

1-1-2022

Effect of egg white protein and agar-agar on quality of button mushrooms(*Agaricus bisporus*) during cold storage

ERDİ YILDIRIM ŞARAN

ŞEYDA ÇAVUŞOĞLU

DUYGU ALPASLAN

ERKAN EREN

NURETTİN YILMAZ

See next page for additional authors

Follow this and additional works at: <https://journals.tubitak.gov.tr/agriculture>



Part of the [Agriculture Commons](#), and the [Forest Sciences Commons](#)

Recommended Citation

ŞARAN, ERDİ YILDIRIM; ÇAVUŞOĞLU, ŞEYDA; ALPASLAN, DUYGU; EREN, ERKAN; YILMAZ, NURETTİN; and UZUN, YUSUF (2022) "Effect of egg white protein and agar-agar on quality of button mushrooms(*Agaricus bisporus*) during cold storage," *Turkish Journal of Agriculture and Forestry*. Vol. 46: No. 2, Article 5. <https://doi.org/10.55730/1300-011X.2969>
Available at: <https://journals.tubitak.gov.tr/agriculture/vol46/iss2/5>

This Article is brought to you for free and open access by TÜBİTAK Academic Journals. It has been accepted for inclusion in Turkish Journal of Agriculture and Forestry by an authorized editor of TÜBİTAK Academic Journals. For more information, please contact academic.publications@tubitak.gov.tr.

Effect of egg white protein and agar-agar on quality of button mushrooms(*Agaricus bisporus*) during cold storage

Authors

ERDİ YILDIRIM ŞARAN, ŞEYDA ÇAVUŞOĞLU, DUYGU ALPASLAN, ERKAN EREN, NURETTİN YILMAZ, and YUSUF UZUN

Effect of egg white protein and agar-agar on quality of button mushrooms (*Agaricus bisporus*) during cold storage

Erdi Yıldırım ŞARAN¹ , Şeyda ÇAVUŞOĞLU^{2*} , Duygu ALPASLAN³ , Erkan EREN⁴ , Nurettin YILMAZ² , Yusuf UZUN⁵ 

¹Horticultural Sciences, Institute of Natural and Applied Sciences, Van Yüzüncü Yıl University, Van, Turkey

²Department of Horticulture, Faculty of Agriculture, Van Yüzüncü Yıl University, Van, Turkey

³Department of Chemical Engineering, Faculty of Engineering, Van Yüzüncü Yıl University, Van, Turkey

⁴Bergama Technical and Business College, Mushroom Programme, Ege University, İzmir, Turkey

⁵Department of Pharmaceutical Botany, Faculty of Pharmacy, Van Yüzüncü Yıl University, Van, Turkey

Received: 06.02.2021 • Accepted/Published Online: 23.02.2022 • Final Version: 25.04.2022

Abstract: The commercialization of mushrooms is critical because they have a short shelf life. For this reason, we investigated the effect of agar-agar and egg white protein on weight loss, polyphenol oxidase and catalase, protein content, total phenolics, total antioxidant capacity, respiration rate, ethylene production and storability of button mushrooms. Our findings suggested that the treatment of edible coating delayed remarkably senescence and maintained the quality of button mushroom. Egg white protein coating was more effective on protein content, total phenolics, antioxidant capacity, respiration rate, and ethylene production than agar-agar coating. On the other hand, agar-agar coating was more effective on weight loss, polyphenol oxidase, catalase, and color changes. Ethylene production and respiration rate were significantly ($p < 0.05$) lower in edible coating-treated samples than uncoated samples. Furthermore, a positive correlation was found between total phenolic content and antioxidant activity. It can be recommended that abovementioned edible coatings could be used as a commercial treatment for maintaining the quality of button mushrooms during long-term storage period.

Key words: Edible coating, enzymes, postharvest, protein content

1. Introduction

Button mushrooms are healthy food sources because they are a good source of bioactive compounds such as protein, vitamins, polyphenolics and minerals (Singla et al., 2010; Çavuşoğlu et al., 2021a). However, mushrooms have a short shelf life, and so, their commercialization and consumption are limited.

Edible coatings and films are used to protect foods and extend their shelf life (Alderson et al., 2011). They can also be safely eaten as part of the product and do not add harmful properties to the foods (Baldwin, 1994). Edible coating and films are degradable materials that are environmentally friendly. They can control the mobility of moisture, gas, as well as maturation, development, and respiration rate (Keleş, 2002; Çavuşoğlu et al., 2019). Edible coatings and films overcome oxidative browning and decrease the number of microorganisms in products (Kumar and Bhatnagar, 2014).

Edible coatings are generally made of polysaccharides, protein, and lipids made from various agricultural goods and food processing wastes and byproducts (Huang et al., 2019).

* Correspondence: scavusoglu@yyu.edu.tr

Polysaccharide coatings are hydrophilic, including chitosan, pectin, carrageenans, cellulose derivatives, starch derivatives, alginate, agar, and gums (Nisperos-Carriedo, 1994). Proteins are also hydrophilic, including corn zein, wheat gluten, peanut, soy, collagen, gelatin, whey, casein, and egg white protein (Gennadios et al., 1994; Korochta, 2002). Edible coatings treat as a barrier to control gas exchange properties and extend the storage and shelf life of fruit and vegetables (Maqbool et al., 2011; Vieira et al., 2016). Moreover, they maintain the antioxidants, phenolics, color, and suppress respiration rate, and ethylene production properties for a longer storage period and some edible coatings act as natural antimicrobial and antifungal compound in many fruit and vegetables (Sharma et al., 2019).

