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Effect of Some Polysaccharide-Based Edible Coatings on Fresh White Button Mushroom (*Agaricus bisporus*) Quality during Cold Storage

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Abstract: This study investigated the effects of pectin, chitosan, sodium alginate, and carboxymethyl cellulose-based edible coatings, individually and/or in combination with *N*-acetyl cysteine as an antibrowning agent, on some physical, chemical, and antioxidant properties of white button mushrooms. The weight loss, color change, browning index, degree of cap opening, soluble solid content, total phenolic content, antioxidant activity and malondialdehyde content of control and coated mushrooms were evaluated during 14 days of storage at 4 ± 1°C. All coatings, both alone and with N-acetyl-cisteine, delayed weight loss and cap opening in mushrooms compared with the control. Sodium alginate was the most effective in controlling weight loss, followed by carboxymetyhyl cellulose, chitosan and pectin. The browning process and lipid peroxidation were best controlled by sodium alginate followed by pectin coatings, while chitosan coating determined a significant increase in the browning index. Coated samples showed significantly higher total phenolic content and antioxidant activity as compared with the control throughout storage. The treatment with *N*-acetyl cysteine was not effective for mushrooms as it resulted in a significant increase in the browning index in all coated samples. The results suggest that sodium alginate and pectin coatings could be recommended for extending the shelf life of white button mushrooms.

Keywords: white button mushroom; pectin; chitosan; sodium alginate; carboxymethyl cellulose; *N*-acetyl cysteine; refrigerated storage; quality

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1. Introduction

Fresh and preserved mushrooms have been valued by humans from ancient times due to their organoleptic, nutritional and medicinal properties [1]. The consumer demand for mushrooms, as well as their production, has increased significantly in the last few years [2]. White button mushroom is the most widely grown and consumed edible mushroom in the world due to its delicious taste and nutritional value [3]. Although they have a low caloric value, button mushrooms are a good source of high-quality protein, amino acids, dietary fiber, vitamins (vitamin B2, folates and niacin), as well as many healthy minerals (iron, calcium, phosphorous, potassium, selenium, zinc, and copper) and phenolic compounds [4]. Button mushrooms also contain a wide range of therapeutic compounds such as triterpenoids, glycoproteins, natural antibiotics, enzymes, enzyme inhibitors, and soluble and insoluble fibers, with multiple and potent health-enhancing properties. In addition, they contain biologically active phytochemicals responsible for the prevention and treatment of many diseases such as cancer, hyperlipidemia, allergies, cardiovascular and liver diseases, and immune issues [5,6]. However, the high moisture content (over 90%), fast metabolic activity, high respiration and transpiration rates, and lack of epidermal structure makes button mushrooms very perishable [7,8]. The increment of the bacterial and fungal

load, water loss, surface browning and texture softening are the main phenomena that occur during mushroom storage [9], leading to deterioration and the loss of their commercial value [10]. In addition, the reactive oxygen species (ROS) increase lipid peroxidation, as reflected by the increment in malondialdehyde (MDA) content, which damages the integrity of the cell membranes and accelerates senescence [9,11].

The short postharvest shelf-life of button mushrooms (about 3–4 days in ambient temperature without packaging) causes problems in distribution and sales, and limits their consumption [12,13]. To overcome these problems, the development and implementation of special preservation methods and special packaging are required.

Beside the control of storage temperature, many methods have been proposed to preserve the quality and to extend the shelf life of edible mushrooms, including washing treatments with anti-microbial and anti-browning solutions, the use of nanocomposite films and edible coatings, modified atmosphere packaging, controlled atmosphere storage, irradiation, pulsed electric field and ultrasound [2,12]. Of these, the use of edible coatings on mushrooms has been of interest in recent years due to the advantages they present compared to other preservation methods, such as irradiation, which is less accepted by consumers, or modified atmosphere packaging, which is less economically convenient [14].

Edible coatings could enhance the postharvest appearance and preservation of mushrooms and maintain their phytochemical content and physicochemical properties for a longer period, thus preserving their nutritional and health benefits and increasing their shelf life. Edible coatings form a semi-permeable layer on the surface of the product, which provides additional protection, limits microbial contamination, controls moisture loss, suppresses respiration rate and ethylene production, delays senescence and, in addition, gives sheen and luster to coated products, thus making them more attractive to consumers [10,14]. Polysaccharides, including pectin, chitosan, cellulose derivatives, starch derivatives, alginate, agar, carrageenan, and gums, are some of the most used materials for the production of edible coatings, along with proteins and lipids. They have no adverse effects on human health, being safely eaten as part of the product, and are environmentally friendly, being biodegradable [15].

Chitosan is a biopolymer obtained by deacetylating chitin from crustacean exoskeletons, insect cuticles, and fungal mycelia [16]. Due to its antimicrobial properties, chitosan has been extensively explored as an edible coating for fruits and vegetables [17,18]. Jiang et al. [19] showed that a chitosan coating enriched with thyme oil maintained tissue firmness, inhibited the increase in respiration rate and reduced the microbial load of Shiitake mushroom, while Liu et al. [20] developed protocatechuic acid-grafted chitosan coatings for the postharvest storage of *Pleurotus eryngii* mushrooms. Sodium alginate is an eco-friendly polymeric material of the carbohydrate group, showing good barrier- and film-forming properties, extracted from brown algae. Alginate-based edible coatings have been shown to increase the shelf life of fresh and fresh-cut fruits and vegetables [21,22]. Jiang et al. [23] developed alginate/nano-Ag coatings for the postharvest storage of *Lentinus edodes*, while Louis et al. [24] found that the quality of button mushrooms was remarkably improved by alginate-based coatings incorporated with cinnamaldehyde nanoemulsions. Carboxymethyl cellulose (CMC) and pectin are polysaccharides with great potential in making odorless, tasteless, non-toxic, non-allergic, water-soluble and transparent edible coatings, which are able to inhibit microbial decay and enzymatic damage and prevent physical or textural deteriorations in fruits and vegetables during storage. In addition, they could be good carriers for active additives, such as antimicrobials, antioxidants and anti-browning agents [25]. Previous studies have reported that CMC coatings delay the postharvest ripening and softening of bananas and suppress their physiological weight loss [26], while edible coatings based on CMC and pectin extended the shelf life of fresh-cut fruits [27], but only a few studies have evaluated their effects on the evolution of button mushrooms' quality during storage [28].

Several studies have reported on *N*-acetyl cysteine as one of the most effective anti-browning agents for various fresh-cut fruits. Alginate and gellan coatings containing

N-acetyl cysteine have been successfully used to reduce browning in fresh-cut apples [29], while other studies have reported that the incorporation of *N*-acetyl cysteine into coating formulations was effective in preventing fresh-cut pears from browning [30,31].

