



SEVERAL FACTORS AFFECTING TO SHELF-LIFE OF PADDY STRAW MUSHROOM (*VOLVARIELLA* SPP.) IN PRESERVATION

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Abstract

Paddy straw mushroom (*Volvariella* spp.) has good combinations of all attributes like flavour, aroma, delicacy, high content of protein and vitamins and minerals. The fruiting body formation starts with tiny clusters of white hyphal aggregates called primordia and it is followed by several morphological stages in the fruiting body development process. Paddy straw mushroom is very delicate in nature and highly perishable, which accounts for its short shelf life. Pericarp browning and aril decay of paddy straw mushroom fruits shorten post-harvest storage and thus reduce market value. It passes successive stages are called as button, eggs, elongation, mature stages respectively. Differentiation can be seen at the button stage. At maturity the buttons enlarge and umbrella like fruit bodies emerge after the rupture of the volva. Its commercial value goes down at that time. It is necessary to use post-harvest techniques for the extension of paddy straw mushroom shelf life. Edible coatings bring their response by affecting the physical, physiological and biochemical attributes of mushroom. Application of chitosan as edible coating could be considered as a useful approach to maintain its product quality during preservation. Objective of the present study focused on the effect of chitosan coating on some physicochemical, microbial and sensory characteristics of paddy straw mushroom during preservation. Optimal results showed that weight loss, pH, total soluble solids, titratable acidity and ascorbic acid; total plate count; sensory characteristics could be maintained at appropriate levels by coating paddy straw mushroom with 0.20% chitosan. Under 20°C of storage, their shelf life could prolong to 21 days without any deterioration. The present approach attempted to investigate some of the most significant findings to extend the shelf life of paddy straw mushroom fruit.

Keywords: Paddy straw mushroom, chitosan, coating, shelf life, physicochemical, microbial, sensory

Introduction

Paddy straw mushroom (*Volvariella* sp.) accounts for 16% of total production of cultivated mushrooms in the world. It is an edible mushroom of the tropics and subtropics. This mushroom has several advantages like requirement of the tropical or sub-tropical climate, fast growth rate, easy cultivation technology and good acceptability at consumers' level. Paddy straw mushroom contains good amount of protein, crude fibres and ash, all make it a health diet along with superior composition of various elements and essential amino acids (Biswas, 2017). Due to their thin and porous epidermal structure, the respiration rate of mushrooms is relatively high (200–500 mg/kg h at 20°C) compared to other vegetables and fruits (Warwick & Tsureda, 1997). Mushrooms are highly perishable and tend to lose quality right after harvest. Shelf-life of mushrooms is less than 3 days under usual shipping and marketing conditions (Lee, 1999). Therefore, mushrooms need special care to retain freshness.

Edible coatings are thin layers of edible material when applied over the surface of the horticultural commodities not only extend their shelf life but also marketability (Ochoa-Reyes, 2013). They protect produce by acting as a replacement for natural protective waxy coatings known as 'bloom' and provides a barrier against moisture, oxygen, and solute movement (Kumar and Kapur, 2016; Valero, 2013). Edible coating positively influences physical (moisture retention, glossiness, appearance, firmness) (Koh, 2017), physiological (respiration rate, ethylene evolution rate) (Panwar, 2016), biochemical attributes (cell wall degrading enzymes) (Koh, 2017), and pathological factors (disease decay incidence) (Sanchez-Gonzalez, 2016) for retaining post-harvest quality. Edible coatings can be applied solely and in combination with other natural preservatives and postharvest treatments (Zhang, 2016).

There were several researches mentioned to preservation of mushroom by coating. *Agaricus bisporus* edible mushrooms were coated with different gum-based coatings, including alginate and alginate-ergosterol, with or without emulsifier. Coated mushrooms were found to have a better appearance, a better color, and an advantage in weight in comparison with the uncoated ones. The alginate-ergosterol-Tween coating combination was most suitable for maintaining the size and shape of the coated mushroom (Hershko and Nussinovitch, 1998). Effect of modified atmosphere packaging on the shelf life of coated whole and sliced mushroom was examined. The whiteness of whole mushrooms varied significantly with the type of coating, but not with the type of films. The extent of darkening was greater in coated whole mushrooms than in sliced ones (Ki Myong Kim et al., 2006). Chitosan coating could extend the shelf life and maintain acceptable quality besides, controlling decay extent to some extent of Fresh-cut Button mushroom (*Agaricus bisporus*) (Eissa, 2007). *Aloe vera*, and gum tragacanth based edible coating delayed rapid weight loss, color changes, and accelerated softening. Good quality even at higher temperatures of storage was observed on fresh-cut button mushroom (*Agaricus bisporus*) (Mohebbi et al., 2012). Chitosan, glucose and chitosan-glucose complex (CGC) Maintained mushroom quality, extended postharvest life, maintained tissue firmness, lowered respiration rate, reduced microorganism counts. Reduced change in ascorbic acid and soluble solids concentration was noticed on Shiitake (*Lentinus edodes*) mushroom (Jiang et al., 2012). One research described the detailed information on the mechanism, formulation and application of edible coating technology on mushroom (Prasad et al., 2018).

