	0.61l	0.56m
Control	0.98a	0.60l	0.56m	0.45o	0.41p
2022					
Cacl2 2%	0.94a	0.72g-i	0.65i-k	0.56l-n	0.50no
Cacl2 4%	0.94a	0.81c-e	0.74f-h	0.67i-k	0.61k-m
Chitosan 1%	0.94a	0.88a-c	0.81c-e	0.77e-g	0.70g-j
Chitosan 2%	0.94a	0.93a	0.89ab	0.84b-d	0.80d-f
CMC 1%	0.94a	0.64jk	0.60k-m	0.50 no	0.43op
CMC 2%	0.94a	0.69h-j	0.62kl	0.55mn	0.50no
Control	0.94a	0.56l-n	0.50no	0.39p	0.32q

Values with the same letters are not significantly different at P ≤ 0.05 level; Tukey's multiple range test.

Discussion

Edible coating

Edible coating potentially prolongs the shelf life of fruits due to the formation of barrier layer blocking the exposure of gas and moisture. The barrier layer can delay the quality deterioration of fruits by reducing the respiration, delaying volatiles loss, decreasing the broke of moisture migration and thus extend the shelf life of fruits (Rojas – Grau *et al.*, 2009).

Browning Index (BI)

The reduction of the browning Index using chitosan may be due to that chitosan coatings could delay postharvest senescence of fruits and vegetables associated with colour changes and dehydration (Ban *et al.*, 2014).

Polyphenol oxidase activity (PPO)

The reduction of PPO activity under chitosan treatments may be due to that chitosan is a cationic polysaccharide recognized as an excellent protein binder, the decrease in enzyme activity was not simply the result of inadequate extraction procedure but a result of the binding of the enzymes to chitosan (Baldwin *et al.*, 1995; Van Der Lubben *et al.*, 2001). However, chitosan coating partially inhibited enzyme activity and delayed the increase in phenolic content and enzyme activities of fresh-cut mushrooms. Thus, it seems that the effect of chitosan coating on anti-browning is not only due to the reduction in oxygen supply but also to the inhibitory effects of enzyme activities (Li and Yu, 2000; Jiang and Li, 2001). The main function of calcium lactate is to strengthen the cell wall and stabilized the cell membrane (Luna-Guzman and Barrett, 2000), thus keeping PPO, which is a membrane-bound enzyme, away from its phenolic substrates present mainly in vacuoles leading to preserving phenolic content and inhibiting browning process.

Total phenolic contents

A lower level of total phenolic of the chitosan-treated slices may be due to the inhibition of PAL activity. However, the decrease in polyphenols content was due to the binding of the polyphenols to chitosan. Similar results were obtained by Eissa (2008).

Total bacterial count (TBC)

Rabea *et al.* (2003). Revealed that the antimicrobial of chitosan is probably caused by the interaction between chitosan and the microbial cell membranes, which leads to the leakage of proteinaceous and other intracellular constituents. Chitosan can also penetrate to the nuclei of fungi and interferes with RNA and protein synthesis. Krasaekoopt and Mabumrung (2008) found that the fresh-cut fruits coated with chitosan at 1% or 2% reduced the psychrotroph counts below the detectable level of lower than 100 cfug-1 throughout the storage period, also reduced the number of yeast and mold counts to lower than 200 log cfu g⁻¹. This was probably due to the fungicidal action of chitosan that caused alteration in the function of the cellular membrane (Fang *et al.*, 1994). The favourable effect of CaCl₂ Luna-Guzman and Barrett (2000) found that CaCl₂ has provided an inhibitory effect on microbial growth while control treatment allowed for spore spreading and increased counts. The reduction of microorganisms in fresh cut mushroom treated with CaCl₂ may be due to calcium salts can lower intracellular pH or reduce water activity (Shelef, 1994) which provides a protective antimicrobial barrier against food-borne pathogens in the product (Weaver and Shelef, 1993). Also, CaCl₂ treatment may have provided an inhibitory effect on microbial growth (Weaver and Shelef, 1993).

Total yeast and mold counts (TYMC):

Calcium reduced water activity (Beelman *et al.*, 1987) which provides a protective antimicrobial barrier against food-borne pathogens in products (Crowe *et al.*, 2005) in addition, microflora is usually restricted to fungal and lactic acid bacteria at low pH (Chikthimmah *et al.*, 2005). Also, calcium-enhanced tissue develops resistance to fungal attack by stabilizing or strengthening cell walls, thereby making them more resistant to harmful enzymes produced by bacteria and fungi, and it also delays the aging of fruits (Picchioni *et al.*, 1995).

