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Quality Changes of Button Mushrooms (*Agaricus bisporus*) Under Different Storage Conditions

Perubahan Mutu Jamur Kancing (Agaricus bisporus) pada Berbagai Kondisi Penyimpanan

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ABSTRACT
Button mushrooms (Agaricus bisporus) have become an attractive agricultural product due to their high nutritional value and use as food. However, since it has a low shelf life, further storage condition needs to be studied. This research investigated the quality changes of button mushrooms under different storage conditions. The mushrooms were stored both in cold and room temperature. The treatments used are different packaging materials such as Styrofoam, polyethylene, and edible coating, where the unpacked mushroom is used as control. Observed parameters are sensory, water content, and weight loss. Button mushrooms with edible coating at cold and room temperature storage were determined as the best treatment that resulted in the lowest decrease in weight loss and water content. Based on this study, the recommended storage condition for button mushrooms is using edible coating in cold temperatures.

ABSTRAK
Jamur kancing (*Agaricus bisporus*) merupakan produk pertanian yang menarik karena nilai gizinya dan penggunaannya sebagai bahan pangan. Namun karena masa simpan yang pendek, perlu dilakukan penelitian lebih lanjut mengenai kondisi penyimpanannya. Penelitian ini menyelidiki perubahan mutu jamur kancing pada berbagai kondisi penyimpanan. Jamur disimpan pada suhu dingin dan suhu ruang. Perlakuan yang digunakan melibatkan berbagai bahan kemasan yaitu Styrofoam, plastik polietilen, dan *edible coating*. Parameter yang diamati meliputi sensori, kadar air, dan susut bobot. Jamur kancing yang diberi perlakuan *edible coating* pada penyimpanan suhu dingin dan ruang ditentukan sebagai perlakuan terbaik yang menghasilkan penurunan kadar air dan susut bobot terendah. Berdasarkan penelitian ini, kondisi penyimpanan jamur kancing yang direkomendasikan adalah dengan menggunakan *edible coating* pada suhu dingin.

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1. Introduction

Button mushrooms are a popular agricultural commodity among the public and frequently utilized as a food source due to consumers' awareness of their highly beneficial nutritional content [1]–[3]. A study by [4] reported that button mushrooms are rich in protein, minerals, low in cholesterol, and starch. However, as a food product, one of the challenges faced by button mushrooms is their rapid susceptibility to quality deterioration and their limited shelf life. This decrease in quality is attributed to high of metabolism, respiration, and dehydration rates [5], [6].

Fresh button mushrooms have a restricted shelf life, approximately 1 to 3 days at room temperature (22 °C) and 4 to 7 days under cold storage (4 °C) [7]. The primary processes responsible for the deterioration of button mushroom quality are enzymatic browning and textural changes. Enzymatic browning is a consequence of phenol oxidation and spontaneous oxidation mechanisms. Meanwhile, changes in texture result from alterations in metabolism and water content within the tissue during storage [8]. Hence, post-harvest interventions are necessary to preserve the quality of button mushrooms, allowing them to have an extended shelf life.

Various post-harvest handling methods can be employed to maintain the quality of button mushrooms. Some of these methods include storage in modified atmosphere packaging [9], pre-storage washing treatments [10], and cold storage utilizing nanocomposite packaging materials [11]. Nevertheless, there needs to be more research regarding the effects of storage conditions, such as polyethylene plastic packaging, airtight Styrofoam packaging, and the application of edible coatings on the shelf life of button mushrooms at both room and cold temperatures. Therefore, investigating the storage of button mushrooms under various conditions needs to be done. This study aims to investigate the quality changes of button mushroom (*Agaricus bisporus*) under different storage conditions.