The aim of this study was to investigate the effects of pectin, chitosan, sodium alginate, and carboxymethyl cellulose-based edible coatings, individually and/or in combination with *N*-acetyl cysteine as an antibrowning agent, on the quality of white button mushrooms during 14 days of refrigerated storage (4 ± 1°C) as measured by weight loss, color change, browning index, degree of cap opening, soluble solid content, total phenolic content, and DPPH antioxidant activity. Their effects on the MDA content, as an indicator of lipid peroxidation, were also evaluated.

2. Materials and Methods

2.1. Chemicals

Methanol, Folin-Ciocalteu reagent, gallic acid, thiobarbituric acid, 2,2-diphenyl-1-picrylhydrazyl (DPPH), sodium carbonate and sodium acetate were purchased from Sigma-Aldrich (Steinhein, Germany). Trichloracetic acid, 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox) and malondialdehyde were from Merck (Darmstadt, Germany).

2.2. Materials

White button mushrooms were purchased from a local supermarket. Mushrooms of a similar size, with a completely closed cap, without any browning symptoms and mechanical damage were selected for the experiments. The samples were transferred to the laboratory within 1 h and stored at 4°C and 85% relative humidity for 24 h until use in the experiments.

Sosa Fruit Pectin NH from Sosa Ingredients S.L (Moià, Spain), food-grade sodium alginate from BOS FOOD (Meerbusch, Germany), chitosan from BiOrigins (Fordingbridge, UK) and carboxymethyl cellulose Methocel K4 M from Dow Wolff Cellulosics Gmbh (Bomlitz, Germany) were the biopolymers used in the coating formulations. Glycerol (Merck, Whitehouse Station, NJ, USA) was added to the coatings as a plasticizer. Calcium chloride (Sigma-Aldrich, Steinhein, Germany) was used to induce crosslinkage between the polymer chains. *N*-acetyl-cysteine (N-AC) from Myprotein (Manchester, UK) was used as the antibrowning agent.

2.3. Preparation of Edible Coatings

Pectin coating (PE) was obtained as described by Moreira et al. [32] by dissolving 2% (*w/v*) pectin powder in distilled water at a temperature of 70 °C under stirring on a magnetic stirrer/hot plate. The sodium alginate coating (SA) was prepared by dissolving sodium alginate powder in distilled water at 2% (*w/v*) followed by heating at 70 °C while stirring until the solution became clear [21]. The chitosan coating (CH) solution (2%, *w/v*) was prepared by dissolving chitosan in 1% acetic acid aqueous solution according to Duan et al. [33]. The mixture was heated to boiling (about 100 °C) on a magnetic stirrer/hot plate until the solution became clear. Carboxymethyl cellulose (CMC) coating (1% *w/v*) was prepared by solubilizing CMC powder in distilled water at 70 °C under stirring for 30 min as described by Kumar et al. [34]. All coating solutions were finally agitated in an ultrasonic bath for 60 min to eliminate bubbles and then kept at room temperature until use for coating. Glycerol was added to all coatings as a plasticizer at 0.5% (*w/v*) after cooling to room temperature (~20 °C). An aqueous crosslinking solution of 1% calcium chloride was prepared. The antibrowning agent (N-AC, 1% *w/v*) was incorporated in the coating film-forming solution.

2.4. Treatments

The selected mushrooms were washed with water, wiped dry with blotting paper and randomly divided into nine batches, in order to carry out the treatments presented in Table 1. Control samples were dipped in distilled water, while the others were dipped

into the coating film-forming solutions. The dipping time was 2 min at room temperature for all treatments. The excess coating solution was allowed to drip off for 1 min before the 1% $CaCl_2$ crosslinking solution was applied using an atomizer bottle. Samples were then drained, air-dried for 1 hour at room temperature (20 °C) in a laminar flow hood, placed into perforated lid disposable plastic containers (750 mL capacity) and stored at 4 °C and 80–85% relative humidity for 14 days. Between six and ten mushroom pieces, weighing approximately 150 g, were placed per container, avoiding overlapping. Six containers were prepared per treatment. The entire experiment was repeated three times.

Table 1. Treatment formulations and respective codes.

Treatment	Components
C	Distilled water (control)
TP0	2% PE + 1% $CaCl_2$
TP1	2% PE + 1% $CaCl_2$ + 1% N-AC
TC0	2% CH + 1% $CaCl_2$
TC1	2% CH + 1% $CaCl_2$ + 1% N-AC
TA0	2% SA + 1% $CaCl_2$
TA1	2% SA + 1% $CaCl_2$ + 1% N-AC
TM0	2% CMC + 1% $CaCl_2$
TM1	2% CMC + 1% $CaCl_2$ + 1% N-AC

Weight loss, color, browning index, open-cap percentage, total soluble solids, total phenolic content, DPPH antioxidant activity and MDA content were evaluated on days 1, 7, and 14 during storage. The experiment was repeated three times and each determination was run in triplicate within each experiment.

2.5. Weight Loss

The weight loss of the mushrooms was determined using a digital balance (Sartorius CP124S, UK, accuracy = 0.01 g). The mushrooms were weighed after packaging (time 0, initial weight) and then on days 1, 7 and 14 of storage. Weight loss was reported as the percentage loss of the mushrooms' initial weight and calculated using the following equation [14]:

$$\text{Weight loss (\%)} = (\text{Initial weight} - \text{weight after the specific storage period})/\text{initial weight} \times 100 \quad (1)$$

2.6. Color and Browning Index (BI)

The surface color of the mushroom caps was measured at 1, 7, and 14 days of storage using a digital portable reflectance colorimeter model PCE-CSM1 (PCE Instruments, Southampton, UK) calibrated against a white standard. Color was expressed as L* (lightness), a* (redness), and b* (yellowness) reflectance values of the CIEL*a*b* color system. The analysis was performed on three randomly selected samples from each treatment with three readings on each sample.

The browning index (BI) was used as an indicator of brown color intensity, and was calculated as described by Cavusoglu et al. [15]:

$$BI = 100\,(x - 0.31)/0.17 \quad (2)$$

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

2.7. Percentage of Open Caps

One of the determinants of senescence and loss of white button mushroom quality is the opening of caps [12]. The percentage of open caps during the storage period was

evaluated visually based on the formation of an umbrella-like shape in mushrooms caps and veil detachment [8], and calculated as:

$$\% \text{ Open caps} = (\text{N0}/\text{Nt}) \times 100 \quad (4)$$

where N0 is the number of open-capped mushrooms and Nt is the total number of mushrooms in the same package.

