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Original Article

Comparative Efficacy of Wheat-Gluten-Coated Paper, Polyethylene, and Polypropylene Packaging for Quality Retention of *Agaricus bisporus* During Refrigerated Storage

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ABSTRACT: *Agaricus bisporus* (button mushroom) belongs to the family Agaricaceae, is a macroscopic fungus, and is the most popular cultivated mushroom variety. It is highly demanded among consumers due to its extraordinary nutritive, organoleptic, and therapeutic properties. However, due to its high respiration rate, it has rapid postharvest degradation, with a shelf life of 1-2 days at ambient temperature (Temp 25, RH 70%). This study investigated the effect of WG-paper, polyethylene, and polypropylene packaging on maintaining and increasing the shelf life of *Agaricus bisporus*. All the samples were stored at 2°C and ambient temperature (control) without packaging. The results showed differences among the evaluated treatment conditions in the measured quality attributes. The WG-paper exhibited good quality, characterized by the highest firmness and L* values, a lower percentage of weight loss, a reduced percentage of open caps, a smaller ΔE, and a better BI. PE and PP were not very effective in the quality retention of mushrooms with an increase in storage time. PE and PP have shown unpleasant water condensation on the inner surface of the packaging film, which may be due to low water permeability; this condensation affects the quality of the mushrooms, and their non-biodegradability is also an important environmental consideration. The best results were obtained at 2°C, as at this temperature, due to less respiration, metabolic activity occurs, which reduces mushroom senescence and maintains their quality. However, at ambient temperature, the samples completely deteriorated after 15 days of storage. Among the evaluated conditions, WG-paper at 2°C provided the best retention of physical-quality attributes through 15 days of storage. Microbiological safety and sensory acceptability were not evaluated; therefore, "shelf life" is used cautiously and refers only to the measured physical-quality attributes.

Keywords: *Agaricus bisporus*, Mushroom, Packaging Material, Post-harvest, Shelf Life.

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1. INTRODUCTION

Agaricus bisporus (button mushroom) is an edible basidiomycete mushroom that belongs to the family Agaricaceae, native to Europe and North America (Dandge, 2012). It is the most popular variety grown, accounting for 30% of total worldwide mushroom production (Ramos et al., 2019). *Agaricus bisporus* is gaining popularity among consumers because of its nutritive and therapeutic properties and is the most commonly cultivated edible mushroom species (Lin & Sun, 2019). Mushrooms contain a high content of protein, fiber, minerals, vitamins, antioxidants, and a low fat content. Mushroom protein consists of essential amino acids, and among the fatty acids, the most abundant are palmitic, stearic, oleic, and linoleic acids (Palacios et al., 2011). It is highly enriched in vitamins such as B1, B2, B3, and C; mineral elements such as Cu, Se, and Mo; and also folate, niacin, ergosterol, and polysaccharides (Gantner et al., 2017). The

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chemical composition of mushrooms is also extremely variable. Fresh mushrooms have a solid content ranging from 6 to 11% and a very high water content of 89-94%. Fresh mushrooms also contain 2.5-5.8% carbohydrates, crude fat (0.2-0.7%), protein (2.6-4%), fiber (0.6-1.1%), and more than 1% ash (Walde et al., 2006). Extracts from mushrooms (mushroom nutraceuticals) are a potential treatment for cardiovascular disorders, boost the immune system, and inhibit the growth of tumors (Tariq et al., 2020; Atila et al., 2017). Over the last ten years, global production and consumption of fresh cultivated mushrooms have risen significantly. However, their high respiration rate (RR) and rapid post-harvest degradation remain an economic issue (Guillaume et al., 2010). Mushrooms have a very thin and porous epidermal structure, due to which the rate of respiration in mushrooms is relatively high (200-500 mg kg^{-1} h^{-1} at 20±1) compared with that of other fruits and vegetables (Zalewska et al., 2018; Wang et al., 2024). High metabolic activity, respiration rate, and dehydration contribute to the rapid decay of mushrooms (Wrona et al., 2016; Zhang et al., 2018). Storage for 1 day at ambient temperature results in browning and cap opening, stem elongation, and softening and sponginess of texture, causing a depression in their value (Guillaume et al., 2010). The rate of post-harvest quality deterioration in mushrooms can be slowed through different approaches, such as various cold storage temperatures, chemical treatments, pre-cooling, and the use of different packaging materials (Qin et al., 2015; Salamat et al., 2020). The impact of storage temperature on post-harvest mushroom quality is significant, as key degradation reactions are highly temperature-dependent; these include respiration, browning, and maturation (Ares et al., 2007). Texture softening and sponginess in mushrooms increase as storage temperature increases (Gao et al., 2014). The role of packaging in controlling the mushroom senescence rate is also important. It is an effective tool for controlling microbial growth and influencing physiological effects in mushrooms (Kim et al., 2007). Selecting the right packaging material greatly influences mushroom quality, and these materials should be selected in relation to storage conditions (Gholami et al., 2017). It is conveyed that the postharvest appearance of mushrooms is effectively maintained using polypropylene film by substantially decreasing the occurrence of unattractive aerial hyphae on the surface and inhibiting softening in mushrooms (Qin et al., 2015; Esmer et al., 2021). Using different biobased packaging materials, such as paper coated with wheat gluten solution, is also effective in preventing deterioration and senescence of button mushrooms (Barron et al., 2002).