Weight loss percentage

Increases in weight loss of fresh cut mushroom during the storage period can be attributed to the loss of water which is relatively easy to evaporate (Vasey, 2006). Bolin and Huxsoll (1989) found that the effect of CaCl₂ on reducing weight loss is likely due to strengthening the cell wall and reducing the respiration rate in the stored vegetable fruits. Chong *et al.* (2015) revealed that CaCl₂ or chitosan treatments can effectively prevent moisture loss in fresh-cut honeydew melon by coating the fruit surface, the migration of moisture from inner fruits to the surface slowed down, leading to a reduced rate of moisture loss and possibly reduced respiration rate, resulting in lowering weight loss. The favourable effect of chitosan treatment in reducing weight loss may be due to the chitosan coating forms a layer of semi-transparent to smooth the pericarp surface (Dong *et al.*, 2004) and can be used as a protective barrier to reduce respiration and transpiration rates through fruit surface (Kester and Fernema, 1986). Also, Shiri *et al.* (2013) found that chitosan coating reduced weight loss during storage as it enables epidermal tissues to control water loss and reduce respiratory activity, the barrier to water vapor, reducing moisture loss and delaying fruit dehydration (Baldwin *et al.*, 1995). Carboxymethyl cellulose coatings are effective physical barriers to moisture loss and slower rates of weight loss in coated fruits because of the cover features for gas diffusion of stomata, the organelles that regulate the transpiration process and gas exchange between the fruit and the surroundings (Almenar *et al.*, 2006). Thereby, weight loss reducing during storage. CMC edible coating provides a semi-permeable barrier to O₂, CO₂, H₂O and moisture transfer slowing down fruit respiration (Baldwin *et al.*, 1995).

Total flavonoids contents

The effect of chitosan in this concern could be due to the fast oxidation of flavonoids compound on the mushroom surface, directly in contact with the O₂. Enzymatic oxidation of phenolics via polyphenol oxidase (PPO) has been associated with mushroom browning. Previous research shows a significant positive relationship between total phenolic and antioxidant activity in mushrooms, the higher radical scavenging activity in chitosan-coated mushrooms in the present study could be mainly attributed to its higher level of total phenolic compounds. The main function of CaCl₂ is to strengthen the cell wall and stabilize the cell membrane (Jones and Jacobsen, 1983), thus keeping PPO, which is a membrane-bound enzyme, away from its phenolic substrates present mainly in vacuoles leading to preserving phenolic content and inhibiting browning process (Koushki *et al.*, 2011).

Conclusions

It could be concluded that, dipping mushroom fresh-cut in chitosan at 2% could be considered as an effective method in increasing its shelf life and keeping it at high quality during shelf life. That was clear by reducing deterioration rate (browning – PPO activity - total phenolic loss - total bacterial, yeast and mold counts). Moreover, keeping its contents of total flavonoids for up to 12 days at 4 °C.

Authors' Contributions

Conceptualization, SA, MH; methodology, SA, MH, software, SA, MH, AFA; investigation, SA, MH, AFA, KhA; resources, SA, MH, AFA, KhA; writing—original draft preparation, SA, MH, AFA, KhA, AA. writing—review and editing, SA, MH, AFA, KhA, AA; funding acquisition, SA, MH, AFA, AA, KhA; All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicable.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