2.8. Total Soluble Solids (TSS)

Mushrooms were crushed in a mortar and squeezed with a handpress as described by Nasiri et al. [10]. The content of total soluble solids was determined in the juice using a digital refractometer (Hanna Instruments, Woonsocket, RI, USA) and the results are expressed in %. Three replications were performed for each treatment.

2.9. Total Phenolic Content

Mushroom samples (1.5 g) were homogenized in 10 mL methanol, then extraction was carried out in a Bandelin Sonorex Digital 10P ultrasonic bath (Bandelin Electronic GmbH, Berlin, Germany) for 60 min at ambient temperature. After extraction, the samples were centrifuged at 6000 rpm for 5 min. Supernatants were collected and stored at 4 °C until analysis.

The total phenolic content in the mushroom extracts was measured according to the Folin–Ciocalteu procedure as described by Singleton et al. [35]. Briefly, aliquots of extracts (0.1 mL) were mixed with 5 mL of distilled water and 0.5 mL of Folin–Ciocalteu reagent. After 3 min, 1.5 mL of sodium carbonate (20% *w/v*) was added and the mixture was made up to 10 mL with distilled water. The vials were shaken and kept in the dark at 40 °C for 30 min, then the absorbance was measured at 765 nm using a Varian Cary 50 UV spectrophotometer (Varian Co., USA). Total phenolic content was expressed as milligrams of gallic acid equivalents (GAE) per 100 g of fresh weight. Three replicates were carried out for each sample.

2.10. DPPH Free Radical-Scavenging Activity

The free radical-scavenging effect of the mushroom extracts on 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical was measured according to the procedure described by Oliveira et al. [36]. Firstly, 3 mL of 0.004% DPPH methanolic solution was added to 50 µL of mushroom extract. After shaking and incubation in darkness for 30 min, the absorbance of the reaction mixture was read at 517 nm using a Varian Cary 50 UV spectrophotometer (Varian Co., Palo Alto, CA, USA) against a blank of methanol without the DPPH reagent. The inhibition of the DPPH radical by the sample extract was calculated according to the following formula:

$$\text{DPPH scavenging activity } (\%) = [1 - \text{absorbance of sample}/\text{absorbance of blank}] \times 100 \quad (5)$$

Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) was used as a standard reference, and the results are expressed as milimoles Trolox equivalent (TE) per 100 g of fresh weight. Three replicates were carried out for each sample.

2.11. Measurement of Lipid Peroxidation (MDA content)

The degree of lipid peroxidation was determined as MDA content, as described by Pogorzelska-Nowicka et al. [8]. The mushroom cup tissue (1 g) was homogenized and extracted in 10 mL of 0.5% 2-thiobarbituric acid (TBA) made in 10% trichloroacetic acid (TCA). The mixture was vortexed for 15 min and then centrifuged at 6000 rpm for 10 min. The collected supernatant was incubated in a water bath at 100 °C for 20 min and then cooled in an ice bath. The absorbance of the supernatant was measured at 450, 532, and

600 nm against blank using a Varian Cary 50 UV spectrophotometer (Varian Co., Palo Alto, CA, USA). The MDA content was calculated using the following formula:

$$\text{MDA content} = 6.45 \times (A_{532} - A_{600}) - 0.56 \times A_{450} \quad (6)$$

The results are expressed as μmol of MDA equivalent per gram of fresh weight. Three replicates were carried out for each sample.

2.12. Statistical Analysis

The results are reported as means ± standard deviations. Statistical analyses of the influence of different coating formulations and storage times on the mushrooms' quality were performed by two-way analysis of variance using Statgraphics Centurion XVI software (StatPoint Technologies, Warrenton, VA, USA). Multiple comparisons among means with significant differences tested in ANOVA were conducted using the least significant difference (LSD) test and differences were considered significant at $p < 0.05$.

3. Results and Discussion

3.1. Weight Loss

The weight loss of mushrooms during storage is mainly determined by the moisture evaporation and respiration rate through the mushroom's surface. Mushrooms have a very high transpiration rate as their thin epidermal layer has an extremely low effectiveness in preventing the rapid loss of water and protecting their epidermal structure [14]. Weight loss has a decisive influence on the quality and freshness of mushrooms, as high levels of weight loss (more than 4–6%) are related to visible signs of wilting or shrinkage [9,15]. Some previous studies have reported reductions in mushroom weight loss by using various edible coatings on mushrooms based on sodium alginate [37], chitosan, guar gum [38], aloe vera gel [11], egg white protein [13], and lecithin [15].

Weight loss was significantly ($p < 0.05$) increased in all samples during the 14 days of storage (Table 2) as a result of the senescence of the product and the loss of moisture content of mushrooms over time. Due to their hydrophilic nature, polysaccharide-based coatings exhibit limited water vapor barrier properties. However, weight loss was significantly ($p < 0.05$) higher in the control samples than in the edible coating-treated samples. All edible coatings, both alone and with N-acetyl cisteine, retarded the weight loss in mushrooms compared with the control, which is mainly attributed to the action of the protective layer formed by the edible coating that has hygroscopic properties and acts as a barrier to water diffusion between the mushroom and the environment [14].

Table 2. Effects of treatments on the weight loss (%) of button mushrooms during storage for 14 days at 4 ± 1 °C. Data are presented as means ± SD.[1]

Treatments	Storage Period (Days)		
	1	**7**	**14**
C	3.89 ± 0.21^{fA}	19.94 ± 0.11^{gB}	34.13 ± 0.18^{fC}
TP0	2.76 ± 0.13^{dA}	13.60 ± 0.08^{dB}	32.71 ± 0.95^{eC}
TP1	2.43 ± 0.09^{bcA}	12.92 ± 0.38^{cB}	29.73 ± 0.98^{dC}
TC0	3.27 ± 0.19^{eA}	14.85 ± 0.66^{fB}	29.61 ± 1.26^{dC}
TC1	2.28 ± 0.14^{bA}	16.40 ± 0.67^{eB}	31.15 ± 1.48^{deC}
TA0	1.97 ± 0.06^{aA}	10.82 ± 0.39^{aB}	22.37 ± 1.06^{aC}
TA1	2.54 ± 0.12^{cdA}	11.74 ± 0.46^{bB}	25.04 ± 1.32^{bC}
TM0	2.47 ± 0.08^{bcA}	14.24 ± 0.57^{deB}	27.89 ± 1.21^{cC}
TM1	2.27 ± 0.10^{bA}	14.09 ± 0.45^{deB}	28.73 ± 0.96^{cC}

[1] Different lowercase letters indicate significant differences between treatments ($p < 0.05$) for the same storage period, while different uppercase letters are indicative of significant differences between sampling times for the same treatment ($p < 0.05$). C—distilled water (control); TP0—2% PE + 1% $CaCl_2$; TP1—2% PE + 1% $CaCl_2$ + 1% N-AC; TC0—2% CH + 1% $CaCl_2$; TC1—2% CH + 1% $CaCl_2$ + 1% N-AC; TA0—2% SA + 1% $CaCl_2$; TA1—2% SA + 1% $CaCl_2$ + 1% N-AC; TM0—2% CMC + 1% $CaCl_2$; TM1—2% CMC + 1% $CaCl_2$ + 1% N-AC.

