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Application of UV-C Irradiation on Quality and Textural Properties of Button Mushrooms

M. Ghasemi-Varnamkhasti, S .H. Yoosefian. A. Mohammad- Razdari

***Abstract*—**The effect of 1.0 kJ/m^2 Ultraviolet-C (UV-C) light on pH, weight loss, color, and firmness of button mushroom (*Agaricus bisporus*) tissues during 21-days storage at 4 ºC was studied. UV-C irradiation enhanced pH, weight, color parameters, and firmness of mushroom during storage compared to control treatment. However, application of 1.0 kJ/m^2 UV-C treatment could effectively induce the increase of weight loss, firmness, and pH to 14.53%, 49.82%, and 10.39%, respectively. These results suggest that the application of UV-C irradiation could be an effective method to maintain the postharvest quality of mushrooms.

***Keywords*—**Mushroom, polyethylene film, quality, UV-C irradiation.

I. Introduction

MUSHROOMS have been widely used as a human food for centuries and have been appreciated for their healthy properties. They have been proven to be effective as anti-inflammatory, antitumor, antibacterial, antioxidant, and antiviral agents. Button mushroom (*Agaricus bisporus*) is one of the most common and widely consumed edible mushroom types due to their functional properties [1]. However, mushrooms lose their quality quickly after the harvest in 1-3 days at ambient temperature [2] because of their thin epidermal structure, high respiration rate, high moisture content, and tyrosinase activity [3]. The critical quality indicators include browning, softening [4], cap development, weight loss and free of mold growth [5].

It is well known that browning is a major cause of quality losses of mushrooms and decreases the commercial value of the products. Browning of button mushroom during picking, handling, and storage are considered to be mediated by polyphenol oxidase (PPO) enzyme, which catalysed oxidation of phenolic substrates such as tyrosine, g-glutaminyl-4-hydroxybenzene (ghb) g-gluta-minyl-3,4dihydroxybenzene (GDHB) into quinines [5].

Polyethylene used in many cases has a wide range of physical properties. The main reason for its compliance with various applications lies in the configuration of semi-crystalline and molecular variables that can control the process during packaging [6].

UV irradiation is generally classified as UV-C (200– 280 nm), UV-B (280–320 nm), and UV-A (320–400 nm [7]. As a postharvest treatment on fresh produce, UV irradiation has been proven beneficial to reduce respiration rates, to control rot development, to induce disease resistance and to delay senescence and ripening in different fruits and vegetables [8]. All previous applications of UV-C treatment have been made postharvest. Moreover, the strategy that has been adapted to date has been to ensure that, as much as possible, the entire surface of the fruit receives exposure to UV-C. In laboratory studies, this has been achieved by manually rotating the fruit, whilst it is situated within the UV-C field [9]. Our previous research showed that UV-C radiation applied at proper doses (lower than 1.0 kJ/m^2) was effective in reducing Escherichia coli O157:H7 and microbial loads and inhibiting browning lesion development on button mushroom surface, also it may potentially extend storage periods without causing deterioration of nutritional quality of button mushrooms [10], [11].

The objective of this work was to evaluate the effects of UV-C irradiation on firmness, weight loss, color, pH, and microbial changing of mushroom during cold storage, which would help to elucidate the mechanism of UV-C.

II. Materials and Methods

A. Sample Preparation

Button mushroom material was used in this study and obtained from local place in Hamadan, Iran in 2015. The mushrooms were immediately transferred to the laboratory. Whole, white, and closed cap mushrooms with caps of 4–5 cm in diameter were chosen for each trial and treated within 6h after harvest.

B. UV-C Equipment

A germicidal UV-C irradiator containing two 0.6 m UV-C emitting bulbs with a peak emission at 254 nm (HIDROTEK, 110 W, England) was used. The UV-C dose rate was determined by UVX Digital Radiometer and the intensity of the UV-C lamp is 1 Wm^{-2} at a distance of 0.2 m. Mushrooms were illuminated with the UV-C lamp from the caps and stem sides for 100 s, respectively. Each side of mushrooms was subjected to irradiation treatment at a dosage of 1.0 kJ/m^2. Irradiation experiments were carried out at ambient temperature (ca. 25 ºC). After UV-C irradiation, mushrooms were packed in polyethylene film bags MH0075 (0.3 mm, 6.5 and 19 cm). The packed mushrooms were then stored at 4 ºC.