There have been a few studies about agar-agar and egg white protein (EWP) effect on white button mushroom quality, antioxidative enzymes, enzymatic browning, protein content, total phenolics, total antioxidant capacity, respiration rate and ethylene production. This study aimed to investigate the effect of agar and EWP on white button mushroom quality and senescence during 4 °C storage.

2. Materials and methods

2.1. Materials and methods

Composts were supplied from a commercial company. Mushrooms were originally grown in rooms where growing conditions could be controlled and then harvested. After harvesting, mushrooms of uniform size, shape, and free from defects were selected for the experiment.

2.2. Preparation of edible coating and treatments

The edible coating materials were purchased from a commercial company, Benosen Co., Ltd. Briefly, EWP (5 g) and agar-agar (2.75 g) were prepared by dissolving in 500 mL distilled water. The mushrooms were randomly divided into three lots for different treatments. Samples in the first group were considered as control without treatment. The second and third groups were dipped in agar-agar and EWP edible coatings for one minute. After treatments, all samples were dried by means of a ventilator at room temperature (25 °C). Later, the samples were placed in foam plates (300 g per pack) and covered with stretch film (eight microns), then stored at 4 °C and 90%–95% relative humidity (RH) for 20 days.

2.3. Weight loss

During the storage period, weight loss was measured with precision scale at 5-day intervals and calculated as a percentage of initial weight.

2.4. Color

The color of the mushroom caps (10 pcs for each replicate) was measured by a chromameter (Minolta CR-400, Japan) in L^* , b^* , C^* and h° color space.

2.5. Total phenolic content (TP) and total antioxidant capacity (AOC)

Total phenolic content was detected with a spectrophotometer (Thermo Scientific Genesys 10S UV-VIS, Grafton, MA, USA) at 725 nm as indicated by Cavusoglu et al. (2021b). It was evaluated based on gallic acid equivalent (GAE) mg 100 g⁻¹ FW).

The Ferric reducing antioxidant power (FRAP) method was used to express the total antioxidant capacity at 593 nm, and results were expressed based on μ mol Trolox equivalent (TE) g⁻¹ FW (Benzie and Strain, 1996).

2.6. Catalase (CAT) and polyphenol oxidase (PPO) activity

The activity of CAT enzyme was measured with a spectrophotometer according to the methods of Alp and Kabay (2019) at 240 nm. PPO activity was also measured at 420 nm for 4 min at 5 s intervals based on Çavuşoğlu (2018).

2.7. Respiration rate and ethylene production

The respiration rate of mushrooms was presented as ml CO₂ kg⁻¹ h⁻¹ (Çavuşoğlu, 2018). For this reason, mushrooms (300 g per pack) were kept in closed jars for 2 h, and then, the carbon dioxide (CO₂) emission

of mushrooms was detected with the Headspace Gas Analyzer GS3/L analyzer.

Ethylene production was determined from the samples in the above-mentioned jars by withdrawing 2 ml of gas. The ethylene production was expressed as μ L C₂H₄ kg⁻¹ h⁻¹ (Guillén et al., 2013).

2.8. Protein content (%)

The nitrogen content was determined according to Dumas using a Dumatherm (C. Gerhardt Analytical Systems, Königswinter, Germany). For estimating the protein amount of the samples, the following equation was used: protein amount = nitrogen content \times 4.38. The results were expressed as a percent of dry weight (Hultberg et al., 2020).

2.9. Statistical analysis

This study was conducted as a completely randomized design with three replications. The data were subjected to one-way factorial ANOVA. Then, treatments were considered as factor. Duncan's multiple range test comparisons was also used to identify different levels of treatment factor. Statistical significance level was considered as 5%, and SPSS 20.0 statistical program was used.

3. Results

3.1. Weight loss

Weight losses increased in all treatments during the storage period, as expected. However, the lowest weight loss was found in samples treated with edible coatings (Table 1). There were significant differences between the control and edible coating-treated samples ($p < 0.05$).

3.2. Color

The samples treated with edible coatings resulted in higher values of L^* compared with the untreated samples at the end of storage period. The highest values of L^* was detected in the samples treated with agar-agar, followed by samples treated with EWP after 20 days of storage period (Table 2). Significant differences ($p < 0.05$) were observed between the control and edible coating-treated samples. b^* values generally increased in all treatments during the storage period, but the lowest b^* values were observed in samples treated with edible coatings (Table 2). Significant differences ($p < 0.05$) were observed between the control and edible coating-treated samples.

The highest value of C^* was 21.04 in mushrooms treated with EWP after 20 days of storage (Table 2). Significant differences ($p < 0.05$) were observed between the control and edible coating-treated samples.

The highest value of h° was found in caps treated with EWP with 86.16 while the lowest value was found in control treatment with 84.82 at the end of storage (Table 2). Significant differences ($p < 0.05$) were observed between the control and edible coating-treated samples.

Table 1. The changes in weight loss (%) during storage of mushroom (*Agaricus bisporus*). Data presented are the means ± sd.