At the end of the storage period, the highest level of weight loss was observed in control samples (34.13%) and the lowest level was observed in sodium alginate-coated samples (22.37%). Mohebbi et al. [14] reported 30%, 32%, and 35% weight loss at 4 °C after 13 days of storage in tragacanth gum, aloe vera gum tragacanth and aloe vera coating, respectively, as well as 47% weight loss in the control mushrooms at this temperature.

Sedaghat and Zahedi [28] reported means of weight loss of 44.13%, 33.59% and 33.12% in uncoated, gum Arabic- and carboxymethyl cellulose-coated mushrooms after 10 days of storage at 7 °C. However, lower weight loss values have been reported by Zhu et al. [37] in control and sodium alginate-coated *Pholiota nameko* mushrooms (7.73% and 6%, respectively) after 9 days storage at 20 °C, and by Huang et al. [38] in chitosan- and guar gum-coated mushrooms. These differences could be attributed to the storage conditions and packaging systems. The comparison of the mean values showed that there were significant ($p < 0.05$) differences among the four types of coatings. The most effective in controlling weight loss was sodium alginate, followed by carboxymetyhyl cellulose, chitosan and pectin. These findings are consistent with previous studies reporting on the water vapor permeability of polysaccharide-based films. Galus and Lenart [39], in a study on the physical properties of composite edible films based on sodium alginate and pectin, found that films with a higher content of alginate showed significantly lower water vapor permeability values compared to pectin-containing films. The films made of 100% alginate had the lowest water vapor permeability, and those made of pectin had the highest water vapor permeability. Tong et al. [40] found that sodium alginate films had lower water vapor permeability than CMC films, while Chambi and Grosso [41] found that the films produced from pectin had slightly lower water vapor permeability than those form methyl cellulose. Due to the strongly hydrophilic character of chitosan, its barrier properties against water vapor are limited. Kim et al. [42] reported that chitosan coating did not significantly ($p > 0.05$) reduce the weight loss of sliced mushrooms packed in polyolefine film. However, other studies reported on the positive effects of chitosan coatings in controlling weight loss in mushrooms [12] or pistachio [43].

3.2. Color and Browning Index

At harvest, the mushrooms are white, but during storage the browning of the surface develops as a result of the enzymatic oxidation of phenolic substrates, caused by the release of polyphenol oxidases (PPO) (mainly by the activation of tyrosinase, which is the main PPO enzyme responsible for browning in mushrooms), or by spontaneous oxidation and the Maillard reaction [44]. The color of button mushrooms is the most important determinant of their shelf life, as it is the most indicative of mushroom quality and freshness [15].

The changes in L*, a* and b* values and browning index (BI) of control and coated mushrooms stored for 14 days at 4 °C are shown in Table 3.

Table 3. Effect of treatments on color (L*, a* and b* values) and browning index (BI) of button mushrooms during storage for 14 days at 4 ± 1 °C. Data are presented as means ± SD.[1]

Color Parameter	Treatments	Storage Period (Days)		
		1	7	14
L*	C	92.91 ± 0.49 ^{cdB}	88.68 ± 0.50 ^{deA}	87.30 ± 2.12 ^{dA}
	TP0	91.53 ± 1.24 ^{cdB}	90.67 ± 1.17 ^{efAB}	89.38 ± 1.82 ^{dA}
	TP1	91.17 ± 2.11 ^{cB}	84.33 ± 2.97 ^{cA}	82.38 ± 2.85 ^{cA}
	TC0	73.43 ± 2.40 ^{aB}	71.76 ± 2.76 ^{bAB}	69.08 ± 1.10 ^{aA}
	TC1	80.28 ± 1.92 ^{bB}	68.98 ± 3.35 ^{aA}	66.39 ± 2.93 ^{aA}
	TA0	92.11 ± 1.95 ^{cdC}	89.98 ± 1.04 ^{defB}	87.06 ± 0.80 ^{dA}
	TA1	93.30 ± 1.47 ^{dC}	87.75 ± 1.56 ^{dB}	80.48 ± 1.31 ^{bA}
	TM0	91.77 ± 2.29 ^{cdB}	90.64 ± 1.01 ^{efAB}	89.24 ± 2.15 ^{dA}
	TM1	93.52 ± 1.23 ^{dB}	91.45 ± 1.98 ^{fB}	87.43 ± 3.57 ^{dA}

Table 3. *Cont.*

Color Parameter	Treatments	Storage Period (Days)		
		1	7	14
a*	C	0.83 ± 0.11 bcA	2.47 ± 0.23 bB	2.91 ± 0.32 aC
	TP0	2.12 ± 0.33 efA	1.84 ± 0.46 aA	2.67 ± 0.45 aB
	TP1	1.39 ± 0.10 dA	2.83 ± 0.28 bcB	5.80 ± 0.35 cC
	TC0	8.49 ± 0.45 gA	8.70 ± 0.41 dA	10.55 ± 0.38 dB
	TC1	5.58 ± 0.38 f	9.83 ± 0.51 e	11.34 ± 0.49 e
	TA0	1.17 ± 0.88 cdA	1.72 ± 0.63 aA	2.96 ± 0.35 aB
	TA1	0.51 ± 0.05 abA	3.06 ± 0.54 cB	6.04 ± 0.50 cC
	TM0	1.45 ± 0.12 dA	1.58 ± 0.16 aA	2.73 ± 0.36 aB
	TM1	0.22 ± 0.04 aA	2.61 ± 0.28 bcB	3.53 ± 0.21 bC
b*	C	12.57 ± 0.66 aA	15.72 ± 3.51 bB	16.96 ± 1.02 aB
	TP0	15.45 ± 0.61 cA	15.22 ± 0.76 bA	16.90 ± 0.36 aB
	TP1	15.62 ± 0.84 cA	21.11 ± 0.35 dB	27.06 ± 1.24 cC
	TC0	19.10 ± 0.62 dA	24.28 ± 0.88 eB	28.81 ± 1.05 cC
	TC1	18.56 ± 0.53 dA	26.28 ± 0.95 eB	31.10 ± 0.77 dC
	TA0	12.25 ± 0.63 aA	13.12 ± 0.52 aB	15.97 ± 0.85 aC
	TA1	14.15 ± 0.62 bA	18.64 ± 1.35 cB	19.84 ± 1.33 bB
	TM0	13.15 ± 1.71 abA	14.79 ± 0.84 abA	17.83 ± 1.99 abB
	TM1	14.11 ± 1.80bA	16.18 ± 0.53 bB	19.09 ± 0.52 bC
BI	C	14.65 ± 0.76 aA	20.98 ± 2.87 cB	23.31 ± 1.62 aB
	TP0	19.53 ± 0.54 bA	19.22 ± 1.26 bcA	22.44 ± 1.18 aB
	TP1	19.24 ± 1.21 bA	30.32 ± 1.23 eB	43.75 ± 2.93 dC
	TC0	37.65 ± 1.67 dA	48.96 ± 2.17 fB	63.35 ± 3.37 eC
	TC1	30.52 ± 1.46 cA	56.93 ± 2.35 gB	73.49 ± 5.37 fC
	TA0	14.67 ± 1.48 aA	16.58 ± 0.49 aB	22.05 ± 1.05 aC
	TA1	16.24 ± 0.83 aA	25.73 ± 1.52 dB	34.32 ± 1.47 cC
	TM0	16.06 ± 2.66 aA	18.42 ± 1.07 abB	24.03 ± 0.58 abC
	TM1	15.92 ± 2.31 aA	20.89 ± 0.99 bcB	26.80 ± 1.54 bC