M. Ghasemi-Varnamkhasti is with the Department of Mechanical Engineering of Biosystems, Shahrekord University, Shahrekord, Iran (corresponding author, phone: +98-03832324405, fax: +98-03832324428, e-mail: ghasemymahdi@gmail.com).

S. H. Yoosefian is with the Department of Mechanical Engineering of Biosystems, Bu-Ali Sina University, Hamadan, Iran, (e-mail: hoad.mchanic@yahoo.com).

A. Mohammad-Razdari is with the Department of Mechanical Engineering of Biosystems, Shahrekord University, Shahrekord, Iran (e-mail: am.razdari@gmail.com).

Control mushrooms were handled similarly without UV-C exposure. For three weeks of storage, parameters had been measured.

C. pH Value

After that, the waste on mushrooms was discarded, 20 fresh mushrooms in each package were cut into small pieces, were homogenized with a blender, and were filtered through cheese cloth. pH value was measured by pH meter (PH-2211, Hana, Italy) [12].

D. Color

The color of mushrooms was measured with a portable colorimeter (HP-200, China). Standard white plate (CR-A43) was used to calibrate the colorimeter. CIE color space coordinates L*(Lightness), a* (red-green), and b* (yellow-blue) were recorded by using the colorimeter. Browning index (BI) and whiteness index (WI) were calculated by using following equations [13]:

$$BI = \frac{[100(x - 0.31)]}{0.17} \quad (1)$$

$$x = \frac{\left(a^* + 1.75L^*\right)}{\left(5.645L^* + a^* - 3.012b^*\right)} \quad (2)$$

E. Weight Loss

Package weights of mushrooms were recorded at the beginning of storage and at each sampling day. Subsequently, all packages were coded before the experiment. Results were expressed as the percentage loss of initial package weight of samples [14].

F. Firmness

Texture was used to measure penetration resistance. Firmness was measured with a texture analyzer Instron (500 N, Xforce hp, Germany). A 2-mm flat probe was used to penetrate the convex side of each clove at 5 mm depth and 1 mm/s.

G. Statistical Analysis

The data are presented as the averages of three measurements. For the evaluation of data significance statistical programs SAS and ANOVA were used. The level of significance was set at $P<0.05$ (95% statistical confidence level).

III. Results and Discussion

A. pH and Color

A significant decrease in the pH values of the samples was observed during the storage (Fig. 1). It is possible that the production of organic acids by microorganisms resulted in decreases in pH values of mushrooms [15]. The lower changes were observed in the control mushrooms and the mushrooms in polyethylene film. As it was previously reported, many factors such as the production system used in the grapevine cultivation [16] or postharvest treatments such as UV-C radiation [17] may alter the specialized or secondary metabolism of plants. Previous studies regarding the effects of UV-C irradiation on pH and antioxidant activity of fruits and vegetables have reported decrease in pH and increase in antioxidant capacity. Decrease in pH capacity of inner cap and gill might be as part of the defense mechanism produced by mushroom tissues in reacting to stress induced by UV-C exposure despite the low penetrating ability of UV-C [7].

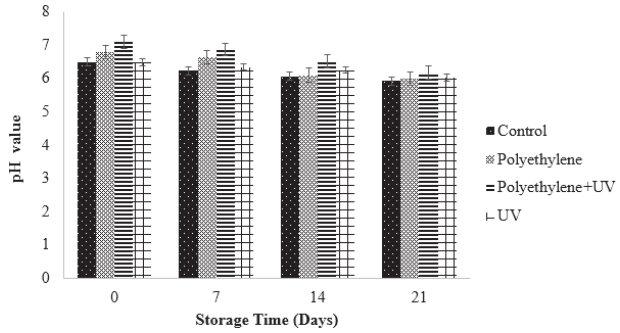
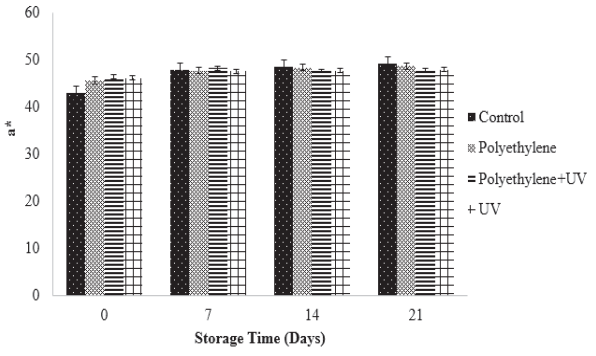
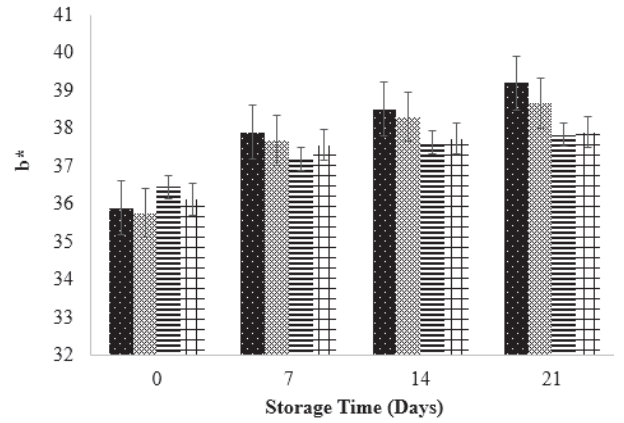


