Extension of Postharvest Life of Oyster Mushroom by Modified Atmosphere Packaging Technique

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ABSTRACT: Mushrooms were packaged in polypropylene, low-density polyethylene, linear low-density polyethylene (LLDPE) packages after washing with 0.5% calcium chloride and 0.5% citric acid (CA), and based on off-color and off-odor development, suitable packaging material and washing solution were selected. Effectiveness of magnesium oxide in modifying the in-package gaseous atmosphere and thereby extending the postharvest life was tested by monitoring the physicochemical properties. Oxygen concentration was 5.5% and 9.9% and carbon dioxide concentration was 8.1% and 4.5%, in the control and packages containing 3 g of magnesium oxide, respectively, on day 12 in storage. Packaging mushroom in 0.015 mm LLDPE packages with 3 g of magnesium oxide after washing with 0.5% calcium chloride and 0.5% CA was successful in extending the postharvest life at 8 °C and 70% RH from 6 d in commercial samples to 12 d.

Keywords: mushroom, postharvest life, modified atmosphere packaging

Introduction

The abundance of imported mushrooms in retail shops and supermarkets in Sri Lanka reflects the need for a continuous supply of good-quality, locally grown mushrooms. Oyster mushroom (*Pleurotus* spp) is popular in Sri Lanka as a vegetable and as an ingredient in soup due to its high nutritive content, unique flavor, and medicinal properties. Physiological disorders are the main causes of postharvest loss of mushroom (Kannaiyan and Ramasamy 1980) and limits the availability of fresh mushrooms to Sri Lankan consumers. Physiological disorders such as shriveling, liquefaction, and textural and flavor changes shorten the shelf life (Barden and others 1990). Storage temperature further enhances the physiological disorders as the rate of biological reactions increase with increase in temperature (Tano and others 1999). Storage of mushroom at 0 °C and 95% RH has been reported to be the optimum condition to extend marketable life (SLS 1991). It may not be practical to store fresh mushrooms at 0 °C as temperatures inside refrigerators and display cabinets, which could be used for low-temperature storage of perishable products, are maintained between 6 °C and 10 °C. The shelf life of these packages is about 4 d under the low-temperature conditions used in supermarkets. Condensation of moisture inside these packages, off-odor development, and off-color development are common problems in mushroom packaging, probably due to low permeability of packaging films to water vapor (Exama and others 1993), oxygen, and carbon dioxide. Moisture condensation is further aggravated under low RH conditions of refrigerated storage.

Modified atmosphere packaging (MAP) is reported to be the most economical and effective method of extending the shelf life of mushroom (Roy and others 1995; Tano and others 1999). In MAP, a low O₂ and high CO₂ environment resulting from respiration has been successful in slowing down deterioration and growth of microorganisms in fresh mushrooms (Kader and others 1989). Low-temperature storage in combination with MAP is reported to extend the postharvest life of vegetables (Paull 1999). The success of MAP is due to the creation and maintenance of an optimal in-package atmosphere that is determined by the respiration rate of the product and the permeability of the packaging film to oxygen and carbon dioxide.

This study was carried out to select a suitable packaging material for storage of oyster mushroom at 8 °C and 70% relative humidity and to identify a suitable washing treatment to maintain mushroom quality. The effectiveness of magnesium oxide as a carbon dioxide scavenger in extending the postharvest life was also tested.

Materials and Methods

Fresh oyster mushrooms (*Pleurotus* spp.) of the 2nd flush were harvested under normal commercial conditions from a commercial farm at Haragama, Kandy district. Harvested mushrooms were kept on plastic crates and transported to the laboratory. Mushrooms were sorted by size and appearance. Diseased, damaged, and extremely large or small mushrooms were discarded to minimize biological variability.

Experiment 1

A preliminary experiment was carried out to select a suitable washing treatment and a packaging material.