Parameter	Storage period (days)	Control	EWP	Agar-agar
Weight loss	0	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
	5	2.288 ± 0.196 ^C	2.680 ± 0.080 ^B	3.241 ± 0.241 ^A
	10	5.328 ± 0.008 ^A	4.021 ± 0.021 ^C	4.408 ± 0.008 ^B
	15	6.223 ± 0.006 ^A	5.003 ± 0.001 ^C	5.280 ± 0.010 ^B
	20	8.857 ± 0.057 ^A	7.678 ± 0.256 ^B	6.722 ± 0.002 ^C
Significant effects		$p^{\text{treatments}} = 0.001$	$p^{\text{storage}} = 0.001$	$p^{\text{treatment}} \times p^{\text{storage}} = 0.001$

A.B.C: The differences among treatments were shown with capital letters for the same storage period ($p < 0.05$).

Table 2. The changes in L*, b*, C°, and hue during storage of mushroom (*Agaricus bisporus*). Data presented are the means ± sd.

Parameters	Storage period (days)	Control	EWP	Agar-agar
L*	0	89.520 ± 1.773	89.520 ± 1.773	89.520 ± 1.773
	5	87.170 ± 0.078 ^C	89.383 ± 0.306 ^B	88.653 ± 0.514 ^A
	10	85.620 ± 0.178 ^B	87.690 ± 0.242 ^A	87.403 ± 0.297 ^A
	15	86.863 ± 0.101 ^B	88.300 ± 0.789 ^A	85.800 ± 0.161 ^C
	20	82.523 ± 0.003 ^C	84.183 ± 0.186 ^B	85.023 ± 0.003 ^A
Significant effects		$p^{\text{treatments}} = 0.001$	$p^{\text{storage}} = 0.001$	$p^{\text{treatment}} \times p^{\text{storage}} = 0.012$
b*	0	12.850 ± 0.660	12.850 ± 0.660	12.850 ± 0.660
	5	16.903 ± 0.003 ^A	16.463 ± 0.003 ^B	15.896 ± 0.006 ^C
	10	16.860 ± 0.030 ^C	17.123 ± 0.003 ^B	17.200 ± 0.010 ^A
	15	15.043 ± 1.000 ^B	16.597 ± 1.628 ^{AB}	18.230 ± 0.668 ^A
	20	18.140 ± 1.000 ^B	20.920 ± 1.005 ^A	19.793 ± 0.467 ^{AB}
Significant effects		$p^{\text{treatments}} = 0.004$	$p^{\text{storage}} = 0.001$	$p^{\text{treatment}} \times p^{\text{storage}} = 0.001$
C°	0	12.913 ± 0.705	12.913 ± 0.705	12.913 ± 0.705
	5	16.936 ± 0.006 ^A	16.506 ± 0.006 ^B	15.916 ± 0.016 ^C
	10	16.886 ± 0.006 ^C	17.153 ± 0.013 ^B	17.223 ± 0.023 ^A
	15	14.736 ± 0.016 ^C	16.670 ± 0.270 ^B	18.280 ± 0.080 ^A
	20	19.870 ± 0.070 ^B	21.036 ± 0.035 ^A	19.853 ± 0.013 ^B
Significant effects		$p^{\text{treatments}} = 0.001$	$p^{\text{storage}} = 0.001$	$p^{\text{treatment}} \times p^{\text{storage}} = 0.001$
h°	0	86.807 ± 2.634	86.807 ± 2.634	86.807 ± 2.634
	5	86.523 ± 0.562 ^B	87.933 ± 0.800 ^A	88.137 ± 0.477 ^A
	10	87.147 ± 0.023 ^C	87.840 ± 0.040 ^B	88.130 ± 0.060 ^A
	15	86.990 ± 0.090 ^B	86.550 ± 0.050 ^C	88.236 ± 0.006 ^A
	20	84.820 ± 0.120 ^B	86.160 ± 0.150 ^A	85.977 ± 0.261 ^A
Significant effects		$p^{\text{treatments}} = 0.093$	$p^{\text{storage}} = 0.001$	$p^{\text{treatment}} \times p^{\text{storage}} = 0.820$

A.B.C: The differences among treatments were shown with capital letters for the same storage period ($p < 0.05$).

3.3. Total phenolic content (TP) and total antioxidant capacity (TAC)

Total phenolic content increased in all samples, during the storage period. At the end of the storage period, the highest value of total phenolic content was 11.42 mg 100 g⁻¹ in

mushrooms treated with EWP (Table 3). Furthermore, mushrooms treated with edible coatings resulted in higher antioxidant capacity than uncoated samples at the end of storage period. Significant differences ($p < 0.05$) were observed between the control and edible coating-

treated samples in total phenolic content, and antioxidant capacity.

3.4. Respiration rate and ethylene production

Ethylene production and respiration rate reduced in all treatments as storage time increases. However, the lowest values were observed in samples treated with an edible coating (Table 4). Both ethylene production and respiration rate were significantly ($p < 0.05$) lower in edible coating-treated than in control samples.

3.5. Catalase (CAT) and polyphenol oxidase (PPO) activity

The highest CAT enzyme activity was 0.042 and 0.032 mmol g⁻¹ for the agar-agar and EWP-treated samples at the 5th day, respectively (Table 5). Significant differences ($p < 0.05$) were observed between the control and edible coating-treated samples.

PPO enzyme activity generally increased in all treatments during the storage period, but the lowest

Table 3. The changes in total phenolic content (mg GAE/100 g FW) and antioxidant capacity (µmol TE/g FW) during storage of mushroom (*Agaricus bisporus*). Data presented are the means ± sd.