Compared to cereal crops, fruits and vegetables are more susceptible to spoilage due to their nature and composition; the main spoilage occurs during harvesting, handling, transportation, and storage (Ares et al., 2007). Post-harvest quality loss occurs because of physiological and biological processes, the activity of which is influenced by storage temperature and packaging (Beetz & Kustudia, 2004). The perishable nature of mushrooms is an obstacle to their supply and marketing as a fresh product. Therefore, prolonging shelf life while preserving quality benefits growers and consumers. Considering these points, the present investigation was carried out with the following objectives: First, to compare different effective & viable packaging materials for maintaining the attributes of button mushrooms. Second, to check the shelf life improvement of button mushrooms at different cold storage temperatures.

2. MATERIALS AND METHODS

2.1 Plant material

Samples of harvested button mushrooms were collected from the PMAS Arid Agriculture University, Rawalpindi project area, and the research trial was conducted using different packaging materials, such as WG-paper, polyethylene bags, and polypropylene boxes. The dimensions of the WG paper and PE packaging were 20 × 15 cm, and the dimensions of the PP containers were 20 × 15 × 5 cm. The thickness of the WG paper was to be 80–150 μm, the PE film 30–60 μm, and the PP container wall 0.5–1.0 mm. The mushroom loading was to be 250–500 g per package. Fresh fruiting bodies of *Agaricus bisporus* were deemed to be picked at the closed to partly closed button stage, reasonably uniform commercial-grade size, around 30–50 mm in cap diameter, and free from apparent bruising, rot, and mechanical harm. The packed treatments (WG-paper, PE, and PP) were kept at 2°C and 60-70% relative humidity, and the control was kept at AT (ambient temperature) without packaging. Samples were analyzed after storage for 0, 5, 10 & 15 days.

2.2. Preparation of wheat gluten coating

For this purpose, according to Gastaldi et al. (2007), wheat gluten coating was prepared by tendering an equal part of an aqueous preparation of gluten (gluten concentration & sodium sulfite at 40% and 0.08% (w/v), respectively).

Then, a 2% (v/v) acetic acid solution was added under stirring. The prepared solution was then deposited on paper and dried in the oven at 120 for 30 s.

2.3. Firmness measurement (N)

Mushroom firmness was measured by a penetration test using a penetrometer with a 2 mm diameter probe. The probe was penetrated to a depth of 5mm into the mushroom cap. The force applied to the punctured mushroom cap was recorded as firmness or texture (Gholami et al., 2020).

2.4. Weight loss

Weight loss was measured by weighing whole mushrooms on an electronic weighing machine (g) before and after storage. The weight loss was expressed as a percentage of the loss of weight with respect to the initial weight.

Weight loss% = $\frac{(Wo-W1)}{Wo}$ x100

Where, W_0 is the initial weight, and W_t is the weight after the specified storage period (Gantner et al., 2017).

2.5. Color Analysis

Color analysis of the mushroom cap (an important quality parameter) was done using a digital portable colorimeter. For this, three samples from each treatment were randomly selected and numbered. Then, with the help of a marker, a specific area on the mushroom cap was marked, and color changes at that area were recorded after storage. A colorimeter was used to check the samples, and the CIE L*a*b* coordinates were recorded. To calculate overall color variation (ΔE), the following equation was used.

$$\Delta E = \sqrt{\Delta L * 2 + \Delta a * 2 + \Delta b * 2}$$

Further, to calculate the browning index, the following equation was used. In products with high enzymatic activity, this is an important factor.

Where, the subscripts 0 and t represent measurements before and after storage, respectively.

2.5.1.-Total Color Difference (ΔE)

$$\Delta E = \sqrt{[(L_t^* - L_0^*)^2 + (a_t^* - a_0^*)^2 + (b_t^* - b_0^*)^2]}$$

Where, L_0^*, a_0^*, and b_0^* are the initial CIE L*a*b* values, and L_t^*, a_t^*, and b_t^* are the corresponding values after storage.

2.5.2. Browning Index (BI)

The browning index was calculated using the following equation:

$$BI = \frac{100\,(x-0.31)}{0.172}$$

$$x = \frac{a+1.75L}{5.645L+a-3.012b}$$ (Oliveira et al., 2012)

Where, L*, a*, and b* are the CIE color coordinates.

2.6 Percent Open Cap

Button mushroom cap opening, which develops into an umbrella-shaped cap, is an important determinant of mushroom senescence and quality loss that directly influences marketability. During storage, the percentage of cap opening was measured by the following equation:

Percent open caps (%) = $\frac{No}{Nt}$ x 100 (Gholami et al., 2020)

Where N_o is the number of opened caps, and N_t is the total number of mushrooms evaluated.

2.7. Statistical Analysis

The experiment used a completely randomized design (CRD) with one-way ANOVA as the appropriate statistical design, with three replicates. Figures were analyzed using analysis of variance (ANOVA) techniques, and mean differences between treatments were compared using the Least Significant Difference (LSD) test at the $P < 0.05$ significance level, with the help of Statistix 8.1 software (Steel et al., 1997).