2. Research Methods

2.1 Materials and Equipment

Fresh button mushrooms (white color without browning indication, diameter 3-4 cm, containing 7-8 pieces in 100 g) were purchased from Koga Market, Bandar Lampung, Indonesia. The mushrooms were packed with black colored polyethylene plastic and transferred in the morning (at 28-30 °C) to the laboratory within 20 minutes. Upon arriving at the laboratory, the surface of mushroom was cleaned to remove dirt using running water and quickly drained with a tissue, followed by storing it at 4 °C and 75% relative humidity for 4 h before used. Packaging materials used in this study are Styrofoam containers (18x12x6.5 cm) and polyethylene plastic (12x25 cm, thickness around 0.03 cm) with the permeability properties as shown in **Table 1**.

Table 1. Packaging permeability properties

Materials	Oxygen permeability ($10^4 cm^3 \mu m^{-2} d$ atm)	Water vapor transmission rate ($g \mu m^{-2} d$ at 25 °C, 90% RH)	Source
Styrofoam	9.8-15	1750-3900	[12], [13]
Polyethylene	4.0-7.3	125	

Other materials used in this study include distilled water, glycerol (food grade, One Med), cassava starch, and carrageenan (food grade, Indo Gum). The equipment used included a refrigerator, digital scales, glassware, a hot magnetic stirrer, an oven (Memmert) and a stirring rod.

2.2 Experimental Design

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The experimental design used was a complete group randomized design with four treatments: unpacked (A) as control, packed with styrofoam (B), packed with polyethylene plastic (C), and application edible coating (D). The samples were stored in room and cold temperature, and each experiment was repeated three times.

2.3 Edible Coating Preparation

For the mushrooms with the edible coating treatment, the process began with preparing an edible coating solution made from 1 mL glycerol, 3 g of starch, 3 g of carrageenan, and 100 mL aquadest. This solution was prepared [14] by combining the ingredients and stirring them using a hot magnetic stirrer for 15 minutes at 70 °C at a moderate speed. The edible coating solution was then cooled to room temperature before being applied to the mushrooms.

2.4 Sample Storage

Mushrooms were weighed around 100 g and then consecutively were placed into containers according to the treatments. The unpacked mushroom used as a control was placed on a plate. Before storing the samples with edible coating treatment, it is prior to applying an edible coating solution to the mushrooms by using the dipping method for 1 minute [15], followed by draining for 30 minutes. Subsequently, all the samples were stored at room temperature (25 °C, 90% RH, relative humidity) and cold temperature (4 °C and 70% RH, relative humidity). Observations were conducted daily for 3-5 days, but it stopped when the samples showed visible signs of fungi growth on samples.

2.5 Observation Parameters

Observations were focused on various parameters following a study by [16]. These parameters included visual observation of sensory changes (color, texture, and appearance), measurement of water content by thermogravimetric method [17], and weight loss [18].

2.6 Data Analysis

The acquired data analyzed statistically through analysis of variance using SPSS v.25 to determine the significance of treatments. If there are significant treatment effects, Duncan's test will assess the distinct differences among each treatment within a 95% confidence interval with a significance level of $p<0.05$.

3. Results and Discussion

3.1 Sensory Changes

Observations regarding color, texture, and appearance of button mushrooms were carried out descriptively by comparing four packaging methods stored at both cold and room temperatures. Color and appearance changes during the storage are presented in **Table 2**. **Table 2** shows the color changes of all treatments during cold and room temperature storage. The unpacked mushroom displays a range of shades from white to brown. In treatment B, treated Styrofoam packaging, the color of mushrooms during storage varies from white to dark brown. Treatment C, involving polyethylene packaging, results in mushroom color ranging from white to off-white with hints of brown. In treatment D, using an edible coating layer, the mushroom color spans from white to slightly brown. Color changes within each packaging type during the storage process signify a reduction in the quality of the button mushrooms. Color changes in button mushrooms during storage are a consequence of the browning process, both enzymatic and non-enzymatic. This browning is attributed to the presence of the polyphenol oxidase enzyme, which is exposed to oxygen. The reaction between carbohydrates and amino acids, known as the Maillard reaction, also contributes to non-enzymatic browning. Additionally, the growth of

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microorganisms can influence the transition from yellow to brownish hues. Antoxanthin pigments in mushrooms are believed to degrade due to enzymatic action and causing a color change [19].