References

- Aguirre L, Frías JM, Barry-Ryan C, Grogan H (2008). Assessing the effect of product variability on the management of the quality of mushrooms (*Agaricus bisporus*). *Postharvest Biology and Technology* 49:247-254. <https://doi.org/10.1016/j.postharvbio.2008.01.014>
- ALmenar E, Del-Valle V, Catala R, Gavara R (2006). Controlled atmosphere storage of wild strawberry fruit (*Fragaria vesca* L.). *Journal of Agricultural and Food Chemistry* 54:86-91. <https://doi.org/10.1021/jf0517492>
- Anshu S, Anju B (2018). Effect of pretreatments and drying on the quality of oyster mushrooms. *International Journal of Current Microbiology and Applied Sciences* 7(4):93-101. <https://doi.org/10.20546/ijcmas.2018.704.011>
- Attia MM (2014). Effect of calcium chloride, calcium lactate and hydrogen peroxide treatments on quality of fresh cut cantaloupe during cold storage. *Egyptian Journal of Agricultural Research* 92(3). <https://doi.org/10.21608/ejar.2014.156419>
- Baldwin EA, Nisperos-Carriedo MO, Baker RA (1995). Use of edible coatings for lightly processed fruits and vegetables. *HortScience* 30:35-38. <https://doi.org/10.21273/HORTSCI.30.1.35>
- Ban Zh, Li L, Junfeng G, Jianhua F, Maoyu W, Xinming X, Jiang L (2014). Modified atmosphere packaging (MAP) and coating for improving preservation of whole and sliced *Agaricus bisporus*. *Journal of Food Science and Technology* 51:3894-3901. <https://doi.org/10.1007/s13197-013-0935-9>
- Barros L, Falcão S, Baptista P, Freire C, Vilas-Boas M, Ferreira ICFR (2008). Antioxidant activity of *Agaricus* sp. mushrooms by chemical, biochemical and electrochemical assays. *Food Chemistry* 111:61-66. <https://doi.org/10.1016/j.foodchem.2008.03.033>
- Bautista-Banos S, Hernandez-Lauzardo AN, Velazquez-del Valle MG, Hernandez-Lopez M, Ait Barka E, Bosquez-Molina E, Wilson CL (2006). Chitosan as a potential natural compound to control pre and postharvest diseases of horticultural commodities. *Crop Protection* 25:108-118. <https://doi.org/10.1016/j.cropro.2005.03.010>

- Beelman R.B, Quinn JJ, Okereke A, Schisler LC, Muthersbaugh HR, Evenson K (1987). Effect of peat casing layer and the addition of calcium chloride to watering treatments on quality and shelf life of mushrooms. In: Wuest PJ, Royse DJ, Beelman RB (Eds). *Cultivating Edible Fungi*. Elsevier, pp 271-282.
- Bolin HR, Huxsoll CC (1989). Storage stability of minimally processed fruit. *Journal of Food Processing and Preservation* 13:281-292. <https://doi.org/10.1111/j.1745-4549.1989.tb00107.x>
- Chikthimmah NLF, La Borde B, Beelman RB (2005). Hydrogen peroxide and calcium chloride added to irrigation water as a strategy to reduce bacterial populations and improve quality of fresh mushrooms. *Journal of Food Science* 70(6):273-278. <https://doi.org/10.1111/j.1365-2621.2005.tb11446.x>
- Chong JX, Shaojuan L, Hongshun Y (2015). Chitosan combined with calcium chloride impacts fresh-cut honeydew melon by stabilising nanostructures of sodium-carbonate-soluble pectin. *Food Control* 53:195-205. <https://doi.org/10.1016/j.foodcont.2014.12.035>
- Crowe KM, Bushway AA, Bushway RJ (2005). Effects of alternative postharvest treatments on the microbiological quality of lowbush blueberries. *Small Fruits Review* 4(3):29-39. https://doi.org/10.1300/J301v04n03_03
- Dong H, Cheng L, Tan J, Zheng K, Jiang Y (2004). Effects of chitosan coating on quality and shelf-life of peeled litchi fruit. *Journal of Food Engineering* 64(3):355-358. <https://doi.org/10.1016/j.jfoodeng.2003.11.003>