3. RESULTS AND DISCUSSION

3.1 Firmness

The textural changes are caused by the progressive softening of fruit during ripening. Firmness is closely related to hardness but is rarely used to define the property of a substance capable of resisting alteration under its own weight (Buruleanu et al., 2018). According to Guillaume et al. (2010), firmness is a force required to bite through the food. Mushroom ageing causes softening and sponginess in texture, which is considered an unstiffening of mushroom tissue. The general trend in firmness changes in mushrooms of all packaging during storage at 2°C and AT. Fig. 2 illustrates the relative weight loss in packaging during storage at 2°C, and the control is shown in Fig. 1. The observed trend could be due to degradation of polysaccharides and proteins, shrinkage of hyphae, and disruption of the central vacuole (Muszynska et al., 2017). At day 15 of storage at 2°C, the highest level (13.7±0.5) was obtained with paper-WG packaging, followed by PE (12.1±0.1) and the lowest with PP (11.9±0.1). However, in the control (at ambient temperature), more significant changes were observed: firmness was 14.8±0.7 on day 0 and decreased to 2.5±0.5 on day 15. Similar results were reported by Singh et al. (2018), who found that paper-WG, which has a higher water transmission rate than common PE packages, maintained maximum firmness.

Furthermore, mushrooms packaged in the paper-WG were significantly (p<0.05) firmer than those packaged in PE, PP and the control treatment. Changes in firmness were comparatively slow at 2°C in all packages, increased with rising storage temperature, and were faster at ambient temperature (control). The improved retention of firmness, colour and moisture in WG-paper might be attributed to its ability to create a favourable moisture- and gas-transfer environment during refrigerated storage. Recent studies have shown that packaging systems with suitable gas permeability can control the internal O2/CO2 atmosphere, reduce respiration and enzymatic browning, and preserve the colour and texture of A. *bisporus* (Jiang et al., 2024).

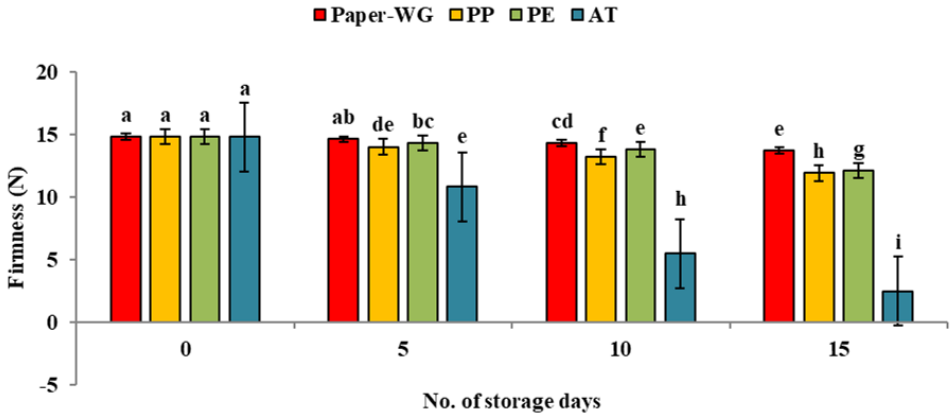


Figure 1. Effect of packaging material stored at 2⁰C and control on firmness of button mushroom

3.2 Weight loss %

The dehydration process is an imperative aspect of quality reduction in mushrooms during postharvest storage. The relative weight loss in packaging during storage at 2°C and the control is shown in Fig. 2. In general, weight loss tends to increase with time in all packages. Singh et al. (2010) reported that a loss of 5-6% of harvested mushrooms leads to a reduction in commercial value due to noticeable quality deterioration. After 15 d of storage at 2°C, weight loss was 0.3%, 1.7%, and 2.8% for paper-WG, PE, and PP, respectively, and 58.6% for the control at AT. This may be because mushrooms are protected only by a thin epidermal structure, which may not impede rapid superficial dehydration, and because mushrooms have a relatively high respiration rate (Muszynska et al., 2017).

Furthermore, mushrooms packaged in paper-WG had significantly (p<0.05) less weight loss (%) than those packaged in PE, PP, and the control treatment. This is in agreement with the results of Guillaume et al. (2010), where the overall quality of mushrooms was best on day 3 when stored with WG-paper. In the case of PE, a PP packaging film, condensed water was observed on the inner surface of the film at 10 d of storage. This might be due to the low water vapour permeability of the packaging materials combined with a high transpiration rate. The very little weight loss in WG-paper shows efficient moisture retention during refrigerated storage. This supports previous research that packaging permeability is linked to moisture loss in *A. bisporus*, and recent biobased and modified-atmosphere films have shown lower weight loss than conventional packaging systems (Oliveira et al., 2012; Sun et al., 2023).

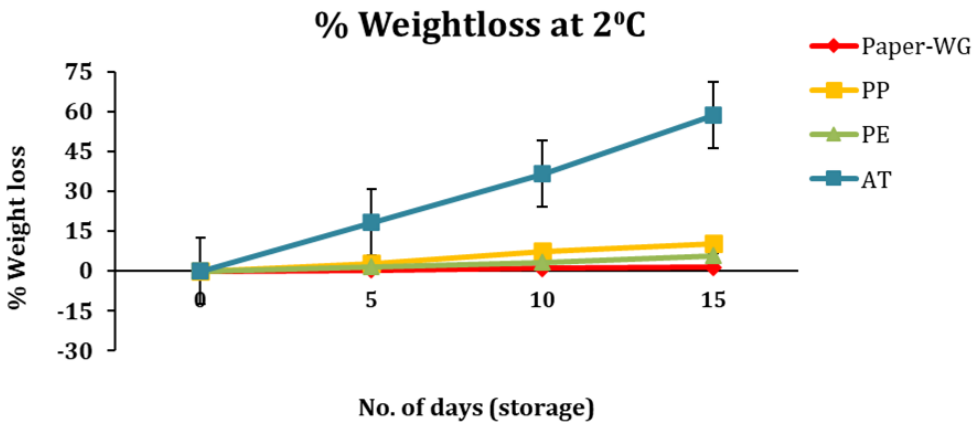


Figure 2. Effect of packaging material stored at 2⁰C and control on weight loss % of button mushroom