Paddy straw mushroom is a tropical fruit that undergoes postharvest deterioration rapidly. It's a highly perishable fruit and easily damaged, softens very rapidly during ripening, and becomes mushy and difficult to consume fresh. Paddy straw

mushroom fruit is highly susceptible to enzymatic browning that is catalyzed by oxidoreductase enzymes such as PPO and POD. Pericarp browning is one of the most significant problems in marketing and export of longkong fruit. Pericarp browning leads to the loss of economic value of paddy straw mushroom fruit, although it does not affect its flavor and nutritional contents. Temperature (low and high) and environmental conditions are the key factors that cause the majority of quality losses in paddy straw mushroom fruit, followed by postharvest decay. Application of chitosan as edible coating could be considered as a useful approach to maintain its product quality during preservation. Objective of the present study focused on the effect of chitosan coating on some physicochemical, microbial and sensory characteristics of paddy straw mushroom during preservation.

Materials and Method

Material

Paddy straw mushroom bubs were collected in Soc Trang province, Vietnam. They must be cultivated following VietGAP to ensure food safety. After harvesting, they must be conveyed to laboratory within 8 hours for experiments. They were thoroughly rolled to remove dirt, dust and adhered unwanted material. Besides paddy straw mushroom fruits we also used other materials during the research such as chitosan, cacboxymethyl cellulose, sodium alginate, modified starch distilled water, Petrifilm - 3M. Lab utensils and equipments included colony counter, refrigerator, colorimeter, digital balance etc.



Fig. 1 : Paddy straw mushroom

Researching procedure

(i) Effect of different edible coating material to the physico-chemical, microbial and sensory characteristics of paddy straw mushroom

Different edible coatings (chitosan, cacboxymethyl cellulose, sodium alginate, modified starch) with the same concentration 0.1% were examined to verify the effectiveness of coating material on the preservation of paddy straw mushroom. The testing parameters included the weight loss (%), mannitol content ($\mu\text{mol}/\text{mg}$), surface color (L value), maturity index. All samples were analyzed after 3 days of storage at normal ambient temperature without packaging.

(ii) Effect of different chitosan concentration to the physico-chemical, microbial and sensory characteristics of paddy straw mushroom

Different chitosan concentration (0.1%, 0.15%, 0.20%, 0.25%) were examined to verify the effectiveness of chitosan concentration on the preservation of paddy straw mushroom. The testing parameters included the weight loss (%), mannitol content ($\mu\text{mol}/\text{mg}$), surface color (L value), maturity index. All samples were analyzed after 3 days of storage at normal ambient temperature without packaging.

(iii) Effect of storage temperature to the physico-chemical, microbial and sensory characteristics of paddy straw mushroom

Different storage temperatures (4°C, 12°C, 20°C, 28°C) were examined to verify the effectiveness of storage temperature on the preservation of paddy straw mushroom. The testing parameters included the weight loss (%), mannitol content ($\mu\text{mol}/\text{mg}$), surface color (L value), maturity index. All samples were analyzed after 3 days of storage without packaging.

(iv) Shelf-life of coated paddy straw mushroom during storage

The stability of coated paddy straw mushroom was monitored in 21 days of storage by 3 day interval sampling. The testing parameters included the weight loss (%), mannitol content ($\mu\text{mol}/\text{mg}$), surface color (L value), maturity index.

Physico-chemical, microbial and sensory evaluation

Weight loss (%) was determined by dividing the weight change during storage by the original weight.

Mannitol content ($\mu\text{mol}/\text{mg}$) was determined by gas-liquid chromatography. The surface color (L value) of mushrooms was measured using a Hunter-Lab Chroma Meter CR-300. *Coliform* (cfu/g) was enumerated during the storage period by Petrifilm - 3M. The maturity index was assigned to mushrooms based on the extent of cap opening on a 7 point-scales ((1) veil intact tightly; (2) veil intact stretched; (3) veil partially broken (half); (4) veil partially broken (4half); (5) veil completely broken; (6) cap open and gills well exposed; and (7) cap open and gill surface flat) (Roy et al., 1995).