The experimental treatment structure was a 2-factor factorial with packaging materials and washing treatments as the 2 factors laid out in a complete randomized design. Six packaging materials, 0.05-mm polypropylene (PP), 0.0375-mm PP, 0.075-mm low-density polyethylene (LDPE), 0.05-mm LDPE, 0.0375-mm LDPE, 0.015-mm linear low-density polyethylene (LLDPE), and 4 washing treatments, water, 0.5% citric acid, 0.5% calcium chloride, and 0.5% citric acid with 0.5% calcium chloride, were used as the levels of the factors. Mushrooms were dipped in the washing treatment solutions for 1 min, air-dried, and packaged in a surface (surface area of the package) to weight (weight of mushroom packaged) ratio of 2:1.
Extension of post harvest life of mushroom . . .

(cm²/g). The heat sealed packages were stored at 8 °C and 70% RH for 8 d. Packages were opened on day 6, and subjective measurements of off-color and off-odor development were taken as described subsequently. The data were analyzed by Kruskal-Wallis test using the MINITAB statistical package. A suitable packaging material and a washing treatment were selected by comparing the means at P < 0.05 according to the multiple comparison procedure.

In the 2nd stage of the preliminary study, the following experiment was carried out to find out the optimum ratio of surface area to weight for packaging of mushroom. Three surface-to-weight ratios, 2:1, 3:1, and 4:1, were used in a completely randomized design, and in-package concentration of carbon dioxide, oxygen, and color of mushroom were measured daily in triplicate for 8 d. Data of this experiment were subjected to variance analysis using the SAS package. Treatment means were compared at P < 0.05 according the least significant difference (LSD) mean separation procedure, and the best surface-to-weight ratio was selected.

**Experiment 2**

Fresh oyster mushrooms were sorted, washed in the washing solution containing 0.5% calcium chloride and 0.5% citric acid, air-dried, and packaged (200 g per package) in 0.015-mm LLDPE in a 3:1 ratio of surface area to weight with carbon dioxide scavengers. Magnesium oxide 1, 3, or 5 g wrapped with muslin cloth was used as carbon dioxide scavengers and placed inside the packages in a completely randomized design. The packages were stored at 8 °C and 70% RH for 14 d. In-package concentrations of carbon dioxide, oxygen, acetaldehyde, and ethanol contents, color, and weight loss were measured at 2-d intervals in triplicate as described subsequently for 14 d. Data from this experiment were subjected to variance analysis using the SAS package. Treatment means were compared at P < 0.05 according to the LSD mean separation procedure.

Three commercial mushroom packages were analyzed for in-package concentrations of carbon dioxide, oxygen, acetaldehyde, and ethanol contents, weight loss, and color on day 8 in storage at 8 °C and 70% RH. Results of this experiment were compared with those obtained for mushrooms in the MAP system developed in this study and stored for 12 d at 8 °C and 70% RH. Mushroom packaged in perforated LLDPE was used as a control. Data of this experiment were analyzed by ANOVA. The General Linear Model Procedure developed by Statistical Analysis System (SAS Inst. 1994) was used to perform ANOVA. Treatment means were compared at P < 0.05 according to the LSD mean separation procedure.

**Gaseous composition**

In-package concentrations of oxygen and carbon dioxide were measured using a gas chromatograph (Shimadzu, model GC-14B). For oxygen measurement, a molecular sieve column, a thermal conductivity detector, helium carrier gas at a flow rate of 40 mL/min, and column, injector, and detector temperatures of 50 °C, 90 °C, and 110 °C, respectively, were used. Carbon dioxide was measured using a Porapak Q column, and the conditions were as same as for oxygen.

**Acetaldehyde and ethanol contents**

Mushroom (5 g) was homogenized with 5 mL of distilled water using a mortar and pestle. The homogenate was centrifuged at a 6000 rpm for 10 min, and 2 µL of the supernatant was injected to the gas chromatograph (Shimadzu, model GC-14B). Acetaldehyde and ethanol contents were analyzed according to the AOAC method (1990) using a Porapak Q column, a flame ionization detector, nitrogen carrier gas at a flow rate of 40 mL/min, and column, injector, and detector temperatures of 190 °C, 200 °C, and 200 °C.