3.3 Color Analysis

L* value: L* is used to denote the luminosity of the mushroom sample. A lower L* value reflects darkening or blackening of the mushroom samples. Mushroom's quality can be categorized as good quality for L* values higher than 86 and fair quality for L* values between 85 and 80 (Fernandes et al. 2012). The analysis in Fig. 3 shows a significant influence ($p<0.05$) of packaging film and storage temperature on the L* (brightness) colour parameter of white button mushrooms. The L* value showed a decreasing trend across all packaging materials, consistent with the previous study by Oliveira et al. (2012). The initial L* of fresh mushroom samples was 90.59±1.5. The decrease in L* was slower at a storage temperature of 2°C than in the control. At the end of 15 days of storage, the highest L* was with WG-paper (82.6±2.1), followed by PE (78.8±1.4), while PP had the lowest L* value (74.6±0.46). In addition, the control at ambient temperature significantly affected the L* of white button mushrooms, with an L* value of 47.9±2.3 at the end of 15 days of storage. Simón et al. (2010) reported that this decrease in L* can be associated with enzymatic browning, and that the brown colour of mushrooms is linked to dark pigments, melanins, which are products of the oxidation and polymerisation of phenolic substrates. PP had more browning, colour change, and cap opening than WG-paper, suggesting worse quality retention. The current research did not explicitly examine packaging gas-transfer properties, although recent investigations have shown that they greatly affect A. *bisporus* respiration, PPO-mediated browning, and senescence (Sun et al., 2023; Lei et al., 2024).

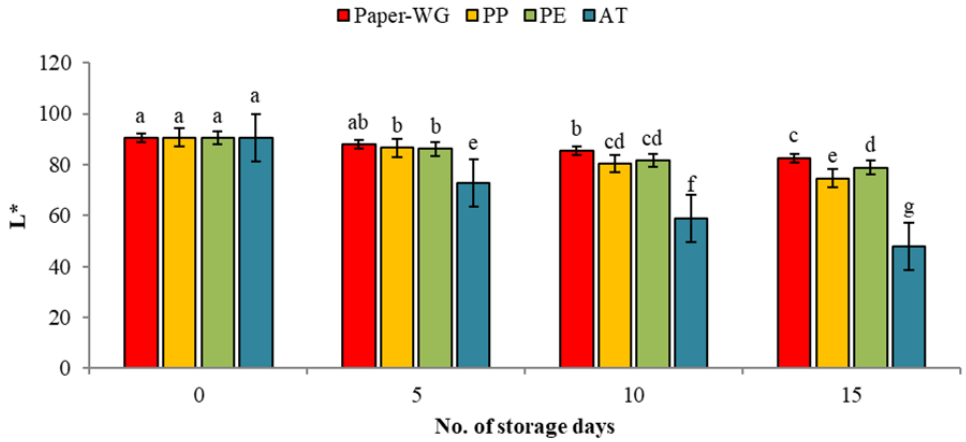


Figure 3. Effect of packaging material stored at 2⁰C and control on L* value of button mushroom

Change in color (ΔE): ΔE is the total colour variation in the mushroom. An increasing trend in ΔE was shown in Fig. 4 for all packaging materials over subsequent days of storage in all samples. Results show that packaging material type significantly ($p<0.05$) influences total colour change. On the 15th day of storage, the highest ΔE values were found in PP (15.0±0.4), then in PE (13.09±0.7), and the least colour change was with WG-paper (5.22±1). The control treatment at AT greatly influenced the ΔE value; on the 15th day of storage, the recorded ΔE was 50.62±2.21. Furthermore, mushrooms packaged in paper-WG changed significantly ($p<0.05$) less in colour than those packaged in PE, PP, and the control treatment.

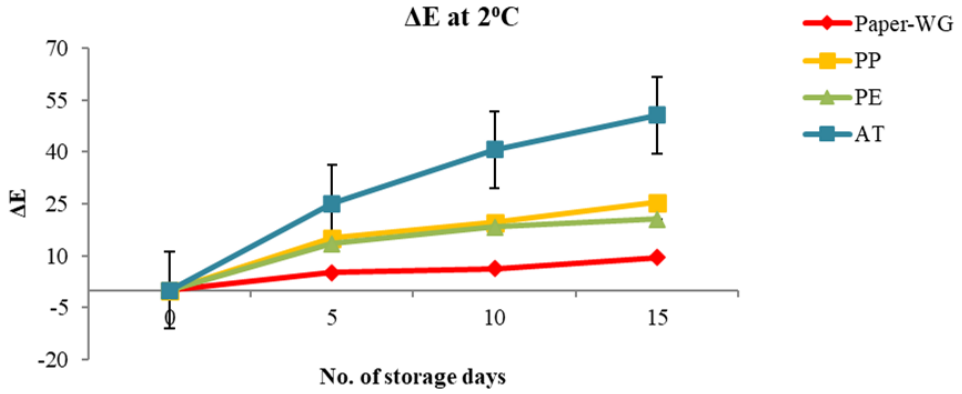


Figure 4. Effect of packaging material stored at 2⁰C and control on ΔE of button mushroom