Statistical Analysis

The experiments were run in triplicate with three different lots of samples. Data were subjected to analysis of variance (ANOVA) and mean comparison was carried out using Duncan's multiple range test (DMRT). Statistical analysis was performed by the Statgraphics Centurion XVI.

Result and Discussion

Effect of different edible coating material to the physico-chemical, microbial and sensory characteristics of paddy straw mushroom

Edible coatings maintain the quality by forming a protective film over the produce acting as a barrier to different gases like O_2 and CO_2 , and water vapour. It created a modified atmosphere around the horticultural commodity and thereby retains postharvest quality (Xing Y., 2013; Pinto AM., 2015). Coating vegetables and fruits with semi-permeable film has the beneficial effect of delaying ripening and prolonging the storage life of fresh produce (Vergano, & Testin, 1994). Rapid pericarp browning, softening and loss of freshness during transportation and in retail stores are the major problems in paddy straw mushroom fruit. Different edible coatings (chitosan, cacboxymethyl cellulose, sodium alginate, modified starch) with the same concentration 0.1% were examined to verify the effectiveness of coating material on the preservation of paddy straw mushroom. The testing parameters included the weight loss (%), mannitol content ($\mu\text{mol}/\text{mg}$), surface color (L value), maturity index. All samples were analyzed after 3 days of storage at normal ambient temperature without packaging. From table 1, the paddy straw mushroom should be coated with 0.10% chitosan

Table 1 : Effect of different edible coating material to the physico-chemical, microbial and sensory characteristics of paddy straw mushroom

Coating material	Control	Chitosan 0.1%	Carboxymethyl cellulose 0.1%	Sodium alginate 0.1%	Modified starch 0.1%
Weight loss (%)	24.32±0.03 ^a	2.15±0.02 ^e	3.77±0.01 ^c	2.49±0.00 ^d	4.28±0.02 ^b
Mannitol (µmol/mg)	0.11±0.00 ^c	1.86±0.02 ^a	0.63±0.03 ^d	0.91±0.01 ^b	0.72±0.00 ^c
Surface color (L value)	62.19±0.02 ^d	84.16±0.03 ^a	81.69±0.02 ^b	80.31±0.00 ^c	81.12±0.03 ^{bc}
Coliform (cfu/g)	1.2x10 ² ±0.01 ^a	5.2x10 ¹ ±0.03 ^c	8.2x10 ¹ ±0.02 ^c	8.9x10 ¹ ±0.01 ^b	8.5x10 ¹ ±0.00 ^{bc}
Maturity index (score)	6.75±0.04 ^a	1.13±0.02 ^e	1.97±0.01 ^c	1.26±0.02 ^d	2.14±0.01 ^b

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant ($\alpha = 5\%$).

Chitosan is derived from chitin; it is an edible polymer, isolated from crustacean animal shells. It is a natural product which is non-toxic and eco-friendly. Chitosan, a high molecular-weight cationic polysaccharide produced by deacetylation of chitin, is applied widely in postharvest treatments because of its excellent film forming and bio chemical properties. Chitosan films are tough, long lasting, flexible and very difficult to tear. Chitosan coating, form an ideal semipermeable film on the fruit surface, modify the fruit internal atmosphere, regulate gas exchange, reduce transpiration losses thus delays the ripening (Varasteh, 2017). Carboxymethyl cellulose (CMC) films possess a good film-forming characteristic, are generally odorless and tasteless, flexible and of moderate strength, transparent, resistant to oil and fats, water-soluble, and moderately permeable to moisture and oxygen transmission. The mechanical and physical barrier properties of cellulose edible coating are primarily due to the molecular weight, higher the molecular weight better are the properties (Adetunji, 2014). Alginate is extracted from brown algae, which are sodium salts of alginic acid. Alginate contains excellent barrier to moisture and water vapour (Koh, 2017). The alginate forms a cross linkage with calcium chloride to form an edible film over the produce surface (Koh, 2017). Starch is a polymeric carbohydrate consisting of a large number of glucose units joined by glucosidic bonds. Starch is the storage polysaccharide found in cereals, legumes, and tubers vegetables, widely available