Fig. 1 Changes in pH values of mushrooms, Control (control mushrooms), polyethylene (mushrooms packed in polyethylene film), polyethylene + UV (irradiated UV mushrooms packed in polyethylene film), UV (irradiated UV) for 21-days storages at 4 ºC

The redness of mushrooms fruit was reflected by a* values, which means green (−60) and red (60). These values increased substantially in all groups (Fig. 2 (a)). There were no significant differences between control, polyethylene film, and UV groups during storage at 21-days period where a* value of polyethylene + UV treated fruit was a little lower than those of the other groups. The biggest changes of b* values occurred with control treatments after the third week. On the other hand, increasing the storage time increased the amount of b*, and the brightness is reduced. Increasing the amount of yellowing with increasing storage is because of mushrooms which usually lost plenty of volatiles during adulthood and ripening, and browning of the white mushroom after harvest had a linear relationship with the elapsed time that is proportional to the dose [18].



(a)



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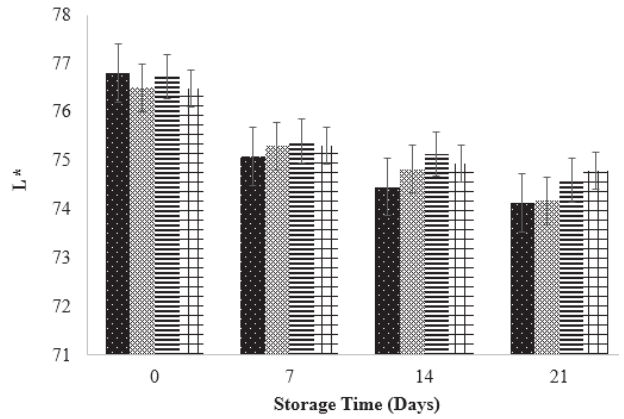

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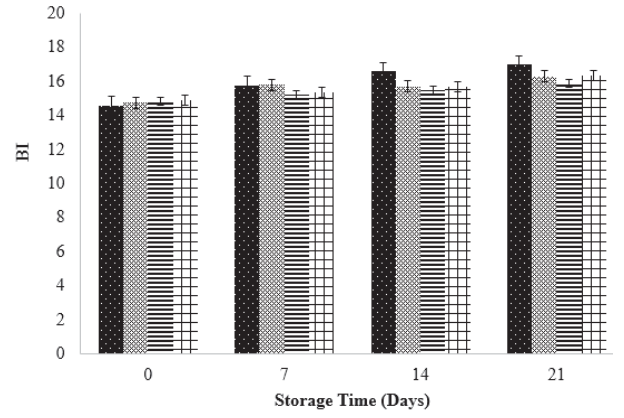

(d)

Fig. 2 Changes in color parameter (a) a*, (b) b*, (c) L* and (d) BI, of mushroom for control (control mushrooms), polyethylene (mushrooms packed in polyethylene film), polyethylene + UV (irradiated UV mushrooms packed in polyethylene film), UV (irradiated UV) for 21-days storage at 4 ºC

B. Weight Loss

Weight losses of all of samples are shown in Table I. Quality of mushrooms loses rapidly due to the water loss from their thin epidermal layer during storage [4]. A significant increase was observed for the weight loss of all samples. The statistical analysis showed that there were significant differences between the irradiated samples in polyethylene film and control samples. The weight loss was lower for UV-C irradiated samples in polyethylene film than control samples, non-irradiated samples at polyethylene films and UV-C irradiated samples without packaging by an amount of 10.14%, 7.05%, and 9.6%, respectively. That is because samples lost its tissue with increasing of storage time, and their interstitial water has been dried. Of course, due to biological activity breathing, moisture content decreased [21]. Because the cells are full of water in fresh mushrooms, and substance density is higher [19].

