LWT - Food Science and Technology 68 (2016) 44–51

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Application of electrolyzed water for improving postharvest quality of mushroom

Mehmet Seckin Aday

Department of Food Engineering, Canakkale Onsekiz Mart University, 17020, Canakkale, Turkey

ARTICLE INFO

Article history:
Received 26 July 2015
Received in revised form
5 December 2015
Accepted 9 December 2015
Available online 12 December 2015

Keywords:
Electrolyzed water
Mushroom
Quality
Browning index

ABSTRACT

This paper focused on the effectiveness of electrolyzed water (EW) at different concentrations (5, 25, 50 and 100 mg/L) combined with passive atmosphere packaging on the quality of mushroom. In order to understand the effect of EW on mushrooms, gas composition inside packages, weight loss, pH, whiteness and browning index, texture profile analysis (TPA), cap development, electrolyte leakage and FT-NIR analysis were performed during the twelve days of storage at 4 °C. Samples washed with 25 and 50 mg/L EW consumed O_2 lower than the other treatments. Mushrooms treated with 25 mg/L EW had a significantly lower electrolyte leakage values than untreated and 5 mg/L treated mushrooms. Mushrooms treated with 25 mg/L EW had the highest whiteness index and lowest browning index. EW treatments at the concentrations of 25 and 50 mg/L maintained the textural parameters and slowed down the weight loss better than other treatments. FT-NIR analysis supported the results obtained by weight loss and electrolyte leakage. In conclusion, the results of this research support the idea that combined use of EW treatment and passive modified atmosphere packaging can be used to extend the shelf life of mushrooms.

1. Introduction

Button mushroom (*Agaricus bisporus*) is one of the most common and widely consumed edible mushroom type due to their functional properties (Guan, Fan, & Yan, 2013). However, mushrooms lose their quality quickly after harvest in 1–3 days at ambient temperature (Oliveira, Sousa-Gallagher, Mahajan, & Teixeira, 2012a) because of their thin epidermal structure, high respiration rate, high moisture content (Mahajan, Oliveira, & Macedo, 2008) and high tyrosinase activity (Taghizadeh, Gowen, Ward, & O'Donnell, 2010). The critical quality indicators include browning, softening, (Yurttas, Moreira, & Castell-Perez, 2014) cap development, weight loss (Kim, Ko, Lee, Park, & Hanna, 2006) and free of mold growth (Mohapatra, Bira, Frias, Kerry, & Rodrigues, 2011). Therefore, different methods were reported such as electron-beam irradiation, (Mami, Peyvast, Ziaie, Ghasemnezhad, & Salmanpour, 2014) packaging with different films, (Taghizadeh et al., 2010) active papers with cinnamon oil, (Echegoyen & Nerín, 2015) modified atmosphere packaging, (Kim et al., 2006) washing with hydrogen peroxide (Sapers, Miller, Choi, & Cooke, 1999) and ozone (Yuk, Yoo, Yoon, Marshall, & Oh, 2007) to retain freshness of mushroom during shipping and marketing.

Electrolyzed water (EW) is a promising disinfectant which is generated by electrolysis of a salt solution (Vázquez-Sánchez, Cabo, & Rodríguez-Herrera, 2014). In contrast with other disinfectants, EW is not corrosive to organic materials and it reverts to ordinary water when diluted with tap water (Jemni et al., 2014). The effectiveness of EW depends on free available chlorine, presence of chlorine species and oxidation reduction potential (Al-Haq, Sugiyama, & Isobe, 2005). The use of EW on fresh produce has been officially approved by Japan and USA at a maximum 200 mg/L of free available chlorine (Lee et al., 2014). Previous studies have shown the effectiveness of EW on carrot, (Abadias, Usall, Oliveira, Alegre, & Viñas, 2008) spinach, (Guentzel, Liang Lam, Callan, Emmons, & Dunham, 2008) cabbage, (Koide, Takeda, Shi, Shono, & Atungulu, 2009) and broccoli (Martínez-Hernández et al., 2015).

Until now, EW has only been applied to the oyster mushroom (*Pleurotus ostreatus*) on the basis of microbiological point of view (Ding, Rahman, & Oh, 2011). Therefore this paper focused on white button mushroom (*Agaricus bisporus*) in order to determine the combined effect of passive modified atmosphere and electrolyzed water during cold storage.

E-mail address: mseckinaday@comu.edu.tr.

http://dx.doi.org/10.1016/j.lwt.2015.12.014
0023-6438/

2. Materials and methods

2.1. Materials

White button mushrooms *(Agaricus bisporus)* were purchased from a farm in Canakkale, Turkey and transported to the food engineering laboratory within 2 h. Subsequently, samples were sorted for similar size, maturity and color. Extremely large or small and damaged mushrooms were discarded. Then, mushrooms were divided into five groups. The first group was washed with water as an untreated and second, third, fourth and fifth group of samples were washed with electrolyzed water at concentrations of 5, 25, 50 and 100 mg/L free chlorine respectively for 3 min. After air drying, mushrooms (around 150 g) were packaged with MAP25 packaging machine in air conditions (21% O_2, 0.03% CO_2 and 79% N_2) to reach equilibrium state. Samples were stored at 4 °C for 12 days.