**Off-odor and off-color**

Off-odor and off-color were determined as described by Burton and others (1987) using a scale of 1 to 4: 1 = none, 2 = slight, 3 = moderate, and 4 = high and 10 panelists.

**Weight loss and color**

Weight loss was determined during storage by monitoring the weight of the contents of the package before and after the storage period. Weight loss was expressed as the percentage of the loss of weight with respect to the initial weight. Mushroom color was measured using a Color Difference Meter (ZE 2000 Nippon Denshuku). The lightness value (L) was used to evaluate the color. The measurements were made directly on the cap surface 3 times on each mushroom.

**Results and Discussion**

**Experiment 1**

Interaction effect between washing treatment and packaging material was significant in off-odor and off-color development (Table 1 and 2). Mushrooms packaged in PP showed severe off-odor and off-color development regardless of the washing treatment. Mushrooms washed with water also showed severe off-odor and off-color development regardless of the packaging material. Mushrooms packaged in LLDPE washed with 0.5% calcium chloride and 0.5% calcium chloride with 0.5% citric acid showed the least off-odor development. Mushrooms packaged in 0.015-mm LLDPE after washing with a solution containing 0.5% calcium chloride and 0.5% citric acid was found to be the best treatment to prevent both off-odor and off-color development.

In-package oxygen concentration increased and carbon dioxide concentration decreased with increase in surface area to product weight ratio (Figure 1). Carbon dioxide concentrations were 9.8%, 4.1%, and 3.0%, respectively, in 2:1, 3:1, and 4:1 on day 8 on storage at 8 °C and 70% RH. The L values of mushrooms increased with the increase in surface area to product weight ratio and were 63.1, 70.0, and 72.0, respectively, under similar conditions. However, the difference in L value, in-package oxygen, and carbon dioxide concentration were not significant (P < 0.05) between the treatments of 3:1 and 4:1.

![Figure 1—Effect of package surface area-to-weight ratio on mushroom color (L value) in-package oxygen and carbon dioxide concentrations on day 6 in storage (least significant difference [LSD] 0.05 for CO₂ %, O₂ %, and L value was 1.2, 1.7, and 3.4, respectively).](image-url)
Experiment 2

Gaseous composition. In-package oxygen and carbon dioxide concentrations of mushrooms in the control and in the packages containing 1, 3, and 5 g of magnesium oxide were significantly (P < 0.05) different at 8 °C (Figure 2). Oxygen concentration was 4.0%, 8.5%, 9.9%, and 5.5% in the packages containing 1, 3, and 5 g of magnesium oxide and the control, respectively, on day 12 in storage. Under similar conditions, carbon dioxide concentrations were 7.5%, 4.5%, 3.0%, and 8.1% (Figure 2). On day 14, oxygen concentrations reduced to 3.0%, 7.3%, 7.8%, and 5.0%, and carbon dioxide concentrations increased to 8.3%, 7.2%, 5.6%, and 10.0% in the packages containing 1, 3, and 5 g of magnesium oxide and the control, respectively. In-package carbon dioxide concentrations increased above 5% after 12 d in all treatments. Oxygen concentrations in packages containing 3 g and 5 g of magnesium oxide remained at 5% up to day 14 in storage and was below 5% in the control and packages containing 1 g of magnesium oxide.

Weight loss. Treatments with 3 and 5 g of magnesium oxide showed the highest weight loss of 2.2%, whereas mushrooms treated with 1 g of magnesium oxide showed the lowest weight loss of 1.9% after 12 d of storage at 8 °C and 70% RH. On day 14, mushrooms packaged with 1 g of magnesium oxide showed the lowest weight loss of 2.2%, whereas mushrooms treated with 5 g of magnesium oxide showed the highest weight loss of 5.0% after 12 d of storage. There was no significant difference in the weight loss of samples packaged with 3 or 5 g of magnesium oxide (Figure 3).