Browning Index (BI): The white colour of the button mushroom is an important parameter for consumer acceptance. Button mushrooms have a short shelf life, as they turn brown and lose quality within a few days of storage. The BI is one of the key quality features for measuring the degree of deterioration in the appearance of white button mushrooms. (Lagnika et al., 2013; Quevedo et al., 2016). Oliveira et al. (2012) reported that browning is mainly due to the oxidation of phenolic compounds catalysed by tyrosinase. In general, an increasing trend was observed in all samples, with all packaging materials shown in Fig. 5. On the 15th day of storage at 2°C, the highest BI values were found in PP (48.2±5), then in PE (32.6±2.4), and the least colour change was observed in WG-paper (15.1±0.8). The control treatment at AT greatly influenced the BI value; on the 15th day of storage, the BI recorded was 70.01±2.7.

Furthermore, mushrooms packaged in paper-WG had a significantly lower (p<0.05) browning index (BI) value than those packaged in PE, PP, and the control treatment. These results agree with those for sliced mushrooms reported by Qin et al. (2015), who observed that BI increased up to 12 days of storage in all packaging films. The reduced ΔE and browning index in WG-paper suggest improved mushroom white appearance retention. Recent studies have demonstrated that proper packing atmospheres may reduce browning-related physiological and enzymatic processes, particularly PPO activity, to preserve mushroom colour during refrigerated storage (Jiang et al., 2024; Lei et al., 2024).

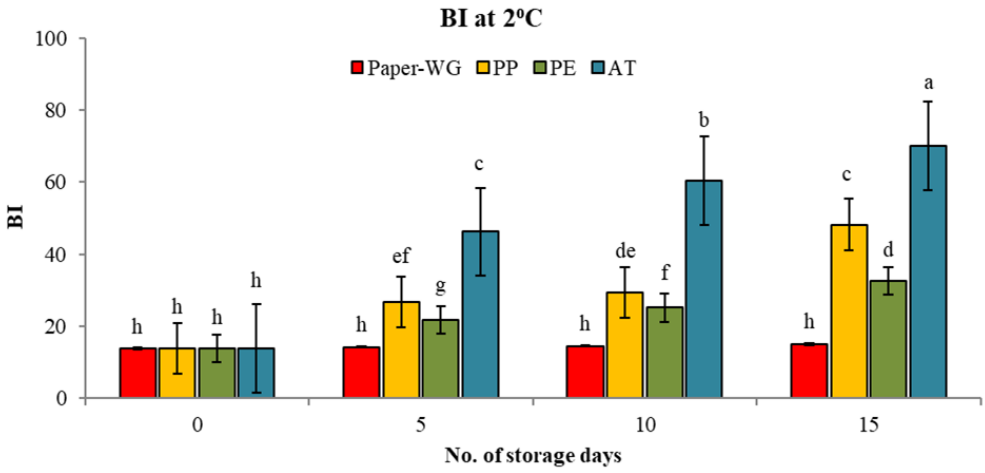


Figure 5. Effect of packaging material stored at 2⁰C and control on BI of button mushroom.

3.4 Percent Open Cap

Cap opening increased in all treatments during the whole storage period. The percentage of cap opening during the storage period is considered the maturity index and indicates decreased moisture content. The opening of mushroom caps was related to mushroom dryness due to water loss during storage (Ban et al., 2014). The general trend of percent open cap is shown in Fig. 6. After 15 days of storage at 2°C, the highest level was observed in PP (33.3%), followed by PE packaging (13.3%). However, no caps were opened in WG-paper at 2°C. More significant differences (p<0.05) were observed at ambient temperature, where 100% of caps were opened at the end of 15 days of storage. These results are consistent with those reported by Gholami et al. (2020) on the post-harvest quality of *Agaricus bisporus L*. Furthermore, mushrooms packaged in the paper-WG had a significantly lower percentage of opened caps than those packaged in PE, PP and the control treatment (p<0.05). The lack of cap opening in WG-paper after 15 days suggests

greater closed-cap retention under testing circumstances. This supports prior studies showing that low-temperature packing may delay maturity-related alterations and cap opening in *A. bisporus* (Gholami et al., 2017; Vazirianjafari et al., 2023). Representative images of mushroom samples after 15 days of storage under the different treatment conditions are shown in Fig. 7.