[1] Different lowercase letters indicate significant differences between treatments ($p < 0.05$) for the same storage period, while different uppercase letters are indicative of significant differences between sampling times for the same treatment ($p < 0.05$). C—distilled water (control); TP0—2% PE + 1% $CaCl_2$; TP1—2% PE + 1% $CaCl_2$ + 1% N-AC; TC0—2% CH + 1% $CaCl_2$; TC1—2% CH + 1% $CaCl_2$ + 1% N-AC; TA0—2% SA + 1% $CaCl_2$; TA1—2% SA + 1% $CaCl_2$ + 1% N-AC; TM0—2% CMC + 1% $CaCl_2$; TM1—2% CMC + 1% $CaCl_2$ + 1% N-AC.

The treatment with edible coatings without antibrowning agent did not lead to significant ($p < 0.05$) variations in the L* value, except for chitosan coating, which led to a significant decrease in the L* value and an initial uniform brown appearance of the mushrooms (Table 3). The addition of *N*-acetyl cysteine in the coating formula resulted in higher values of L* after 1 day of storage, compared to the samples with the same coating without an antibrowning agent. However, the differences were significant ($p < 0.05$) only in the case of chitosan. As expected, the L* values decreased in all samples during the storage period. However, after 14 days of storage, no significant differences were found between the L* values of the control (87.30) and of the samples coated with pectin (89.38), carboxymethyl cellulose (89.24) and alginate (87.06) alone (without N-AC), while the lowest L* values were found in samples coated with chitosan (69.08). In addition, the samples with coatings incorporating N-AC presented lower L* values compared to the corresponding samples without antibrowning agent. Button mushrooms may not be classified as acceptable if their L* value is lower than 80 [3], while according to Taghizadeh et al. [45], mushrooms with an L* less than 69 would not be acceptable even at retail levels. The chitosan-coated samples were the only ones that fell below the acceptability threshold of 80 for L* values, while the samples coated with chitosan incorporating N-AC showed L* values even below the 69 threshold.

After one day, coating with pectin or CMC caused a significant increase in the a* values, while the alginate coating did not determine a significant variation in the a* values.

Sedaghat and Zahedi [28] also reported an increase in the redness (a*) of CMC-coated mushrooms during storage at 7 °C. By far the largest increase in a* values occurred in chitosan-coated samples. In all treatments, the incorporation of 1% N-AC in the coating mixture determined a significant decrease in a* values compared to the corresponding samples without antibrowning agent.

During storage, there was an increase in a* values in all samples. At the end of the storage period, no significant differences were found between the a* values of the controls and those of the samples coated with pectin, CMC and alginate alone (without N-AC), while the highest a* values were found in samples coated with chitosan. Moreover, the samples with coatings incorporating N-AC presented significantly higher ($p < 0.05$) a* values compared to the corresponding samples without antibrowning agent. One day after treatments, the coatings with alginate and CMC did not show significant variations in their b* values, but a significant increase in the b* values was found in samples with pectin and chitosan coatings. Nakilcioğlu-Taş and Ötleş [46] also found that the chitosan coating led to a lower lightness and denser red and yellow color in the mushroom samples than the control one. These changes have been attributed to the spongy texture of the button mushroom and to the acceleration of the enzymatic activity by the chitosan solution, which increases the browning index and decreases the lightness during the storage time [12].

The browning index (BI) gradually increased during storage in both control and edible coating-treated samples (Table 3). At the end of the 14-day storage period, the lowest BI values were found for sodium alginate-coated (22.05) and pectin-coated (22.44) samples. The slowing down of the browning process by applying some surface coatings could be explained by the reduction in the enzymatic browning activities as a result of the suppression of oxygen absorption [47]. The level of oxygen produced by suppressing the enzymatic browning reaction is considered the main determinant of the color of fresh mushrooms [14]. Nevertheless, the highest BI values were found for chitosan-treated samples, after both 7 and 14 days of storage. Gholami et al. [12] reported also that chitosan coating resulted in a severe reduction in the L* and an increase in the BI of button mushrooms, and found that, at the end of the storage time, the lowest level of L* and the highest level of BI were observed in the chitosan-coated samples. However, Pen and Jiang [48] reported that chitosan coating delayed discoloration and browning in fresh-cut Chinese water chestnut.

Several previous studies reported that the addition of *N*-acetyl cysteine to different coatings may reduce browning in fresh-cut fruits [30,31,49]. Zhu et al. [37] reported that the composite coating prepared by adding 1% thyme essential oil, 0.3 g/L L-cysteine and 0.4 g/L nisin to the sodium alginate coating exhibited the best effectiveness in controlling the browning process, and attributed this action to the L-cysteine added into the coating material as an antibrowning substance. L-cysteine at a 0.5% concentration also alleviated the internal browning in plum fruit by enhancing the antioxidant capacity and inhibiting the polyphenol oxidase activities [50]. However, in the present study, the addition of *N*-acetyl cysteine into the edible coatings used for mushrooms resulted in a significant ($p < 0.05$) increase in the BI in all the edible coating-treated samples compared to the samples without antibrowning agent.

3.3. Percentage of Open Caps

The opening of caps is an indicator of senescence and a decrease in mushroom quality, which directly impinge on mushrooms' marketability [12]. The percentage of open caps increased in all samples during the storage period; the highest level of cap opening was found in uncoated samples (62.67% after 14 days storage) (Table 4).