Table 2. Color and appearance changes of button mushroom at the initial and end of storage

Storage condition		Control (unpacked mushroom)	Styrofoam	Polyetyhlene	Edible coating
Cold temperature (4 °C, 70% RH)	Day 1				
	Day 4				
Room temperature (25 °C, 90% RH)	Day 1				
	Day 3				

Noticeable variations in color changes are observed in button mushrooms stored without packaging. These mushrooms are slightly yellow and brownish on the first day of storage at room and cold temperatures. Meanwhile, when mushrooms are packed with Styrofoam and stored at room and cold temperatures, color changes begin on the second day with fungal growth and darken to a brown hue by the third day of storage. For the mushrooms packed with polyethylene plastic, color changes began on the second day, shifting from brown to a yellowish hue, while on the third day of storage, the color turned brown, and the mushroom surface became wet. However, mushrooms treated with an edible coating do not show significant color changes at either room or cold temperatures. Color changes commence on the third day in the absence of fungal growth. Color changes at cold temperatures tend to occur more slowly than at room temperature. These color changes arise with a decline in quality due to metabolic processes, affecting button mushrooms' appearance during storage. Similar results on Color changes are also associated with water absorption from the packaging surface due to respiration processes, causing a reduction in color intensity during storage [20]. Using starch, carrageenan, and glycerol to produce edible coatings can prevent dehydration, oxidation, and browning processes on the coated material's surface by controlling the rate of CO_2 and O_2 gas respiration [21].

The texture of button mushrooms changes when stored using various packaging methods, both at room temperature and under cold conditions. The texture of unpacked mushrooms ranges from firm to very soft.

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Mushrooms with Treatment B, utilizing styrofoam packaging, induce changes in mushroom texture by day 1, exhibiting a firm-to-slightly-soft texture. In the case of Treatment C, which employs polyethylene plastic packaging, the texture of the mushrooms transforms from firm to soft, accompanied by a wet surface. Conversely, mushrooms treated with edible coating led to texture changes from firm to moderately soft during storage. The changes in mushroom firmness can be attributed to the respiration process, which results in the breakdown of carbohydrates into water-soluble compounds. As the respiration rate increases, the texture becomes softer. [22] explained that an increase in texture softening can be influenced by transpiration processes, causing a decrease in mushroom water content and continuous weakening of cell tissues. The firmness of button mushrooms decreases across all treatments during storage. The edible coating treatment demonstrates a higher firmness level than other packaging methods. This outcome is attributed to the capacity of edible coating to hold mushrooms' senescence by preventing oxygen ingress through a permeable layer covering the surface. Additionally, applying edible coating can prevent microbiological deterioration, thereby regulating the metabolism process that leads to the breakdown of carbohydrates into water-soluble compounds. Therefore, mushroom firmness can be maintained [23].

Observations on the appearance of button mushrooms during room temperature storage reveal that the unpacked mushrooms (A) and those packed with styrofoam (B) show more rapid deterioration, occurring on day 1 of storage. This is indicated by the emergence of white-colored fungi on the surface of the button mushrooms, accompanied by a wet surface. However, their freshness is retained for only up to 3 days. In contrast, Treatment C (polyethylene plastic) and Treatment D (edible coating) manage to preserve freshness up to day 4. This highlights the impact of packaging capabilities in absorbing and maintaining oxygen (O_2) content during storage on the perishability of stored commodities. The lower oxygen presence during storage results in a slower commodity deterioration rate [18]. These findings align with the research of [24], demonstrating the color change of white oyster mushrooms to yellow and brown over extended storage. The phenomenon of fungi growth in unpacked button mushroom storage is similar with the other study [25] which showed an increase of fungi colony from 9.5×10^4 to 4.5×10^5 cfu/g after 10 days storage at 10 °C. In the case of cold storage with lower relative humidity, the deterioration of button mushrooms becomes apparent on day 2 of storage. The fungi growth in storage can be attributed to the humid packaging environment and restricted air exchange, facilitating fungi growth and leading to spoilage.