- Eissa AAH (2008). Effect of chitosan coating on shelf life and quality of fresh-cut mushroom. *Journal of Food Quality* 30(2007):623-645. <https://doi.org/10.1111/j.1745-4557.2007.00147.x>
- EL-Badawy MSA (2014). Effect of spray with some safety compounds on growth and productivity of some strawberry cultivars. M.Sc. Thesis, Fac. Agric., Banha Univ., Egypt, pp 76.
- Fang S, Li CF, Shih C (1994). Antifungal activity of chitosan and its preservative effect on low-sugar candied kumquat. *Journal of Food Protection* 57(2):136-140. <https://doi.org/10.4315/0362-028X-57.2.136>
- Gonulalan Z, Kose A, Yetim H (2003). Effects of liquid smoke on quality characteristics of Turkish standard smoked beef tongue. *Meat Science* 66:165-170. [https://doi.org/10.1016/S0309-1740\(03\)00080-9](https://doi.org/10.1016/S0309-1740(03)00080-9)
- Hafez MM (2016). Effect of postharvest treatments on quality and storability of fresh cut cantaloupe. PhD. Thesis, Fac. Agric., Ain Shams Univ., Cairo, Egypt.
- Hussein NM, AbdAllah MMF, Abou El-Yazied A, Ibrahim RE (2015). Sweet pepper quality maintenance: impact of hot water and chitosan. *Egyptian Journal of Horticulture* 42(1):471-491. <https://doi.org/10.21608/ejob.2015.1311>
- Jiang T, Lifang F, Xiaolin Zh (2012). Effect of chitosan coating enriched with thyme oil on postharvest quality and shelf life of shiitake mushroom (*Lentinus edodes*). *Journal of Agricultural and Food Chemistry* 60:188-196. <https://doi.org/10.1021/jf202638u>
- Jiang T, Feng L, Li J (2011). Changes in microbial and postharvest quality of shiitake mushroom (*Lentinus edodes*) treated with chitosan–glucose complex coating under cold storage. *Food Chemistry* 131:780-786. <https://doi.org/10.1016/j.foodchem.2011.08.087>
- Jiang Y, Li Y (2001). Effects of chitosan on postharvest life and quality of longan fruit. *Food Chemistry* 73:139-143. [https://doi.org/10.1016/S0308-8146\(00\)00246-6](https://doi.org/10.1016/S0308-8146(00)00246-6)
- Jones RL, Jacobsen JV (1983). Calcium regulation of the secretion of α -amylase isoenzymes and other proteins from barley aleurone layers. *Planta* 158:1-9. <https://doi.org/10.1007/BF00395396>
- Kester JJ, Fernema OR (1986). Edible films and coatings. A review. *Food Technology* 40:47-59.
- Koushki M, Abras SK, Mohammadi M, Hadian Z, Poorfallah NB, Sharayei P, Mortazavian AM (2011). Physicochemical properties of mushrooms as affected by modified atmosphere packaging and CaCl₂ dipping. *African Journal of Agricultural Research* 6(24):5414-5421.
- Krasaekoopt W, Mabumrung J (2008). Microbiological evaluation of edible coated fresh-cut cantaloupe. *Agriculture and Natural Resources* 42(3):552-557.
- Lee J, Sung T, Lee K, Kim M (2004). Effect of gamma-irradiation on color, pungency, and volatiles of Korean red pepper powder. *Journal of Food Science* 69:585-592. <https://doi.org/10.1111/j.1365-2621.2004.tb09904.x>
- Li H, Yu T (2000). Effect of chitosan on incidence of brown rot, quality and physiological attributes of postharvest peach fruit. *Journal of the Science of Food and Agriculture* 81:269-274. [https://doi.org/10.1002/1097-0010\(20010115\)81:2<269::AID-JSFA806>3.0.CO;2-F](https://doi.org/10.1002/1097-0010(20010115)81:2<269::AID-JSFA806>3.0.CO;2-F)
- Luna-Guzman I, Barrett DM (2000). Comparison of calcium chloride and calcium lactate effectiveness in maintaining shelf stability and quality of fresh-cut cantaloupes. *Postharvest Biology and Technology* 19:61-72. [https://doi.org/10.1016/S0925-5214\(00\)00079-X](https://doi.org/10.1016/S0925-5214(00)00079-X)