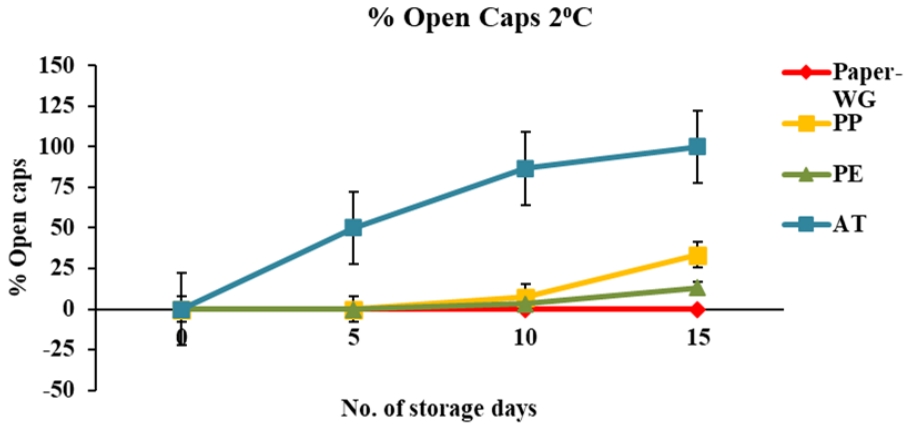


Figure 6. Effect of packaging material stored at 2ºC and control on % open cap of button mushroom

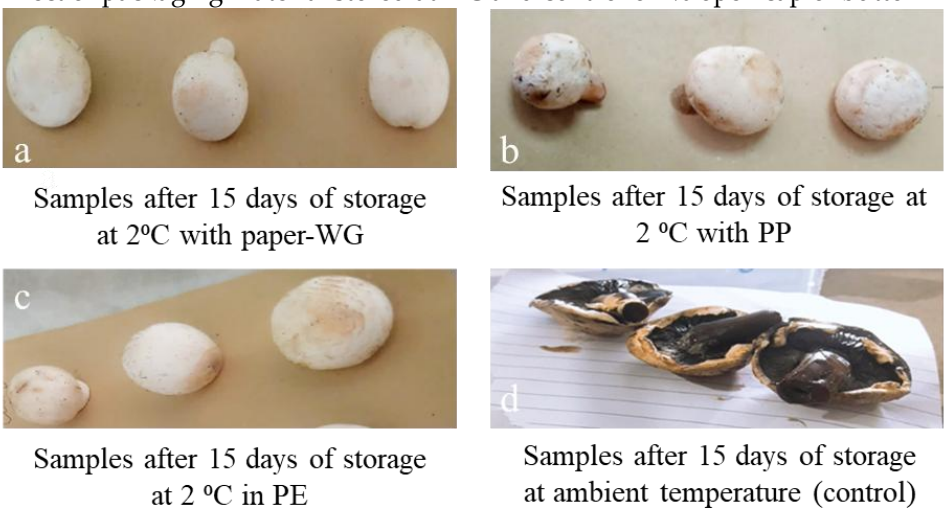


Figure 7. Samples after 15 days of storage under different conditions

4. CONCLUSION

Among the treatment conditions evaluated, WG-paper packaging at 2°C provided the best retention of the measured physical-quality attributes of *Agaricus bisporus* through 15 days of storage. In comparison, the unpackaged control was maintained at ambient temperature. Therefore, the findings represent treatment-condition comparisons rather than independent packaging effects, and 15 days should not be considered definitive shelf life. Further studies incorporating microbial safety, sensory acceptability, and factorial temperature–packaging treatments are recommended.

Ethical Statement

Not Applicable.

Conflicts of Interest

The authors declare no competing interests.

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REFERENCES

Ares, G., Lareo, C., & Lema, P. (2007). Modified atmosphere packaging for postharvest storage of mushrooms. A review. *Fresh Produce*, *1*(1): 32-40. http://doi.org/10.1016/j.postharvbio.2008.01.020

Atila, F., Owaid, M. N., & Shariati, M. A. (2017). The nutritional and medical benefits of *Agaricus bisporus*: A review. *Journal of Microbiology, Biotechnology and Food Sciences*, *7*(3): 281-286. https://doi.org/10.15414/jmbfs.2017/18.7.3.281-286

Ban, Z., Li, L., Guan, J., Feng, J., Wu, M., Xu, X., & Li, J. (2014). Modified atmosphere packaging (MAP) and coating for improving preservation of whole and sliced *Agaricus bisporus*. *Journal of Food Science and Technology*, *51*(12): 3894-3901. https://doi.org/10.1007/s13197-013-0935-9

Barron, C., Varoquaux, P., Guilbert, S., Gontard, N., & Gouble, B. (2002). Modified Atmosphere Packaging of Cultivated Mushroom (*Agaricus bisporus* L.) with Hydrophilic Films. *Journal of Food Science*, *67*(1): 251-255. https://doi.org/10.1111/j.1365-2621.2002.tb11393.x

Beetz, A., & Kustudia, M. (2004). *Mushroom cultivation and marketing*. ATTRA.

Buruleanu, L. C., Radulescu, C., Georgescu, A. A., Danet, F. A., Olteanu, R. L., Nicolescu, C. M., & Dulama, I. D. (2018). Statistical Characterization of the Phytochemical Characteristics of Edible Mushroom Extracts. *Analytical Letters*, *51*(7): 1039-1059. https://doi.org/10.1080/00032719.2017.1366499

Dandge, V. S. (2012). Studies on some fungi in button mushroom cultivated in Akola (Amanatpur). *Recent Research in Science and Technology*, *4*(10): 28-30.