Parameters	Storage period (days)	Control	EWP	Agar-agar
Total phenolic content	0	8.351 ± 1.000	8.351 ± 1.000	8.351 ± 1.000
	5	9.506 ± 1.000 ^A	7.578 ± 0.378 ^B	7.076 ± 1.000 ^B
	10	7.678 ± 1.000 ^A	13.322 ± 1.156 ^C	10.594 ± 0.394 ^B
	15	8.560 ± 1.000 ^B	14.106 ± 1.000 ^A	9.579 ± 1.168 ^B
	20	6.974 ± 0.072 ^C	11.418 ± 1.000 ^A	9.507 ± 0.407 ^B
Significant effects		$p^{\text{treatments}} = 0.001$	$p^{\text{storage}} = 0.001$	$p^{\text{treatment}} \times p^{\text{storage}} = 0.001$
Antioxidant capacity	0	17.002 ± 1.000	17.002 ± 1.000	17.002 ± 1.000
	5	28.235 ± 1.924 ^A	21.459 ± 2.000 ^B	23.892 ± 1.000 ^B
	10	18.313 ± 0.273 ^B	30.557 ± 3.000 ^A	20.902 ± 1.000 ^B
	15	23.579 ± 2.000 ^B	29.855 ± 2.000 ^A	24.824 ± 1.867 ^B
	20	20.555 ± 1.000 ^C	30.959 ± 1.000 ^A	23.611 ± 1.000 ^B
Significant effects		$p^{\text{treatments}} = 0.001$	$p^{\text{storage}} = 0.001$	$p^{\text{treatment}} \times p^{\text{storage}} = 0.001$

A.B.C: The differences among treatments were shown with capital letters for the same storage period ($p < 0.05$).

Table 4. The changes in ethylene production (µL C₂H₄ kg⁻¹ h⁻¹) and respiration rate (mL CO₂ kg⁻¹ h⁻¹) during storage of mushroom (*Agaricus bisporus*). Data presented are the means ± sd.

Parameters	Storage period (days)	Control	EWP	Agar-agar
Ethylene production.	0	1.950 ± 0.150	1.950 ± 0.150	1.950 ± 0.150
	5	1.705 ± 0.200 ^A	1.090 ± 0.040 ^B	0.928 ± 0.102 ^B
	10	0.564 ± 0.004 ^A	0.495 ± 0.002 ^C	0.513 ± 0.003 ^B
	15	0.506 ± 0.006 ^A	0.419 ± 0.016 ^C	0.442 ± 0.002 ^B
	20	0.401 ± 0.006 ^A	0.367 ± 0.001 ^B	0.353 ± 0.008 ^C
Significant effects		$p^{\text{treatments}} = 0.001$	$p^{\text{storage}} = 0.001$	$p^{\text{treatment}} \times p^{\text{storage}} = 0.001$
Respiration rate	0	89.913 ± 1.000	89.913 ± 1.000	89.913 ± 1.000
	5	70.984 ± 2.000 ^A	57.897 ± 1.037 ^B	58.642 ± 1.524 ^B
	10	67.006 ± 2.000 ^A	55.749 ± 0.249 ^B	54.375 ± 1.000 ^B
	15	55.965 ± 1.000 ^A	45.380 ± 7.037 ^B	53.576 ± 0.439 ^{AB}
	20	53.401 ± 2.991 ^A	43.515 ± 0.832 ^B	45.403 ± 0.460 ^B
Significant effects		$p^{\text{treatments}} = 0.001$	$p^{\text{storage}} = 0.001$	$p^{\text{treatment}} \times p^{\text{storage}} = 0.001$

A.B.C: The differences among treatments were shown with capital letters for the same storage period ($p < 0.05$).

enzyme activity was observed in samples treated with edible coatings (Table 5). In addition, the lowest enzyme activity was found in the samples treated with agar-agar. Significant differences ($p < 0.05$) were observed between the control and edible coating-treated samples.

3.6. Protein content (%)

The protein content in control, EWP and agar-agar treated mushroom was approximately 7.31, 13.17, and 4.41 times higher, respectively, than the beginning of storage period (Table 6). Significant differences ($p < 0.05$) were observed between the control and edible coating-treated samples.

4. Discussion

High weight loss causes economic losses in terms of marketing because it is closely related to the visual quality of the product. Indeed, it has been reported that this parameter is quite essential; in the case of weight loss of

more than 4%–6%, the fruits and vegetables show visible signs of wilting or shrinkage (Bico et al., 2009; Huang et al., 2019). In the present study, weight loss was lower 6% in edible coating-treated samples, up to 15 days. Similar results have been reported in other studies where weight loss is reduced by the treatment of chitosan and guar gum (Huang et al., 2019), as well as sodium alginate (Zhu et al., 2019).

Color is one of the most indicators of quality for the preference of consumers. It is associated with the age of the mushrooms, handling, and therefore color has been used as an indicator to evaluate the shelf life and freshness. The color of fresh mushrooms is influenced by the level of oxygen existing by inhibiting the enzymatic browning reaction (Mohebbi et al., 2012). If L^* value is less than 69 in mushrooms, it could not be preferred in most of the marketplaces (Taghizadeh et al., 2009). In the present

Table 5. The changes in catalase (CAT mmol/g FW) and polyphenol oxidase (PPO) activity (Unite) during storage of mushroom (*Agaricus bisporus*). Data presented are the means \pm sd.