The results showed that, similar to the weight loss, the lowest prevalence of cap opening was observed in sodium alginate-coated mushrooms (15.79% and 18.75% in TA0 and TA1, respectively). Similar values of cap opening percentage were reported by Zhu et al. [37] in *P. nameko* mushrooms coated with 1% sodium alginate after 9 days storage. Jiang [51] also reported that alginate coating (2%) + 100% O2 delayed cap opening in button mushrooms (*Agaricus bisporus*). Nasiri et al. [47] found that the percentage of opened caps

in mushrooms coated with Tragacanth gum was 57.8%, while control samples had more opened caps (82.2%) over a 12-day storage period.

Table 4. Effect of treatments on cap-opening percentage (%) of button mushrooms during storage for 14 days at 4 ± 1 °C. Data are presented as means ± SD.[1]

Treatments	Storage Period (Days)	
	7	14
C	29.41 ± 1.22 [h]	62.67 ± 2.88 [h]
TP0	16.67 ± 0.69 [de]	37.50 ± 1.45 [f]
TP1	17.65 ± 0.83 [ef]	46.67 ± 1.89 [g]
TC0	11.50 ± 0.56 [b]	22.22 ± 0.87 [c]
TC1	15.38 ± 0.87 [d]	27.27 ± 1.09 [d]
TA0	9.52 ± 0.36 [a]	15.79 ± 0.66 [a]
TA1	13.68 ± 0.58 [c]	18.75 ± 0.76 [b]
TM0	18.87 ± 0.88 [fg]	31.25 ± 1.25 [e]
TM1	19.18 ± 0.82 [g]	35.00 ± 1.18 [f]

[1] Different lowercase letters indicate significant differences between treatments ($p < 0.05$) for the same storage period, while different uppercase letters are indicative of significant differences between sampling times for the same treatment ($p < 0.05$). C—distilled water (control); TP0—2% PE + 1% $CaCl_2$; TP1—2% PE + 1% $CaCl_2$ + 1% N-AC; TC0—2% CH + 1% $CaCl_2$; TC1—2% CH + 1% $CaCl_2$ + 1% N-AC; TA0—2% SA + 1% $CaCl_2$; TA1—2% SA + 1% $CaCl_2$ + 1% N-AC; TM0—2% CMC + 1% $CaCl_2$; TM1—2% CMC + 1% $CaCl_2$ + 1% N-AC.

Cap opening is related to the decrease in moisture content of mushrooms during storage [37], because water loss induces a decrease in the cohesive forces of proteins, which are responsible for the intact position of the caps and veil in mushrooms [52]. In turn, mushroom cap opening leads to water loss increment [10]. Another influencing factor is the oxygen level, i.e., low oxygen levels have a positive effect on reducing cap opening and preventing the senescence of the product [12]. As a result, the cap opening will be influenced not only by the water vapor permeability of the coating, but also by its gas permeability. Chitosan coating led to lower values of mushroom cap opening, even if the moisture loss in samples coated with chitosan was higher. This could be due to the selective gas permeability of chitosan films, which have a higher permeability to CO_2 and a lower permeability to O_2 [53]. The addition of *N*-acetyl cysteine caused a significant increase in mushroom cap opening for all the tested coatings.

3.4. Total Soluble Solids (TSS)

TSS showed an upward trend during the storage time (Table 5) in all samples, but significant ($p < 0.05$) differences were found between treatments at the end of the storage period. The increases in the soluble polysaccharides content are indicative of mushroom over-ripening [8]. A similar gradual enhancement of TSS in mushrooms during storage has been previously reported [10], while, on the contrary, Zhu et al. [37] observed an apparent decreasing tendency in the soluble sugar content of uncoated and sodium alginate-coated mushrooms during storage. In the first day of storage, there were minimal differences between the coated samples and the controls. However, coated samples showed significantly lower ($p < 0.05$) levels of TSS as compared with the controls after both 7 and 14 days of storage. These findings are supported by the fact that edible coating provides a protective layer for the product, thus reducing the moisture losses and stabilizing the soluble solids [12]. In addition, an edible coating, due to its semi-permeable nature, adjusts the internal atmosphere by decreasing O_2 and/or enhancing CO_2, and suppresses the ethylene production, thus decelerating respiration and metabolic activities and retarding the polysaccharide and hemicellulose hydrolysis process of soluble sugars in the cell wall [10,19,37]. The lowest level of TSS change was observed in sodium alginate-coated samples followed by pectin and chitosan-coated samples. Gholami et al. [12] also reported on the effectiveness of a chitosan coating in slowing down TSS increment in mushrooms during storage.

Table 5. Effect of treatments on total soluble solids (%) of button mushrooms during storage for 14 days at 4 ± 1 °C. Data are presented as means ± SD.[1]

Treatments	Storage Period (Days)		
	1	7	14
C	4.68 ± 0.18 ^{aA}	9.88 ± 0.44 ^{dB}	14.68 ± 0.56 ^{fC}
TP0	5.04 ± 0.29 ^{bA}	7.70 ± 0.37 ^{bB}	10.24 ± 0.59 ^{bC}
TP1	5.22 ± 0.27 ^{bA}	8.28 ± 0.41 ^{cB}	10.96 ± 0.36 ^{bcC}
TC0	5.14 ± 0.23 ^{bA}	7.72 ± 0.83 ^{bB}	12.12 ± 0.48 ^{dC}
TC1	5.04 ± 0.24 ^{bA}	7.66 ± 0.42 ^{bB}	11.46 ± 0.42 ^{cdC}
TA0	5.28 ± 0.22 ^{bA}	6.44 ± 0.35 ^{aB}	8.46 ± 0.36 ^{aC}
TA1	5.08 ± 0.31 ^{bA}	6.66 ± 0.22 ^{aB}	7.74 ± 0.13 ^{aC}
TM0	5.12 ± 0.16 ^{bA}	7.44 ± 0.22 ^{bB}	11.98 ± 1.24 ^{dC}
TM1	5.20 ± 0.20 ^{bA}	7.74 ± 0.23 ^{bcB}	13.20 ± 0.45 ^{eC}

[1] Different lowercase letters indicate significant differences between treatments ($p < 0.05$) for the same storage period, while different uppercase letters are indicative of significant differences between sampling times for the same treatment ($p < 0.05$). C—distilled water (control); TP0—2% PE + 1% $CaCl_2$; TP1—2% PE + 1% $CaCl_2$ + 1% N-AC; TC0—2% CH + 1% $CaCl_2$; TC1—2% CH + 1% $CaCl_2$ + 1% N-AC; TA0—2% SA + 1% $CaCl_2$; TA1—2% SA + 1% $CaCl_2$ + 1% N-AC; TM0—2% CMC + 1% $CaCl_2$; TM1—2% CMC + 1% $CaCl_2$ + 1% N-AC.