TABLE I
CHANGES IN WEIGHT LOSS OF MUSHROOM FOR 21 STORAGE AT 4 ºC

Treatment	Storage Time (Days)			
	0 Week	1 Week	2 Week	3 Week
Control	1.44 ±0.08	1.88±0.06	2.52±0.13	2.74±0.14
Polyethylene	1.52±0.04	1.89±0.07	2.35±0.10	2.71±0.09
Polyethylene + UV	1.37±0.09	1.63±0.05	1.86±0.09	2.17±0.11
UV	1.21±0.13	1.70±0.04	1.94±0.13	2.26±0.19

Data are means ± SD of three replicates.
Control (control mushrooms), polyethylene (mushrooms packed in polyethylene film), polyethylene + UV (irradiated UV mushrooms packed in polyethylene film), UV (irradiated UV).

C. Firmness

Firmness decreased during the storage at 4 ºC in both control and treated mushrooms, but the non-irradiated mushrooms softened earlier (Fig. 3). Immediately after irradiation (0h), there was no significant difference between the firmness values of the control and UV-C treated mushrooms. However, after seven days at 4 ºC, the irradiated mushrooms were firmer than the control mushrooms. Compared with the initial values, firmness of the control group decreased by 49.82%, 36.27%, and 20.71% with respect to UV-C irradiated samples in polyethylene film, non-irradiated samples at polyethylene films, and UV-C irradiated samples without packaging, respectively, by the end of the experimental period.

According to the results, the UV treatment had medium effects on firmness. Pan et al. [20] have shown that the firmness decrease can be reduced by UV-C irradiation, thus extending strawberry fruit postharvest life, and Pombo et al. [21] have shown that UV-C irradiation had effects on a set of genes involved in cell wall degradation, delayed strawberry softening.

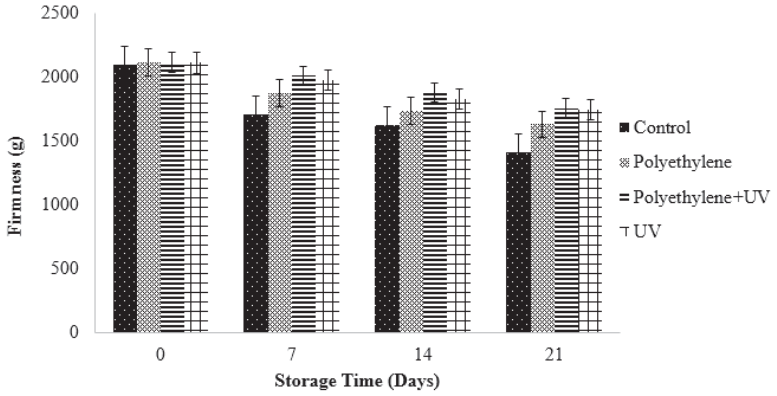

Fig. 3 Changes in firmness of mushroom, control (control mushrooms), polyethylene (mushrooms packed in polyethylene film), polyethylene + UV (irradiated UV mushrooms packed in polyethylene film), UV (irradiated UV) for 21-days storage at 4 ºC

IV. Conclusion

This study was set out to determine the effectiveness of UV-C irradiation with polyethylene film on mushroom shelf life. This research has shown that combination of UV-C irradiation with polyethylene film maintained the quality of mushrooms better than other treatments. The second finding was that the polyethylene film UV-C irradiation treatment did not show any detrimental effect on mushrooms even at high concentration compared to the untreated samples. In conclusion, the results of this research support the idea that the combined use of UV-C irradiation with polyethylene packaging can be used to extend the shelf life of button mushrooms (*Agaricus bisporus*) due to the preservation of weight, color, firmness, and pH.

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