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

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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). 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.

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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 μmol 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 k^{g-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 (CO_2) 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 μL C_2H_4 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 × 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		$p^{treatments} = 0.001$	$p^{storage} = 0.001$	$p^{treatment} \times p^{storage} = 0.001$

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		$p^{treatments} = 0.001$	$p^{storage} = 0.001$	$p^{treatment} \times p^{storage} = 0.012$
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		$p^{treatments} = 0.004$	$p^{storage} = 0.001$	$p^{treatment} \times p^{storage} = 0.001$
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		$p^{treatments} = 0.001$	$p^{storage} = 0.001$	$p^{treatment} \times p^{storage} = 0.001$
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		$p^{treatments} = 0.093$	$p^{storage} = 0.001$	$p^{treatment} \times p^{storage} = 0.820$

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		$p^{treatments} = 0.001$	$p^{storage} = 0.001$	$p^{treatment} \times p^{storage} = 0.001$
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		$p^{treatments} = 0.001$	$p^{storage} = 0.001$	$p^{treatment} \times p^{storage} = 0.001$

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 C_2H_4 kg^{-1} h^{-1}) and respiration rate (mL CO_2 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		$p^{treatments} = 0.001$	$p^{storage} = 0.001$	$p^{treatment} \times p^{storage} = 0.001$
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		$p^{treatments} = 0.001$	$p^{storage} = 0.001$	$p^{treatment} \times p^{storage} = 0.001$

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 ± sd.

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

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 ± sd.

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

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-meyerhofparnas (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.

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