- Mirshekari A, Madani B, Golding JB (2019). Aloe vera gel treatment delays postharvest browning of white button mushroom (*Agaricus bisporus*). Journal of Food Measurement and Characterization <https://doi.org/10.1007/s11694-019-00040-8>
- Nadim Z, Ebrahim A, Hassan S, Reza AC (2015). Effect of methylcellulose-based edible coating on strawberry fruit's quality maintenance during storage. Journal of Food Processing and Preservation 39:80-90. <https://doi.org/10.1111/jffpp.12227>
- Picchioni GA, Watada AE, Conway WS, Whittaker BD, Sams CE (1995). Phospholipid, galactolipid and sterol lipid composition of apple fruit cortical tissue following postharvest CaCl₂ infiltration. Phytochemistry 39:763-769. [https://doi.org/10.1016/0031-9422\(95\)00068-1](https://doi.org/10.1016/0031-9422(95)00068-1)
- Pizzocaro F, Torreggiani D, Gilardi G (1993). Inhibition of apple Polyphenol oxidase (PPO) by ascorbic acid, citric acid and sodium chloride. Journal of Food Processing and Preservation 17:21-30. <https://doi.org/10.1111/j.1745-4549.1993.tb00223.x>
- Queiroz C, Lopes MME, Fialho E, Valente-Mesquita VL (2008). Polyphenol oxidase: characteristics and mechanisms of browning control. Food Review International 24:361-375. <https://doi.org/10.1080/87559120802089332>
- Rabea E, Badawy MEI, Stevens C, Smagghe G, Steurbaut W (2003). Chitosan as antimicrobial agent: Applications and mode of action. Biomacromolecules 4(6):1457-1465. <https://doi.org/10.1021/bm034130m>
- Rageh MA (2018). Maintaining postharvest quality of fresh button mushrooms by application of hydrogen peroxide and anti-browning agent treatments. Annals of Agricultural Science, Moshtohor 56(3):721-730. <https://doi.org/10.21608/asjm.2018.50329>
- Rojas-Grau MA, Soliva-Fortuny R, Martin-Belloso O (2009). Edible coatings to incorporate active ingredients to fresh-cut fruits: a review. Trends in Food Science & Technology 20:438e447. <https://doi.org/10.1016/j.tifs.2009.05.002>
- Ruangchakpet A, Sajjaanantakul T (2007). Effect of browning on total phenolic, flavonoid content and antioxidant activity in Indian gooseberry (*Phyllanthus emblica* Linn.). Agriculture and Natural Resources 41(5):331-337.
- Saba MK, Sogvar OB (2016). Combination of carboxymethyl cellulose-based coatings with calcium and ascorbic acid impacts in browning and quality of fresh-cut apples. LWT Food Science and Technology 66:165-171. <https://doi.org/10.1016/j.lwt.2015.10.022>
- Sangsuwan J, Rattanapanone N, Rachtanapun P (2008). Effect of chitosan/methyl cellulose films on microbial and quality characteristics of fresh-cut cantaloupe and pineapple. Postharvest Biology and Technology 49: 403-410. <https://doi.org/10.1016/j.postharvbio.2008.02.014>
- Shelef LA (1994). Antimicrobial effects of lactates: a review. Journal of Food Protection 57:445-450. <https://doi.org/10.4315/0362-028X-57.5.445>
- Shiri MA, Bakhshi D, Ghasemnezhad M, Dadi M, Papachatzism A, Kalorizou H (2013). Chitosan coating improves the shelf life and postharvest quality of table grape (*Vitis vinifera*) cultivar Shahroudi. Turkish Journal of Agriculture and Forestry 37:148-156. <https://doi.org/10.3906/tar-1101-1671>
- Singh N, Devina V, Vigya M, Thakur KS (2016). Shelf life and storage quality of white button mushrooms (*Agaricus bisporus*) as affected by packaging material. International Journal of Advanced Research 4(11):1790-1799. <https://doi.org/10.21474/IJAR01/2275>
- Singleton VL, Rossi JA (1965). Colorimetry of total phenolics with phosphomolybdic phosphotungstic acid reagents. American Journal of Enology and Viticulture 16:144-158. <https://doi.org/10.5344/ajev.1965.16.3.144>
- Snedecor GW, Cochran WG (1982). Statistical Methods. 7th Ed. Iowa State Univ.Press. Ames. Iowa USA.
- Srivastava S, Bala KL (2016). Effect of arabic gum-carboxymethylcellulose edible coatings on shelf life of button mushroom (*Agaricus bisporus*). International Journal of Research Engineering and Technology 5(6):484-494.
- Van Der Lubben IM, Verhoef JC, Borchard G, Junginger HE (2001). Chitosan and its derivatives in mucosal drug and vaccine delivery. European Journal of Pharmaceutical Sciences 14:201-207. [https://doi.org/10.1016/s0928-0987\(01\)00172-5](https://doi.org/10.1016/s0928-0987(01)00172-5)
- Vasey C (2006). The water prescription: For health, vitality, and rejuvenation. Simon and Schuster.
- Wani BA, Bodha RH, Wani AH (2010). Nutritional and medicinal importance of mushrooms. Journal of Medicinal Plants Research 4(24):2598-2604. <https://doi.org/10.5897/JMPR09.565>
- Weaver RA, Shelef LA (1993). Antisterial activity of sodium, potassium or calcium lactates in pork liver sausage. Journal of Food Safety 13:133-146. <https://doi.org/10.1111/j.1745-4565.1993.tb00101.x>

Zhang Y, Lu J, Wang X, Lin Q, Liu W, Xie X, Wang Z, Guan W (2016). Effects of UV-C irradiation on the physiological and antioxidant responses of button mushrooms (*Agaricus bisporus*) during storage. International Journal of Food Science & Technology 6:1502-1508. <https://doi.org/10.1111/ijfs.13100>

Zhelyazkov S, Zsivanovits G, Brashlyanova B, Marudova- Zsivanovits M (2012). Shelf-life extension of fresh-cut apple cubes with chitosan coating. Bulgarian Journal of Agricultural Science 20(3):536-540



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