Esmer, Ö. K., Koçak, E., Şahiner, A., Türksever, C., Akin, P., Acar, A., & Adman, N. D. (2021). The microperforated packaging design and evaluation of shelf life of fresh-sliced mushrooms. *Potravinarstvo Slovak Journal of Food Sciences*, *15*: 83-94. https://doi.org/10.5219/1530

Fernandes, Â., Antonio, A. L., Barreira, J. C. M., Oliveira, M. B. P. P., Martins, A., & Ferreira, I. C. F. R. (2012). Effects of gamma irradiation on physical parameters of *Lactarius deliciosus* wild edible mushrooms. *Postharvest Biology and Technology*, *74*: 79-84. https://doi.org/10.1016/j.postharvbio.2012.06.019

Gantner, M., Guzek, D., Pogorzelska, E., Brodowska, M., Wojtasik-Kalinowska, I., & Godziszewska, J. (2017). The Effect of Film Type and Modified Atmosphere Packaging with Different Initial GAS Composition on the Shelf Life of White Mushrooms (*Agaricus bisporus* L.). *Journal of Food Processing and Preservation*, *41*(1): e13083. https://doi.org/10.1111/jfpp.13083

Gao, M., Feng, L., & Jiang, T. (2014). Browning inhibition and quality preservation of button mushroom (*Agaricus bisporus*) by essential oils fumigation treatment. *Food Chemistry*, *149*: 107-113. https://doi.org/10.1016/j.foodchem.2013.10.073

Gastaldi, E., Chalier, P., Guillemin, A., & Gontard, N. (2007). Microstructure of protein-coated paper as affected by physico-chemical properties of coating solutions. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, *301*(1-3): 301-310. https://doi.org/10.1016/j.colsurfa.2006.12.079

Gholami, R., Ahmadi, E., & Ahmadi, S. (2020). Investigating the effect of chitosan, nanopackaging, and modified atmosphere packaging on physical, chemical, and mechanical properties of button mushroom during storage. *Food Science & Nutrition*, *8*(1): 224-236. https://doi.org/10.1002/fsn3.1294

Gholami, R., Ahmadi, E., & Farris, S. (2017). Shelf life extension of white mushrooms (*Agaricus bisporus*) by low temperatures conditioning, modified atmosphere, and nanocomposite packaging material. *Food Packaging and Shelf Life*, *14*: 88-95. https://doi.org/10.1016/j.fpsl.2017.09.001

Guillaume, C., Schwab, I., Gastaldi, E., & Gontard, N. (2010). Biobased packaging for improving preservation of fresh common mushrooms (*Agaricus bisporus* L.). *Innovative Food Science & Emerging Technologies*, *11*(4): 690-696. https://doi.org/10.1016/j.ifset.2010.05.007

Jiang, X., Feng, L., Han, J., Li, L., Wang, J., Liu, H., Kitazawa, H., & Wang, X. (2024). Preparation of hydroxypropyl methylcellulose/pueraria-based modified atmosphere film and its influence on delaying the senescent process of postharvest *Agaricus bisporus*. *International Journal of Biological Macromolecules*, *261*(Part 2): 129611. https://doi.org/10.1016/j.ijbiomac.2024.129611

Kim, B. S., Park, S. Y., Jang, M. S., & Kwon, A. S. (2007). Effect of prolongation by precooling treatment and improved packing of mushrooms (*Agaricus bisporus*). *Korean Journal of Food Preservation*, *14*(1): 109-112.

Lagnika, C., Zhang, M., & Mothibe, K. J. (2013). Effects of ultrasound and high pressure argon on physico-chemical properties of white mushrooms (*Agaricus bisporus*) during postharvest storage. *Postharvest Biology and Technology*, *82*: 87-94. https://doi.org/10.1016/j.postharvbio.2013.03.006

Lei, M., Guo, L., Zhang, Y., Yan, X., Jiang, F., & Sun, B. (2024). Effectiveness of anaerobic treatment combined with microperforated film packaging in reducing *Agaricus bisporus* postharvest browning. *Postharvest Biology and Technology*, *211*: 112833. https://doi.org/10.1016/j.postharvbio.2024.112833

Lin, X., & Sun, D.-W. (2019). Research advances in browning of button mushroom (*Agaricus bisporus*): Affecting factors and controlling methods. *Trends in Food Science & Technology*, *90*: 63-75. https://doi.org/10.1016/j.tifs.2019.05.007

Muszyńska, B., Kała, K., Rojowski, J., Grzywacz, A., & Opoka, W. (2017). Composition and Biological Properties of *Agaricus bisporus* fruiting bodies: A review. *Polish Journal of Food and Nutrition Sciences*, *67*(3): 173-181. https://doi.org/10.1515/pjfns-2016-0032

Oliveira, F., Sousa-Gallagher, M. J., Mahajan, P. V., & Teixeira, J. A. (2012). Evaluation of MAP engineering design parameters on quality of fresh-sliced mushrooms. *Journal of Food Engineering*, *108*(4): 507-514. https://doi.org/10.1016/j.jfoodeng.2011.09.025

Palacios, I., Moro, C., Lozano, M., D'Arrigo, M., Guillamón, E., García-Lafuente, A., & Villares, A. (2011). Use of Modified Atmosphere Packaging to Preserve Mushroom Quality during Storage. *Recent Patents on Food, Nutrition & Agriculture*, *3*(3): 196-203. https://doi.org/10.2174/2212798411103030196

Qin, Y., Liu, D., Wu, Y., Yuan, M., Li, L., & Yang, J. (2015). Effect of PLA/PCL/cinnamaldehyde antimicrobial packaging on physicochemical and microbial quality of button mushroom (*Agaricus bisporus*). *Postharvest Biology and Technology*, *99*: 73-79. https://doi.org/10.1016/j.postharvbio.2014.07.018