Table 2 : Effect of different chitosan concentration (0.1%, 0.15%, 0.20%, 0.25%) to the physico-chemical, microbial and sensory characteristics of paddy straw mushroom

Chitosan coating	Control	0.1%	0.15%	0.20%	0.25%
Weight loss (%)	24.32±0.03 ^a	2.15±0.02 ^b	1.94±0.03 ^{bc}	1.76±0.01 ^c	1.70±0.00 ^c
Mannitol (µmol/mg)	0.11±0.00 ^d	1.86±0.02 ^c	2.13±0.01 ^b	2.49±0.00 ^a	2.51±0.03 ^a
Surface color (L value)	62.19±0.02 ^c	84.16±0.03 ^b	84.69±0.02 ^{ab}	85.07±0.01 ^a	85.10±0.02 ^a
Coliform (cfu/g)	1.2x10 ² ±0.01 ^a	5.2x10 ¹ ±0.03 ^b	3.7x10 ¹ ±0.00 ^c	2.2x10 ¹ ±0.03 ^{cd}	2.0x10 ¹ ±0.02 ^d
Maturity index (score)	6.75±0.04 ^a	1.13±0.02 ^b	1.09±0.0 ^{bc}	1.05±0.03 ^c	1.04±0.01 ^c

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant ($\alpha = 5\%$).

Effect of storage temperature to the physico-chemical, microbial and sensory characteristics of paddy straw mushroom

Edible coating maintains the firmness by avoiding excessive respiration and transpiration those involved directly in depleting storage reserves. Edible coating directly affects fruit firmness by delaying ripening process and decreasing the activity of cell wall degrading enzymes (Dang, 2008). It is well known that calcium directly affects fruit firmness, the incorporation of calcium in the edible

Table 3 : Effect of different storage temperature (4°C, 12°C, 20°C, 28°C) to the physico-chemical, microbial and sensory characteristics of paddy straw mushroom

Storage temperature	4°C	12°C	20°C	28°C
Weight loss (%)	1.12±0.03 ^d	1.26±0.01 ^c	1.43±0.02 ^b	1.76±0.01 ^a
Mannitol (µmol/mg)	3.41±0.01 ^a	3.27±0.02 ^b	3.02±0.01 ^c	2.49±0.00 ^d
Surface color (L value)	80.13±0.02 ^c	84.79±0.03 ^b	85.26±0.03 ^a	85.07±0.01 ^{ab}
Coliform (cfu/g)	1.1x10 ¹ ±0.01 ^b	1.4x10 ¹ ±0.02 ^{ab}	1.7x10 ¹ ±0.00 ^{ab}	2.2x10 ¹ ±0.03 ^a
Maturity index (score)	1.18±0.01 ^a	1.11±0.03 ^{ab}	1.03±0.00 ^c	1.05±0.03 ^b

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant ($\alpha = 5\%$).

as raw material and suitable for a variety of industrial uses. The most common starch rich sources include potato, cassava, banana etc. It contains amylose and amylopectin. Starches are good oxygen barrier, used for coating fruits and vegetables characterized by high respiration rates (Durango, 2006).

Effect of different chitosan concentration to the physico-chemical, microbial and sensory characteristics of paddy straw mushroom

External appearance is the face of the horticulture commodity (Prasad, 2016). Rough physical handling of fruits at postharvest stage causes destroy of natural wax coating and bruising injury occurs during the packing and transport operations (Valero, 2013). The edible coating provides a physical barrier between the fruit surface and the external surrounding of harvested produces, which ultimately lead to retention of postharvest quality of horticultural commodities (Ochoa-Reyes, 2013). Different chitosan concentration (0.1%, 0.15%, 0.20%, 0.25%) were examined to verify the effectiveness of chitosan concentration on the preservation of paddy straw mushroom. The testing parameters included the weight loss (%), mannitol content (µmol/mg), surface color (L value), maturity index. All samples were analyzed after 3 days of storage at normal ambient temperature without packaging. From table 2, the paddy straw mushroom should be coated with 0.20% chitosan.

coating was also proved to be effective (Dhall, 2013). Different storage temperatures (4°C, 12°C, 20°C, 28°C) were examined to verify the effectiveness of storage temperature on the preservation of paddy straw mushroom. The testing parameters included the weight loss (%), mannitol content (µmol/mg), surface color (L value), maturity index. All samples were analyzed after 3 days of storage without packaging. From table 3, the paddy straw mushroom should be kept at 20°C.