3.2 Water Content

The results of observations on the water content of button mushrooms under various treatments during storage at cold and room temperatures are presented in **Figure 1,** and the average reduction in water content is also presented in **Figure 2**.

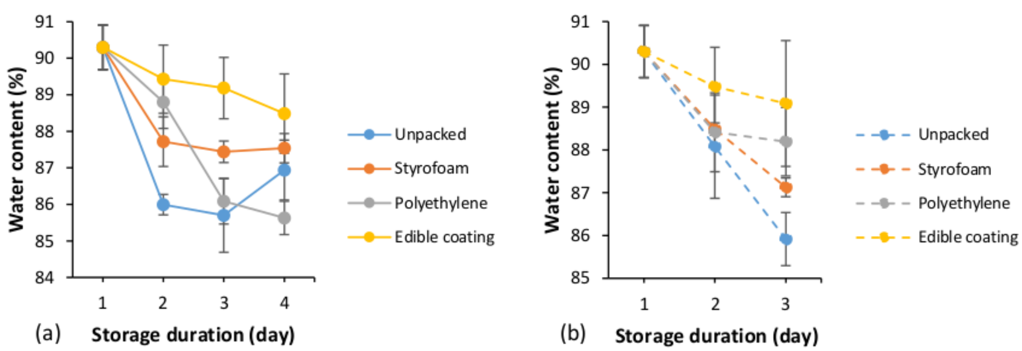

Figure 1. Water content changes of button mushrooms in cold temperature (4°C, 70% RH); (a) and room temperature (25 °C, 90% RH), (b) The error bars indicated the standard deviations of three replications

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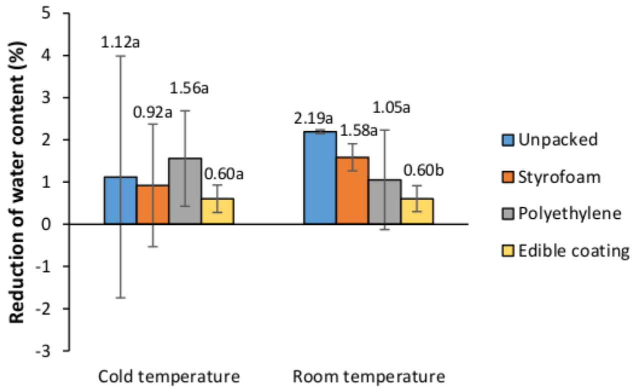

Figure 2. The average reduction in water content of button mushroom. Number followed different font indicate the significant difference ($p<0.05$)

Figure 1 shows that during cold temperature storage, the water content of button mushrooms in treatment A (without packaging) over a 4-day storage period reduced from 90.30 to 86.94%, treatment B (Styrofoam packaging) reduced from 90.30 and 87.54%, treatment C (polyethylene packaging) reduced from 90.30 to 85.63%, and treatment D (edible coating) reduced from 90.30 to 88.48%. While at room temperature storage, the water content of button mushrooms in treatment A over a 3-day storage period also reduced from 90.30 to 85.92%, treatment B reduced from 90.30 to 87.13%, treatment C reduced from 90.30 to 88.19%, and treatment D reduced from 90.30% to 89.08%. The reduction in average water content due to packaging treatments in cold storage did not show significant changes ($p>0.05$), but a significant reduction occurred at room storage ($p<0.05$).

The reduction in water content of all packaging treatments was attributed to temperature and humidity fluctuations during storage, causing food materials to release water content to achieve equilibrium and adapt to environmental changes. This finding is supported by [11], indicating that although water content is expected to increase during storage, in certain conditions continuously, reductions may occur. This could be attributed to temperature increases and humidity decreases, causing the vapor from food materials to move to the environment, ultimately reducing water content. Moreover, the permeability of each packaging type can also influence the water content of the material. Higher packaging permeability results in lower effectiveness in maintaining product water content. Packaging with lower permeability is more efficient in retaining product water content as the water vapor is difficult to penetrate.