Parameters	Storage period (days)	Control	EWP	Agar-agar
CAT	0	0.029 \pm 0.001	0.029 \pm 0.001	0.029 \pm 0.001
	5	0.029 \pm 0.002 ^B	0.032 \pm 0.001 ^B	0.042 \pm 0.002 ^A
	10	0.014 \pm 0.001 ^C	0.030 \pm 0.003 ^A	0.025 \pm 0.001 ^B
	15	0.013 \pm 0.002 ^B	0.019 \pm 0.001 ^A	0.014 \pm 0.002 ^B
	20	0.014 \pm 0.001 ^C	0.021 \pm 0.002 ^B	0.026 \pm 0.001 ^A
Significant effects		$p^{\text{treatments}} = 0.001$	$p^{\text{storage}} = 0.001$	$p^{\text{treatment}} \times p^{\text{storage}} = 0.001$
PPO	0	43.481 \pm 3.252	43.481 \pm 3.252	43.481 \pm 3.252
	5	65.057 \pm 1.915 ^A	60.720 \pm 2.000 ^B	62.560 \pm 2.000 ^{AB}
	10	53.229 \pm 3.000 ^B	77.587 \pm 1.700 ^A	53.229 \pm 1.000 ^B
	15	65.605 \pm 1.000 ^A	56.624 \pm 1.000 ^B	57.062 \pm 1.000 ^B
	20	53.858 \pm 0.058 ^B	55.726 \pm 0.126 ^A	52.177 \pm 0.177 ^C
Significant effects		$p^{\text{treatments}} = 0.001$	$p^{\text{storage}} = 0.001$	$p^{\text{treatment}} \times p^{\text{storage}} = 0.001$

A.B.C: The differences among treatments were shown with capital letters for the same storage period ($p < 0.05$).

Table 6. The changes in protein content (%) during storage of mushroom (*Agaricus bisporus*). Data presented are the means \pm sd.

Parameter	Storage period (days)	Control	EWP	Agar-agar
Protein content	0	39.520 \pm 1.000	39.520 \pm 1.000	39.520 \pm 1.000
	5	39.220 \pm 2.000 ^{AB}	37.370 \pm 1.000 ^B	41.527 \pm 1.449 ^A
	10	39.470 \pm 0.070 ^C	42.673 \pm 0.003 ^A	39.860 \pm 0.060 ^B
	15	43.127 \pm 1.000 ^{AB}	41.383 \pm 1.000 ^B	45.553 \pm 1.812 ^A
	20	42.410 \pm 2.000 ^{AB}	44.726 \pm 1.000 ^A	41.266 \pm 1.000 ^B
Significant effects		$p^{\text{treatments}} = 0.206$	$p^{\text{storage}} = 0.001$	$p^{\text{treatment}} \times p^{\text{storage}} = 0.001$

A.B.C: The differences among treatments were shown with capital letters for the same storage period ($p < 0.05$).

study, L^* values ranged from 82.52 to 89.52. Our findings showed that treated mushrooms had a positive effect on color changes and brightness.

Mushrooms short shelf life may be due to the rapid respiration rate (Rizk et al., 2020). Therefore, the respiration rate must be controlled with the proper storage temperature and treatments that are environmentally and human friendly. It has been reported that fruit treated with edible coatings lower respiration rate and ethylene production compared with uncoated samples (Wong et al., 1994; Jiang, 2013). These results indicated that coating and low-temperature treatment could slow down respiration and metabolic activity (Jiang et al., 2012). The coating can also behave as a gas barrier and suppresses the respiration rate (Mohebbi et al., 2012; Ghasemnezhad et al., 2013). As mentioned earlier, mushrooms treated with edible coatings had lower respiration rate and ethylene production compared to control samples.

According to Reyes and Cisneros-Zevallos (2003), there has been a positive correlation between the total phenolic increase and antioxidant capacity increase. Our findings confirmed earlier study that between total phenolic content, and antioxidant capacity had a positive correlation (Table 7). It was reported in other studies where the total phenolic content was enhanced in grape (Chauhan et al., 2014), blueberry (Yang et al., 2014a), and mushrooms (Rizk et al., 2020) with the treatment of *A. vera* gel, blueberry leaf extracts incorporated in chitosan coating and carrageenan, respectively. Moreover, Synowiec et al. (2014) reported that the effect of pullulan coatings enhanced with basil plant extract and improved the antioxidant activity of apples.

The treatment of *A. vera* gel coatings in raspberry fruit had a higher antioxidant capacity than uncoated samples (Hassanpour, 2015). In the present study, the mushrooms subjected to edible coatings had a higher antioxidant capacity and total phenolic content than the uncoated samples.