2.2. Preparation of electrolyzed water

Mixed oxidant brine system (MIOX Corporation, New Mexico, USA) was used to generate electrolyzed water. Electrolyte cell inside the equipment processed 1% NaCl solution for electrolysis of brine (Clevenger, Wu, DeGruson, Brazos, & Banerji, 2007). Then, stock solution of EW collected from vessel and diluted to 5, 25, 50 and 100 mg/L free chlorine. The N,N-diethyl-p-phenylenediamine (DPD) method was used to measure the amount of free chlorine in solutions by DR/2800 spectrophotometer (HACH, Co., USA).

2.3. The O_2 and CO_2 concentration in package headspace

Oxybaby (Hamburg, Germany) gas analyzer was used to determine gas concentrations inside the package of mushrooms. The needle of oxybaby was penetrated throughout adhesive septum which was placed on the package film for avoiding gas leakage and tearing of package film during analysis (Lu et al., 2009).

2.4. pH value

Around 20 g of samples were homogenized in a mixer and then centrifuged (Sigma 2–12K, Sartorious, Germany) at 5000 × g for 20 min (Jafri, Jha, Bunkar, & Ram, 2013). The pH values of mushrooms were determined by using Sartorius PP-50 pH meter (Goettingen, Germany).

2.5. Color

The cap color of ten mushrooms for each treatment was measured with Minolta CR-400 colorimeter (Minolta, Osaka, Japan). Standard white plate (CR-A43) was used to calibrate colorimeter. CIE color space coordinates L*(Lightness), a* (red-green) and b* (yellow-blue) were recorded by using SpectraMagic NX software. Browning index (BI) and whiteness index (WI) were calculated using following equations (Borchert et al., 2014):

$$BI = 100(x - 0.31)/0.17 \quad (1)$$

$$\text{Where } x = (a + 1.75L)/(5.645L + a - 3.012b) \quad (2)$$

$$WI = L - 3b + 3a \quad (3)$$

2.6. Weight loss

All packages were coded before the experiment. Subsequently, package weights of mushrooms were recorded at the beginning of storage and at each sampling day. Results were expressed as the percentage loss of initial package weight of samples (Koutsimanis, Harte, & Almenar, 2015).

2.7. Electrolyte leakage

Electrolyte leakage was measured by the method of Li et al. (2014) with some modifications. 1 g cap and 1 g stipe tissue were cut and put into 90 ml deionized water and incubated for 60 min at 25 °C. The electrical conductivity of this solution was measured before and after incubation. Then same solution was boiled for 25 min at 121 °C. Following equation was used to determine electrolyte leakage

$$E = (C_{60} - C_1)/C_T \times 100 \quad (4)$$

2.8. Texture profile analysis

Texture profile analysis (TPA) were performed on ten mushroom caps by using TAXT Plus texture analyzer (Stable Micro Systems, Surrey, England) with diameter probe. Following conditions were selected for TPA analysis: pre-test speed of 10 mm/s, test speed of 2 mm/s, post-test speed of 10 mm/s and strain of 30%. Then, force versus time figure were obtained by texture exponent software and firmness, cohesiveness, springiness, gumminess, chewiness parameters of the mushrooms were calculated by using same software.

2.9. Development stage

Cap opening criteria for veil was used to determine development stage. For scoring, seven point scale (where 1 = thight, 2 = stretched, 3 = less than half broken, 4 = greater than half broken, 5 = completely broken, 6 = cap open, 7 = extremely cap open) was used to monitor the development of cap opening (González-Fandos, Giménez, Olarte, Sanz, & Simón, 2000).

2.10. FT-NIR analysis

FT-NIR spectrometer (Bruker Optik, GmbH, Ettlingen Germany) was used to perform reflectance analysis of ten mushrooms for per treatment. Optical probe of FT-NIR spectrometer was placed on the cap surface of mushroom at a 90° angle (Paz, Sánchez, Pérez-Marín, Guerrero, & Garrido-Varo, 2009). Reflectance spectrum was obtained by the average of 64 scans corresponded to one sample between 400 and 12,000 cm^{-1} wavelengths.

2.11. Statistical analysis

SAS 9.4 statistical analysis software (SAS Institute, Inc., Cary, NC) was used to compare the main effect of storage time, different concentrations of EW and interaction effect (storage time × different concentrations of EW) on the postharvest quality of white button mushrooms by Two-way ANOVA and Tukey post hoc comparison test. Overall means were compared when the interaction effect was not found significant. Datas were shown as mean ± standard deviation.