The weight of horticultural commodity determines the returns of farmers. This loss in weight of particular commodity is due to the transpiration process which is determined by the gradient of water vapour pressure between the fruit and the atmosphere. Edible coatings act as an extra barrier between the fruit surface and atmosphere, the process transpiration which occurs across it (Ayranci, and Tunc, 2004; Diaz-Mula, 2012).

Shelf-life of coated paddy straw mushroom during storage

Weight loss from the mushroom surface is caused by loss of water from the package to the surrounding atmosphere, due to vapor pressure difference across the packaging film, and to the loss of carbon upon formation of CO₂ during respiration. Mushrooms lack a protective epidermal structure to prevent excessive moisture loss and, therefore, have a very high transpiration rate. The stability of coated paddy straw mushroom was monitored in 21 days of storage by 3 day interval sampling. The testing parameters included the weight loss (%), mannitol content (μmol/mg), surface color (L value), maturity index.

Table 4 : Shelf-life of coated paddy straw mushroom during storage

Storage (days)	Weight loss (%)	Mannitol (μmol/mg)	Surface color (L value)	Coliform (cfu/g)	Maturity index (score)
0	0 ^d	3.19±0.03 ^a	85.41±0.04 ^a	1.9×10 ¹ ±0.02 ^{ab}	1.00±0.01 ^d
3	1.43±0.02 ^c	3.02±0.01 ^{ab}	85.26±0.03 ^{ab}	1.7×10 ¹ ±0.00 ^{ab}	1.03±0.00 ^d
6	1.65±0.01 ^{bc}	2.95±0.00 ^{ab}	84.89±0.02 ^b	1.3×10 ¹ ±0.02 ^{ab}	1.07±0.03 ^{cd}
9	1.79±0.00 ^{bc}	2.87±0.02 ^b	84.53±0.01 ^{bc}	1.0×10 ¹ ±0.03 ^{ab}	1.12±0.02 ^c
12	1.83±0.03 ^b	2.83±0.02 ^{bc}	84.11±0.03 ^c	0.6×10 ¹ ±0.01 ^{ab}	1.16±0.00 ^{bc}
15	1.94±0.01 ^{ab}	2.76±0.03 ^{bc}	83.94±0.00 ^{cd}	0.4×10 ¹ ±0.03 ^{ab}	1.19±0.03 ^b
18	2.01±0.00 ^{ab}	2.64±0.01 ^c	83.82±0.02 ^d	0.2×10 ¹ ±0.00 ^{ab}	1.23±0.00 ^{ab}
21	2.05±0.03 ^a	2.61±0.00 ^c	83.51±0.01 ^e	0.1×10 ¹ ±0.02 ^{ab}	1.27±0.02 ^a

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant ($\alpha = 5\%$).

Vegetable oils, cellulose gums, emulsifiers, surfactants, and fatty acids applied to coat mushroom. Result showed that the enzymatic browning was reduced; the anti-browning property of coating materials could be improved with the incorporation of antioxidants and chelator (EDTA) (Nisperos-Carriedo *et al.*, 1991). Stearic acid, ascorbic acid and citric acid, in the methyl cellulose based coating decreased oxygen permeability, slowed browning reaction and PPO activity in mushroom. They also reduced vitamin- C loss in mushroom (Ayranci and Tunc, 2003). The coating reduces the respiration rate as well as senescence by delaying and reducing ethylene production (Partial barrier to gas exchange). It also prevents fruits and vegetables against different storage disorders including chilling injuries mainly in tropical crops. It can be also be used successfully for individual packaging of small products such as pears, beans, nuts, and strawberries for increasing shelf life (Koh, 2017).

Conclusion

Pericarp browning is the major post-harvest problem of paddy straw mushroom (*Paddy straw mushroom chinensis*) fruit, resulting in reduced commercial value of the fruit. Visual quality was lost at ambient temperature when fruit were removed from storage due to browning. The edible coating does not leave any post application residues and thus makes the product readily consumable. It positively affects physical (moisture retention, glossiness, appearance, firmness), physiological (respiration rate, ethylene evolution rate), and biochemical attributes (cell wall degrading enzymes) attributes of horticultural commodities. Recent advances have now enabled growers to intelligently apply edible coating both solely and in combination with other postharvest treatments and natural preservatives for retention of postharvest quality with the minimized postharvest loss. We have successfully optimized some physicochemical, microbial and sensory characteristics of paddy straw mushroom during preservation by coating with chitosan. By

this study, there will be an alternative approach to prolong paddy straw mushroom shelf-life during post-harvest.

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