The initial increase in enzymatic activity is known to be related to the abrupt release of enzymes accumulated in vacuoles (Guerrero-Beltrán et al., 2005). CAT is one of the most key enzymes scavenging reactive oxygen species (ROS). This enzyme plays in the chief defense system against hydrogen peroxide's toxicity (Zhu et al., 2019). It was suggested that mushroom treated with edible coatings displayed higher levels of CAT activity than uncoated samples (Khan et al., 2014; Zhu et al., 2019). Moreover, it was reported in different studies where PPO was inhibited by the treatment of ascorbic acid loaded chitosan/tripolyphosphate nanoaggregates (Ojeda et al., 2019), alginate coating (Jiang, 2013), and composite coating (Zhu et al., 2019) in mushrooms. Chitosan, an edible coating, can reduce the fruit's response to environmental conditions by reducing gas formation change on the fruit surface, thus delaying fruit ripening and reducing water loss, respiration rate, and ethylene production (Cissé et al., 2015; Cosme Silva et al., 2017). Moreover, further studies have reported that the coating treatment can increase enzymatic and nonenzymatic antioxidant systems to reduce ROS accumulation, thus improving quality and delaying senescence in postharvest products (Batista Silva et al., 2018; Jiang et al., 2018). We supported the abovementioned studies that PPO activity was inhibited, and the CAT activity was enhanced by treatment of EWP

Table 7. Pearson's correlation coefficients between the measured parameters of *Agaricus bisporus* during the storage period.

	WL	L^*	b^*	C^*	h^*	TF	AOC	EP	RR	CAT	PPO	PC
WL	1											
L^*	-0.852**	1										
b^*	0.802**	-0.751**	1									
C^*	0.853**	-0.827**	0.962**	1								
h^*	-0.250	0.548**	-0.188	-0.264	1							
TF	0.160	0.041	0.304*	0.231	0.162	1						
AOC	0.439**	-0.244	0.612**	0.552**	0.074	0.740**	1					
EP	-0.900**	0.664**	-0.767**	-0.773**	0.069	-0.316*	-0.488**	1				
RR	-0.850**	0.576**	-0.817**	-0.828**	0.038	-0.381**	-0.654**	0.920**	1			
CAT	-0.625**	0.619**	-0.308*	-0.351*	0.266	-0.084	-0.034	0.525**	0.335*	1		
PPO	0.329*	-0.142	0.371*	0.331*	0.149	0.341*	0.698**	-0.461**	-0.524**	0.042	1	
PC	0.577**	-0.472**	0.493**	0.462**	0.075	0.395**	0.550**	-0.527**	-0.478**	-0.392**	0.274	1

*: Correlation is significant at $p < 0.05$. **: Correlation is significant at $p < 0.01$. WL is weight loss, TF is total phenolic content, AOC is antioxidant capacity, EP is ethylene production, RR is respiration rate, PC is protein content.

and agar-agar. It can be stated that the coating positively affected the delay of senescence.

Soluble protein is taken into consideration as a nutrient substrate to maintain metabolic activity. A decrease in soluble protein content has been mostly accepted as an essential indicator of tissue senescence, destruction, and reactive oxygen species (ROS) damage (Bajgai et al., 2006; Khan et al., 2014; Huang et al., 2019). Zhu et al. (2019) noted that coating and low-temperature storage could retard the senescence of *P. nameko* mushrooms. Embden-meyerothofparnas (EMP)-tricarboxylic-acid-cycle (TCA) serves as a major respiration and energy-generating pathway in plants, playing key roles in regulating the senescence of postharvest fruit (Yang et al., 2014b). Therefore, EWP and agar-agar coating might reduce respiration pathway of EMP-TCA. Thus, except for the mechanism of induced resistance as an exogenous elicitor, this study suggested that respiration rate reduced by EWP and agar-agar in mushrooms had a negative correlation between respiration rate and protein content (Table 7). Furthermore, respiration rate was lower edible coating-treated samples. These results showed that the protein content of button mushrooms maintained especially with the treatment of EWP coating.

5. Conclusion

In conclusion, there are various treatments extending the shelf, and storage life of mushrooms, including methyl jasmonate, essential oils, natamycin, coating, high-

pressure argon, ozone gas. Among these treatments, edible coatings are commonly applied for better postharvest food appearance and maintenance of quality, since edible coatings make products shine and make them more tempting to consumers. In the present study, the treatment of edible coating delayed remarkably senescence and maintained the quality of button mushroom. EWP coating was more effective on protein content, total phenolics, antioxidant capacity, respiration rate, and ethylene production than agar-agar coating. On the other hand, agar-agar coating was more effective on weight loss, PPO, CAT, and color changes. A positive correlation was found between total phenolic content and antioxidant activity, and a negative correlation was found between respiration rate and weight loss, and protein content. In the current study, it can be suggested that the aforementioned edible coatings can be used for maintaining the quality of button mushrooms for 15 days as a commercial treatment, since weight loss was lower 6% in edible coating-treated samples, up to 15 days.

Acknowledgement

We would like to thank the Scientific Research Projects Coordinator (BAP) of Van Yüzüncü Yıl University for financial support in my work with the project number FYL-2019-8151. We would also like to thank “Yiğit Mantar” for supplying the composts. This study has been prepared from a master’s thesis.