3.5. Total Phenolic Content and DPPH Radical Scavenging Activity

The total phenolic contents in coated button mushrooms and controls during 14 days storage at 4 ± 1 °C are presented in Table 6. The initial total phenolic content in mushrooms was 45.28 mg GAE/100 g. The results show an upward trend regarding phenolic accumulation in mushrooms in all samples, probably caused by the activation of the phenylpropanoid metabolism resulting in the production of phenolic compounds by the mushroom tissues [54].

Table 6. Effects of treatments on the total phenolic content (mg GAE/100 g) of button mushrooms during storage for 14 days at 4 ± 1 °C. Data are presented as means ± SD.[1]

Treatments	Storage Period (Days)		
	1	7	14
C	46.67 ± 1.65 ^{aA}	54.00 ± 1.48 ^{aB}	65.33 ± 2.89 ^{aC}
TP0	46.85 ± 2.03 ^{aA}	67.67 ± 2.33 ^{dB}	83.33 ± 3.86 ^{eC}
TP1	47.00 ± 1.58 ^{aA}	82.33 ± 3.66 ^{eB}	99.33 ± 4.26 ^{fC}
TC0	45.88 ± 1.55 ^{aA}	57.23 ± 1.62 ^{bB}	77.33 ± 3.67 ^{cdC}
TC1	47.67 ± 2.08 ^{aA}	58.33 ± 2.44 ^{bB}	80.33 ± 3.46 ^{deC}
TA0	46.85 ± 1.28 ^{aA}	58.33 ± 1.88 ^{bB}	71.67 ± 2.56 ^{bC}
TA1	47.25 ± 1.72 ^{aA}	59.09 ± 2.76 ^{bB}	72.22 ± 2.96 ^{bcC}
TM0	47.06 ± 1.02 ^{aA}	63.42 ± 2.34 ^{cB}	72.67 ± 2.85 ^{bcC}
TM1	47.67 ± 0.89 ^{aA}	63.33 ± 1.78 ^{cB}	72.88 ± 2.56 ^{bcC}

[1] Different lowercase letters indicate significant differences between treatments ($p < 0.05$) for the same storage period, while different uppercase letters are indicative of significant differences between sampling times for the same treatment ($p < 0.05$). C—distilled water (control); TP0—2% PE + 1% $CaCl_2$; TP1—2% PE + 1% $CaCl_2$ + 1% N-AC; TC0—2% CH + 1% $CaCl_2$; TC1—2% CH + 1% $CaCl_2$ + 1% N-AC; TA0—2% SA + 1% $CaCl_2$; TA1—2% SA + 1% $CaCl_2$ + 1% N-AC; TM0—2% CMC + 1% $CaCl_2$; TM1—2% CMC + 1% $CaCl_2$ + 1% N-AC.

After both 7 and 14 days storage, all coated samples showed significantly ($p < 0.05$) higher total phenolic contents compared to the control. This could be attributed to the self-defensive reaction of the mushroom against the external stress induced by the coating, resulting in the increment of the total phenolic content and consequently of the antioxidant activity [3]. The highest total phenolic content was found in samples coated with pectin, which was significantly ($p < 0.05$) higher than in the other coated samples. The chitosan-coated samples ranked second, followed by carboxymethyl cellulose- and alginate-coated samples, between which there were no significant differences concerning total phenolic content. The addition of N-AC into the coating formula augmented the total phenolic

contents of coated samples, but the increase was significant ($p < 0.05$) only in pectin-coated samples. N-AC is recognized as a protective agent against various oxidative stress sources [55]. Pleșoianu and Nour [31] and Oms-Oliu et al. [30] also found that a pectin coating incorporating 1% *N*-acetyl cysteine significantly increased the antioxidant activity of fresh-cut pears.

A continuous increase in the total phenolic content in control and egg white protein-coated mushrooms during 15 days cold storage was also reported by Şaran et al. [13]. Zhu et al. [37] also reported that total soluble phenols and flavonoids continuously accumulated in control and sodium-alginate *Pholiota nameko* mushrooms during storage.

Mushrooms treated with edible coatings showed significantly ($p < 0.05$) higher antioxidant activity than uncoated samples at the end of the storage period (Table 7).

Table 7. Effects of treatment on DPPH antioxidant activity (mmol Trolox/100 g) of button mushrooms during storage for 14 days at 4 ± 1 °C. Data are presented as means ± SD.[1]

Treatments	Storage Period (Days)		
	1	7	14
C	0.65 ± 0.02^{aA}	0.85 ± 0.03^{aB}	0.95 ± 0.03^{aC}
TP0	0.92 ± 0.03^{eA}	1.14 ± 0.04^{dB}	1.38 ± 0.06^{fC}
TP1	0.84 ± 0.04^{dA}	1.16 ± 0.05^{dB}	1.59 ± 0.06^{gC}
TC0	0.73 ± 0.03^{cA}	1.00 ± 0.04^{bB}	1.25 ± 0.06^{eC}
TC1	0.92 ± 0.04^{eA}	1.09 ± 0.06^{cdB}	1.23 ± 0.06^{deC}
TA0	0.67 ± 0.03^{abA}	1.00 ± 0.04^{bB}	1.14 ± 0.04^{bcC}
TA1	0.71 ± 0.03^{bcA}	1.04 ± 0.04^{bcB}	1.18 ± 0.04^{cdeC}
TM0	0.79 ± 0.03^{dA}	1.09 ± 0.04^{cdB}	1.16 ± 0.05^{bcdB}
TM1	0.83 ± 0.03^{dA}	1.06 ± 0.03^{bcB}	1.08 ± 0.04^{bB}

[1] Different lowercase letters indicate significant differences between treatments ($p < 0.05$) for the same storage period, while different uppercase letters are indicative of significant differences between sampling times for the same treatment ($p < 0.05$). C—distilled water (control); TP0—2% PE + 1% $CaCl_2$; TP1—2% PE + 1% $CaCl_2$ + 1% N-AC; TC0—2% CH + 1% $CaCl_2$; TC1—2% CH + 1% $CaCl_2$ + 1% N-AC; TA0—2% SA + 1% $CaCl_2$; TA1—2% SA + 1% $CaCl_2$ + 1% N-AC; TM0—2% CMC + 1% $CaCl_2$; TM1—2% CMC + 1% $CaCl_2$ + 1% N-AC.

On the 14th day of storage, mushrooms coated with pectin incorporatng 1% N-AC showed the highest antioxidant activity (1.59 mmol Trolox/100 g). A positive correlation was found between the total phenolic contents and antioxidant activities of mushrooms (r = 0.934), which is in good agreement with the results reported in earlier studies [11,13].