The treatment of edible coating on button mushrooms showed the most significant reduction in water content ($p<0.05$) during room temperature storage compared to other packaging treatments, amounting to approximately 0.60%. This result is attributed to the hydrocolloid-based edible coating's mechanical properties to protect products by inhibiting the diffusion of oxygen, carbohydrates, and lipids. The coating also reduces respiration processes within the material and consequently lowers water content loss [26]. Carrageenan, a complex mixture of various polysaccharides, possesses favorable qualities for forming thin layers. Adding glycerol to starch-based edible coatings can enhance flexibility, elasticity, and permeability to gases, water vapor, and solutes, effectively reducing water content loss during storage [27].

3.3 Weight Loss

Weight loss is one of the processes involving a decrease in weight that occurs in a food material undergoing respiration and transpiration. The results of observations on the weight loss of button mushrooms under

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various treatments during storage at cold and room temperatures are presented in **Figure 3**. The average weight loss is also presented in **Figure 4**.

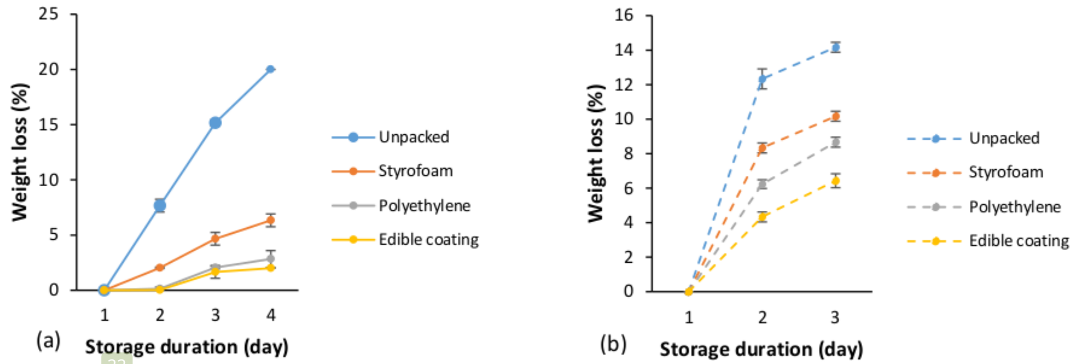

Figure 3. Weight loss changes of button mushrooms in cold temperature (4 °C, 70% RH); (a) and room temperature (25 °C, 90% RH), (b) The error bars indicated the standard deviations of three replications

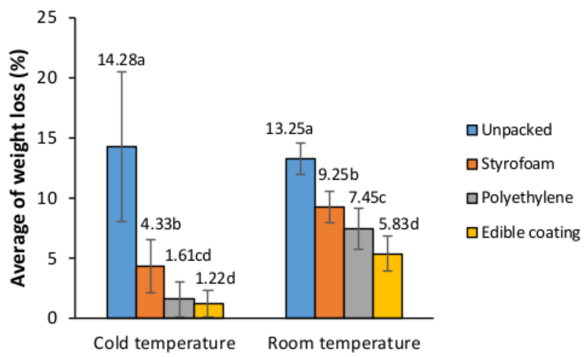

Figure 4. The average weight loss of button mushroom. Number followed different font indicate the significant difference ($p<0.05$)

Figure 3 shows that during cold storage, the weight loss of button mushrooms in treatment A (without packaging) over a 4-day storage period increased from 7.67 to 20.00%, treatment B (styrofoam) increased from 2.03 to 6.33%, treatment C (polyethylene) increased from 0.13 to 2.83%, and treatment D (edible coating) increased from 0.03 to 2%. On the other hand, at room temperature storage, the weight loss of button mushrooms in treatment A over a 3-day storage period increased from 12.33 to 14.17%, treatment B increased from 8.33 to 10.17%, treatment C increased from 6.23 to 8.67%, and treatment D increased from 4.33 to 6.43%. The average increase in weight loss for each packaging treatment of button mushrooms at both room and cold temperatures showed significant differences ($p<0.05$).