References

- Alderson PG, Zahid N, Ali A, Maqbool M (2011). Efficacy of biodegradable novel edible coatings to control postharvest anthracnose and maintain quality of fresh horticultural produce. In IV International Conference Postharvest Unlimited 945 (pp. 39-44).
- Alp Y, Kabay T (2019). The Effect of drought stress on antioxidative enzyme and nutrient exchange in some tomato genotypes. Turkish Journal of Agricultural and Natural Sciences 6 (1): 71-77. doi: 10.30910/turkjans.515352
- Bajgai TR, Hashinaga F, Isobe S, Vijaya Raghavan GS, Ngadi MO (2006). Application of high electric field (HEF) on the shelf life extension of emblic fruit (*Phyllanthus emblica* L.). Journal of Food Engineering 74 (3): 308-313. doi: 10.1016/j.jfoodeng.2005.03.023
- Baldwin EA (1994). Edible coating for fresh fruits and vegetables: past, present and future. In: Krochta JM, Baldwin EA, Nisperos-Carreido MO (eds), Edible coating and films to improve food quality, Technomic publishing company, Inc., Lancaster, Pennsylvania, USA, pp. 25-64.
- Batista Silva W, Cosme Silva GM, Santana DB, Salvador AR, Medeiros DB et al. (2018). Chitosan delays ripening and ROS production in guava (*Psidium guajava* L.) fruit. Food Chemistry 242: 232-238.
- Benzie IEF, Strain JJ (1996). The ferric reducing ability of plasma (FRAP) as a measure of “antioxidant power”: the FRAP assay. Analytical Biochemistry 239: 70-76.
- Bico SLS, Raposo MFJ, Morais RMSC, Morais AMMB (2009). Combined effects of chemical dip and/or carrageenan coating and/or controlled atmosphere on quality of fresh-cut banana. Food Control 20: 508-514. doi: 10.1016/j.foodcont.2008.07.017
- Çavuşoğlu, Ş (2018). Effects of Modified Atmosphere and Methyl Jasmonate Treatments on The Postharvest Quality and Storage Life of *Agaricus bisporus*. The Journal of Fungus 9 (2): 206-218. doi: 10.30708/mantar.458800
- Çavuşoğlu Ş, Keskin N, Türkoğlu N (2019). Yenilebilir film ve kaplamaların hasat sonrası meyvelerin soğukta muhafazasında kullanım olanakları. II. Uluslararası Tarım ve Orman Kongresi. İzmir Türkiye. s: 57-61. (In Turkish)
- Cavusoglu S, Uzun Y, Yilmaz N, Ercisli S, Eren E et al. (2021a). Maintaining the Quality and Storage Life of Button Mushrooms (*Agaricus bisporus*) with Gum, Agar, Sodium Alginate, Egg White Protein, and Lecithin Coating. Journal of Fungi 7 (8): 614.