Phenolic compounds have been recognized as free radical-scavengers and the main substrate of enzymatic browning reactions [56]. Zhu et al. [37] reported that total phenolic content was significantly correlated with the degree of browning in control and alginate-coated button mushrooms (r = 0.861). However, only a weak positive correlation was found in our study between total phenolic content and browning index (r = 0.482, $p < 0.05$).

3.6. Malondialdehyde Content

Malondialdehyde (MDA) is one of the representative end products of lipid peroxides decomposition, and is a commonly used indicator of lipid peroxidation induced by the oxidative stress in foods and tissues [57]. In mushrooms, MDA is produced as a result of membrane lipid peroxidation, and it accumulates with the enhancement of membrane integrity injuries and senescence [11,58]. In turn, MDA damages the integrity of the cell membrane, thus enhancing leakage and the deterioration of mushrooms [9]. The MDA content gradually increased in all samples during 14 days of storage. However, control samples showed great increments of MDA content, while treatments effectively retarded the generation of MDA during storage, as presented in Figure 1.

Significant differences ($p < 0.05$) were found between treatments and the control throughout the storage. The coated samples showed lower levels of MDA compared with the control during the entire storage period. After 7 days of storage, the lowest MDA content was found in sodium alginate-coated samples, both those without and those with

the addition of *N*-acetyl cysteine. The obtained data are in line with those presented by Zhu et al. [37], who reported the reducing effect of sodium alginate coating on the membrane lipid peroxidation of mushrooms, expressed via MDA content, and attributed this effect to the enhancement of the antioxidant enzyme's activity by the edible coatings. After 14 days of storage, the lowest MDA content was found in chitosan-coated samples. Similar results have been reported by Guo et al. [59] in shiitake mushrooms and by Huang et al. [38] in button mushrooms, and these could be attributed to the well-known redox-regulatory activity of chitosan, which inhibits ROS production, prevents lipid oxidation and enhances the intracellular antioxidant enzymes in biological systems [60]. Chitosan coating was found to be effective in inhibiting lipoxygenase activity and retarding MDA accumulation in strawberries [61,62], bananas [63], loquat fruits [64] and mandarin fruits [65]. Moreover, Zhang et al. [66] demonstrated that chitosan coatings delayed the senescence of postharvest nectarine fruit in relation to changes in the redox state and respiratory pathway metabolism (inhibition of respiration rate, enhancement of the antioxidant system, improvement of total phenolics and flavonoids contents and decrease in H_2O_2 and MDA accumulation), while Bahmani et al. [67] confirmed the benefit of using chitosan coatings to maintain strawberries' quality and increase their shelf life by enhancing their antioxidant system and their ability to eliminate free radicals under cold storage. The incorporation of *N*-acetyl cysteine into the coating formula did not determine significant changes in the evolution of MDA content as compared to coated samples without an antibrowning agent.

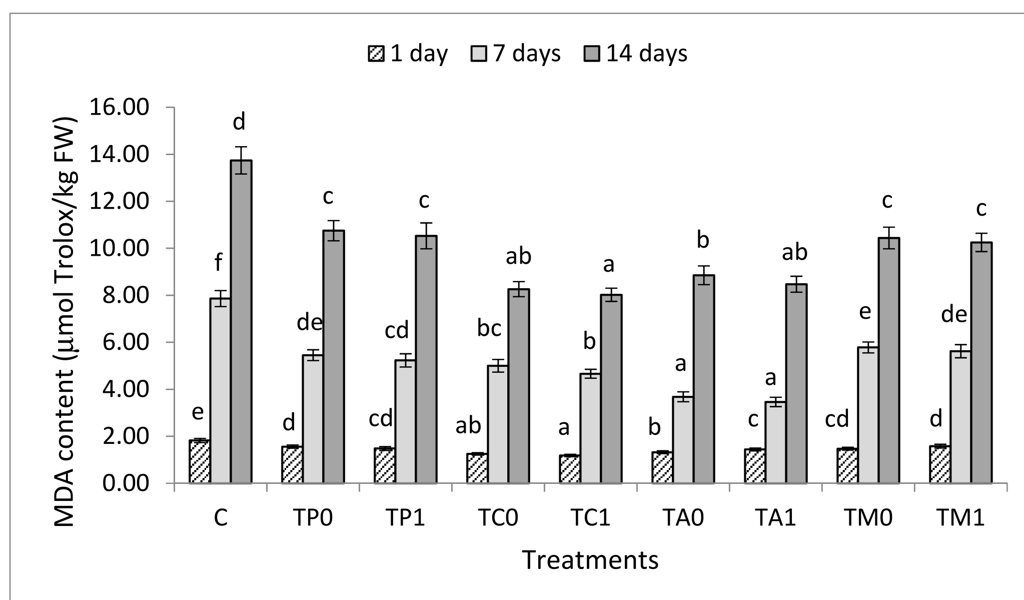

Figure 1. Effect of treatments on MDA (malondialdehyde) content (µmol Trolox/kg) of button mushrooms during storage for 14 days at 4 ± 1 °C. Different lowercase letters indicate significant differences between treatments for the same storage period ($p < 0.05$). C—distilled water (control); TP0—2% PE + 1% $CaCl_2$; TP1—2% PE + 1% $CaCl_2$ + 1% N-AC; TC0—2% CH + 1% $CaCl_2$; TC1—2% CH + 1% $CaCl_2$ + 1% N-AC; TA0—2% SA + 1% $CaCl_2$; TA1—2% SA + 1% $CaCl_2$ + 1% N-AC; TM0—2% CMC + 1% $CaCl_2$; TM1—2% CMC + 1% $CaCl_2$ + 1% N-AC.

4. Conclusions

The results reported in this study show that all tested edible coatings, both alone and with N-acetyl-cisteine, retarded weight loss and cap opening in mushrooms compared with the control. The most effective in controlling weight loss was sodium alginate, followed by carboxymetyhyl cellulose, chitosan and pectin. Sodium alginate and pectin coatings were the most effective in slowing the browning process of mushrooms during storage. The total phenolic content and antioxidant activity increased in mushrooms during storage, and coated samples showed significantly higher values compared to the control. The

highest total phenolic content was found in samples coated with pectin, followed by chitosan-coated samples. The MDA content gradually increased in all samples during the 14 days of storage, but the increase was delayed in coated samples relative to the control. Chitosan coating was the most effective in slowing down the increase in MDA content, but it determined a severe reduction in L* values and increase in the browning index of button mushrooms throughout storage. The addition of *N*-acetyl cysteine into the edible coatings caused a significant increase in the cap opening and browning index of all coated samples, and did not determine significant changes in the evolution of MDA content relative to the samples without antibrowning agent. The results demonstrate the feasibility of using sodium alginate and pectin coatings to extend the shelf life of button mushrooms.

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