Quevedo, R., Pedreschi, F., Bastias, J. M., & Díaz, O. (2016). Correlation of the fractal enzymatic browning rate with the temperature in mushroom, pear and apple slices. *LWT*, *65*: 406-413. https://doi.org/10.1016/j.lwt.2015.08.052

Ramos, M., Burgos, N., Barnard, A., Evans, G., Preece, J., Graz, M., Ruthes, A. C., Jiménez-Quero, A., Martínez-Abad, A., Vilaplana, F., Ngoc, L. P., Brouwer, A., van der Burg, B., del Carmen Garrigós, M., & Jiménez, A. (2019). *Agaricus bisporus* and its by-products as a source of valuable extracts and bioactive compounds. *Food Chemistry*, *292*: 176-187. https://doi.org/10.1016/j.foodchem.2019.04.035

Salamat, R., Ghassemzadeh, H. R., Ranjbar, F., Jalali, A., Mahajan, P., Herppich, W. B., & Mellmann, J. (2020). The effect of additional packaging barrier, air moment and cooling rate on quality parameters of button mushroom (*Agaricus bisporus*). *Food Packaging and Shelf Life*, *23*: 100448. https://doi.org/10.1016/j.fpsl.2019.100448

Simón, A., González-Fandos, E., & Vázquez, M. (2010). Effect of washing with citric acid and packaging in modified atmosphere on the sensory and microbiological quality of sliced mushrooms (*Agaricus bisporus* L.). *Food Control*, *21*(6): 851-856. https://doi.org/10.1016/j.foodcont.2009.11.012

Singh, P., Langowski, H. C., Wani, A. A., & Saengerlaub, S. (2010). Recent advances in extending the shelf life of fresh Agaricus mushrooms: a review. *Journal of the Science of Food and Agriculture*, *90*(9): 1393-1402. https://doi.org/10.1002/jsfa.3971

Singh, S., Gaikwad, K. K., Lee, M., & Lee, Y. S. (2018). Thermally buffered corrugated packaging for preserving the postharvest freshness of mushrooms (*Agaricus bisporus*). *Journal of Food Engineering*, *216*: 11-19. https://doi.org/10.1016/j.jfoodeng.2017.07.013

Steel, R. G. D., Torrie, J. H., & Dickey, D. A. (1997). *Principles and procedures of statistics: A biometrical approach* (3rd ed.). McGraw-Hill.

Sun, T., Bian, J., Wang, Y., Hu, J., Yun, X., Chen, E., & Dong, T. (2023). One-Step Synthesis of Poly(L-Lactic Acid)-Based Soft Films with Gas Permselectivity for White Mushrooms (*Agaricus bisporus*) Preservation. *Foods*, *12*(3): 586. https://doi.org/10.3390/foods12030586

Tariq, R. M. S., Ahmad, T., Aziz, S., Sattar, S., Ahmad, Z., & Ahmad, W. (2020). An outlook of socio-economic, climatic and marketing factors for mushroom cultivation in Pakistan. *Plant Protection*, *4*(2): 103-108.

Vazirianjafari, K., Omid, M., & Soltani Firouz, M. (2023). Power Ultrasound Coupled with Modified Atmosphere Packaging: Synergistic Effects on the Shelf-Life of White Button Mushroom (*Agaricus bisporus*). *Journal of Food Processing and Preservation*, *2023*: 5844322. https://doi.org/10.1155/2023/5844322

Walde, S. G., Velu, V., Jyothirmayi, T., & Math, R. G. (2006). Effects of pretreatments and drying methods on dehydration of mushroom. *Journal of Food Engineering*, *74*(1): 108-115. https://doi.org/10.1016/j.jfoodeng.2005.02.008

Wang, B., Yun, J., Ye, C., Xu, S., Guo, W., Zhao, F., Qu, Y., & Bi, Y. (2024). A novel polyethylene nanopackaging combined with ozone fumigation delayed the browning and softening of *Agaricus bisporus* during postharvest storage. *Postharvest Biology and Technology*, *210*: 112771. https://doi.org/10.1016/j.postharvbio.2024.112771

Wang, X., Tan, J., & Wang, J. (2014). Effect of precooling temperature on physiological quality of cold stored *Agaricus bisporus*. *International Journal of Agricultural and Biological Engineering*, *7*(2): 108-114. https://doi.org/10.3965/j.ijabe.20140702.013

Wrona, M., Pezo, D., Canellas, E., & Nerín, C. (2016). Ultra high performance liquid chromatography coupled to quadruple time-of-flight with MSE technology used for qualitative analysis of non-volatile oxidation markers in sliced packed mushrooms (*Agaricus bisporus*). *Journal of Chromatography A*, *1432*: 73-83. https://doi.org/10.1016/j.chroma.2016.01.004

Zalewska, M., Marcinkowska-Lesiak, M., & Onopiuk, A. (2018). Physicochemical properties of white button mushrooms (*Agaricus bisporus*) as affected by coating. *Journal of Food Processing and Preservation*, *42*(2): e13419. https://doi.org/10.1111/jfpp.13419

Zhang, K., Pu, Y.-Y., & Sun, D.-W. (2018). Recent advances in quality preservation of postharvest mushrooms (*Agaricus bisporus*): A review. *Trends in Food Science & Technology*, *78*: 72-82. https://doi.org/10.1016/j.tifs.2018.05.012