- Cavusoglu S, Sensoy S, Karatas A, Tekin O, Islek F et al. (2021b). Effect of Pre-Harvest Organic Cytokinin Application on the Post-Harvest Physiology of Pepper (*Capsicum annuum* L.). Sustainability 13 (15): 8258.
- Chauhan S, Gupta KC, Agrawal M (2014). Application of biodegradable Aloe vera gel to control postharvest decay and longer the shelf life of grapes. International Journal of Current Microbiology and Applied Sciences 3 (3): 632–642.
- Cissé M, Polidori J, Montet D, Loiseau G, Ducamp-Collin MN (2015). Preservation of mango quality by using functional chitosan-lactoperoxidase systems coatings. Postharvest Biology and Technology 101: 10–14.
- Cosme Silva GM, Silva WB, Medeiros DB, Salvador AR, Cordeiro MHM et al. (2017). The chitosan affects severely the carbon metabolism in mango (*Mangifera indica* L. cv. Palmer) fruit during storage. Food Chemistry 237: 372–378.
- Gennadios A, McHugh TH, Weller CL, Krochta JM (1994). Edible coatings and films based on proteins. In: Edible Coatings and Films to Improve Food Quality. pp. 201-277.
- Ghasemnezhad M, Zareh S, Rassa M, Sajedi RH (2013). Effect of chitosan coating on maintenance of aril quality, microbial population and PPO activity of pomegranate (*Punica granatum* L. cv. Tarom) at cold storage temperature. Journal of the Science of Food and Agriculture 93: 368-374. doi: 10.1002/jsfa.5770
- Guerrero-Beltrán J, Swanson B, Barbosa-Cánovas GV (2005). Inhibition of polyphenoloxidase in mango puree with 4-hexylresorcinol, cysteine and ascorbic acid. LWT- Food Science Technology 38: 625–630.
- Guillén F, Díaz-Mula HM, Zapata PJ, Valero D, Serrano M et al. (2013). *Aloe arborescens* and Aloe vera gels as coatings in delaying postharvest ripening in peach and plum fruit. Postharvest Biology. Technology 83: 54–57. doi: 10.1016/j.lwt.2004.08.002
- Hassanpour H (2015). Effect of Aloe vera gel coating on antioxidant capacity, antioxidant enzyme activities and decay in raspberry fruit. LWT-Food Science and Technology 60 (1): 495–501. doi: 10.1016/j.lwt.2014.07.049
- Huang Q, Qian X, Jiang T, Zheng X (2019). Effect of chitosan and guar gum based composite edible coating on quality of mushroom (*Lentinus edodes*) during postharvest storage. Scientia Horticulturae 253: 382-389. doi: 10.1016/j.scienta.2019.04.062
- Hultberg M, Ahrens L, Golovko O (2020). Use of lignocellulosic substrate colonized by oyster mushroom (*Pleurotus ostreatus*) for removal of organic micropollutants from water. Journal of Environmental Management 272: 111087.
- Jiang T, Feng L, Zheng X (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 (1): 188–196. doi: 10.1021/jf202638
- Jiang T (2013). Effect of alginate coating on physicochemical and sensory qualities of button mushrooms (*Agaricus bisporus*) under a high oxygen modified atmosphere. Postharvest Biology and Technology 76: 91-97. doi: 10.1016/j.postharvbio.2012.09.005]
- Jiang X, Lin H, Shi J, Neethirajan S, Lin Y et al. (2018). Effects of a novel chitosan formulation treatment on quality attributes and storage behavior of harvested litchi fruit. Food Chemistry 252: 134-141.
- Keleş F (2002). Gıda Ambalajlama İlkeleri, Atatürk Üniversitesi Ziraat Fakültesi Ders Yayınları No:189, Erzurum Türkiye.
- Khan ZU, Aisikaer G, Khan RU, Bu J, Jiang Z et al. (2014). Effects of composite chemical pretreatment on maintaining quality in button mushrooms (*Agaricus bisporus*) during postharvest storage. Postharvest Biology and Technology 95: 36–41. doi: 10.1016/j.postharvbio.2014.04.001
- Krochta JM (2002). Proteins as raw materials for films and coatings: definitions, current status, and opportunities. Protein-based films and coatings 1: 1-40.
- Kumar S, Bhatnagar T (2014). Studies to enhance the shelf life of fruits using Aloe vera based herbal coating: A Review, Noida Int. Uni., Greater Noida, and U.P.
- Maqbool M, Ali A, Alderson PG, Zahid N, Siddiqui Y (2011). Effect of a novel edible composite coating based on gum arabic and chitosan on biochemical and physiological responses of banana fruits during cold storage. Journal of Agricultural and Food Chemistry 59: 5474–5482.
- Mohebbi M, Ansarifard E, Hasanpour N, Amiryousefi MR (2012). Suitability of Aloe vera and gum tragacanth as edible coatings for extending the shelf life of button mushroom. Food and Bioprocess Technology 5 (8): 3193-3202. doi: 10.1007/s11947-011-0709-1
- Nisperos-Carriedo MO (1994). Edible coatings and films based on polysaccharides. Edible coatings and films to improve food quality 1: 322-323.
- Ojeda GA, Sgroppo SC, Martín-Belloso O, Soliva-Fortuny R (2019). Chitosan/tripolyphosphate nanoaggregates enhance the antibrowning effect of ascorbic acid on mushroom slices. Postharvest Biology and Technology 156: 110934. doi: 10.1016/j.postharvbio.2019.110934
- Reyes LF, Cisneros-Zevallos L (2003). Wounding stress increases the phenolic content and antioxidant capacity of purple-flesh potatoes. Journal of Agricultural and Food Chemistry 51: 5296–5300
- Rizk AE, Riyadh YM, Helmy MM (2020). Effect of Mixing Rotational Speed on Characteristics of Edible Film Containing Tangerine (*Citrus reticulata*) Essential Oil to Extend the Shelf-Life of Mushroom (*Agaricus bisporus*). Suez Canal University Journal of Food Sciences 7 (1): 23-34. doi: 10.21608/SCUJ.2020.119483
- Sharma P, Kehinde BA, Kaur S, Vyas P (2019). Application of edible coatings on fresh and minimally processed fruits: a review. International Journal of Vegetable Science 25 (3): 295-314. doi: 10.1080/19315260.2018.1510863
- Singla R, Abhijit G, Ghosh M. (2010). Physicochemical and nutritional characteristics of organic acid-treated button mushrooms (*Agaricus bisporus*). Food and Bioprocess Technology. doi: 10.1007/s11947-010-0457-7

- Synowiec A, Gniewosz M, Krasniewska K, Przybyl JL, Baczek K et al. (2014). Antimicrobial and antioxidant properties of pullulan film containing sweet basil extract and an evaluation of coating effectiveness in the prolongation of the shelf life of apples stored in refrigeration conditions. *Innovative Food Science and Emerging Technologies* 23: 171–181. doi: 10.1016/j.ifset.2014.03.006
- Taghizadeh M, Gowen A, O'Donnell CP (2009). Prediction of white button mushroom (*Agaricus bisporus*) moisture content using hyperspectral imaging. *Sensing and Instrumentation for Food Quality and Safety* 3: 219–226. doi 10.1007/s11694-009-9088-y
- Vieira JM, Flores-López ML, de Rodríguez DJ, Sousa MC, Vicente AA et al. (2016). Effect of chitosan-Aloe vera coating on postharvest quality of blueberry (*Vaccinium corymbosum*) fruit. *Postharvest Biology and Technology* 116: 88–97.
- Wong D, Tillin SJ, Hudson JS, Pavlath AE (1994). Gas exchange in cut apples with bilayer coatings. *Journal of Agricultural and Food Chemistry* 42: 2278–2285.
- Yang G, Yue J, Gong X, Qian B, Wang H et al. (2014a). Blueberry leaf extracts incorporated chitosan coatings for preserving postharvest quality of fresh blueberries. *Postharvest Biology and Technology* 92: 46–53. doi: 10.1016/j.postharvbio.2014.01.018
- Yang ZF, Cao SF, Su XG, Jiang YM (2014b). Respiratory activity and mitochondrial membrane associated with fruit senescence in postharvest peaches in response to UV-C treatment. *Food Chemistry* 161, 16–21.
- Zhu D, Guo R, Li W, Song J, Cheng F (2019). Improved postharvest preservation effects of Pholiota nameko mushroom by sodium alginate-based edible composite coating. *Food and Bioprocess Technology* 12 (4): 587-598. doi: 10.1007/s11947-019-2235-5