Weight loss from each treatment increases during storage, both under cold and room temperature conditions. The weight loss increase observed in button mushrooms during storage is attributed to transpiration, where water is released as vapor through the mushroom's skin surface. The most significant increase in weight loss is observed in the control treatment (without packaging), both in cold and room temperature storage. This result is similar with the other study [28] which in a mushroom packed with propylene and polyvinylchloride resulting the lowest weight loss (0.0-2.0%) compared with control (2.5-4.9%) in 5 days storage at 4 °C. Additionally,

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weight increase can also result from respiration, where oxygen is absorbed to combust complex compounds present within the cells, such as carbohydrates. These complex compounds are converted into simpler molecules like carbon dioxide, energy, and water vapor, ultimately reducing weight [29]. This respiration process goes beyond mere gas exchange; it involves oxidation-reduction reactions in which compounds (respiration substrates) are oxidized to CO_2 while absorbed oxygen (O_2) is reduced to form H_2O.

This is due to the absence of packaging layers that protect the button mushrooms in treatment A, allowing respiration to proceed normally and resulting in higher water loss, hence decreasing the weight of the mushrooms. The absence of a protective layer on the mushroom's surface as a barrier increases the oxygen levels entering the button mushrooms, consequently accelerating the respiration process. Also, the packaging material has a major contribution of weight loss regarding their permeability. According to **Table 1**, the Styrofoam packaging has a higher oxygen and water vapor permeability than polyethylene plastic. Packaging material with a low permeability to oxygen and water vapor, providing an effective barrier which limiting the respiration rate of button mushroom. A study by [9] reported that on a modified atmosphere packaging with a lower oxygen, showed the lowest weight loss and respiration rate of *Agaricus bisporus* mushroom. Lower respiration rate will help to maintain the internal water content thereby reducing the overall weight loss.

Conversely, button mushrooms coated with edible coating exhibit the lowest weight loss increase during storage at cold and room temperatures compared to other packaging methods. This study findings are in line with the report of other study by [30] showed that fresh button mushroom coated with polysaccharide-based edible coating significantly producing the lower weight loss (1.97-2.76%) than the untreated sample (3.89%) in 7 days storage at 4 °C. The same trend has reported by [29], indicating that applying an edible coating to melon slices resulted in lower weight loss than uncoated melon slices. This occurs because the edible coating can inhibit the water loss rate in the coated food material. Edible coating is an effective barrier layer against water and oxygen while controlling the respiration rate, ultimately reducing weight gain. [31] reported that due to the low permeability of film, polyethylene plastic packaging also produces a low significant weight loss than the unpacked button mushroom in 12 °C storage for 7 days. The weight loss in unpackaged button mushrooms originates from the mushrooms themselves. In contrast, weight loss in button mushrooms coated with edible coating occurs due to water content loss from the protective layer of carrageenan, glycerol, and starch. Furthermore, edible coating demonstrates permeability to water vapor, thus retaining the water content within the button mushrooms, resulting in minor weight reduction. According to [32], carrageenan-based edible coatings exhibit favorable permeability characteristics, effectively controlling the rate of water vapor and acting as an efficient barrier against oxygen and carbon dioxide.

4. Conclusion

Storage condition with edible coating treatment at cold and room temperature is the most effective treatment to minimize the average decrease in water content and produce the lowest average increase in weight loss. Sensory evaluation indicates that button mushrooms stored with the edible coating treatment exhibit a slightly brownish color, a fungi-free appearance, and a firm texture at the end of the storage period. Further investigations on the nutritional properties of button mushrooms, such as vitamins, minerals, and phytochemicals, are needed to give more information about those storage conditions on the nutritional retention.

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