Color. The lightness of mushroom, as indicated by the L value, was 60.0, 70.0, 71.2, and 72.3 in the control and in packages containing 1, 3, and 5 g of magnesium oxide, respectively, on day 12 in storage (Figure 3). Mushrooms packaged with 3 g and 5 g of magnesium oxide showed the highest lightness values throughout the storage period. The control samples showed the lowest L value (Figure 3), which was significantly different (P < 0.05) from all other treatments. Mushrooms in all the treatments showed L values below 70 after 12 d of storage.

Ethanol and acetaldehyde. There was no production of acetaldehyde and ethanol in all the samples up to 6 d in storage. Concentration of ethanol increased during storage and was significantly higher (P < 0.05) in the control samples than those packaged with magnesium oxide (Figure 4). On day 12, ethanol concentrations of mushrooms with 1, 3, and 5 g of magnesium oxide and in the control, increased to 34.7, 37.3, 35.7, and 52.7 ppm, respectively. Ethanol concentration increased further from day 12 to day 14 (Figure 4).

Comparison of the experimental sample and commercial sample. The experimental and commercial samples were compared at the end of their acceptable period of 12 d and 6 d, respectively. Oxygen and carbon dioxide concentrations in the commercial sample and experimental sample stored at 8 °C and 70% RH were significantly different (Table 3). The experimental sample contained 4.5% carbon dioxide and 8.5% oxygen whereas commercial samples contained 11.6% carbon dioxide and 3.2% oxygen. Perforated packages did not modify the atmosphere surrounding the commodity. Concentrations of ethanol in samples stored in 0.015 mm LLDPE for 12 d and 0.05 mm PP for 6 d were 37.3 and 42.0 ppm, respectively, and this difference was not significant. There was no indication of ethanol production in samples stored in perforated packages. The L value of mushrooms stored in LLDPE for 12 d was significantly higher than that stored in PP for 6 d. However, there was no significant difference in the L value of samples stored in PP.

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Table 1—Estimated means of off-odor in mushrooms on day 6 in storage at 8 °C and 70% RH.

<table>
<thead>
<tr>
<th>Washing treatment</th>
<th>Packaging material</th>
<th>0.5% citric acid</th>
<th>0.5% citric acid + 0.5% CaCl₂</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water</td>
<td>0.5% citric acid</td>
<td>0.5% citric acid + 0.5% CaCl₂</td>
</tr>
<tr>
<td>PP, 0.05 mm</td>
<td>3.9</td>
<td>3.6</td>
<td>3.8</td>
</tr>
<tr>
<td>PP, 0.0375 mm</td>
<td>3.9</td>
<td>3.7</td>
<td>3.8</td>
</tr>
<tr>
<td>LDPE, 0.075 mm</td>
<td>3.3</td>
<td>2.5</td>
<td>2.3</td>
</tr>
<tr>
<td>LDPE, 0.05 mm</td>
<td>3.4</td>
<td>2.7</td>
<td>2.6</td>
</tr>
<tr>
<td>LDPE, 0.0375 mm</td>
<td>2.4</td>
<td>1.8</td>
<td>2.0</td>
</tr>
<tr>
<td>LLDPE, 0.015 mm</td>
<td>1.9</td>
<td>1.6</td>
<td>1.0</td>
</tr>
</tbody>
</table>

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Table 2—Estimated means of off-color in mushrooms on day 6 in storage at 8 °C and 70% RH.

<table>
<thead>
<tr>
<th>Washing treatment</th>
<th>Packaging material</th>
<th>0.5% citric acid</th>
<th>0.5% citric acid + 0.5% CaCl₂</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water</td>
<td>0.5% citric acid</td>
<td>0.5% citric acid + 0.5% CaCl₂</td>
</tr>
<tr>
<td>PP, 0.05 mm</td>
<td>3.8</td>
<td>3.2</td>
<td>2.2</td>
</tr>
<tr>
<td>PP, 0.0375 mm</td>
<td>3.6</td>
<td>2.5</td>
<td>2.1</td>
</tr>
<tr>
<td>LDPE, 0.075 mm</td>
<td>3.2</td>
<td>2.6</td>
<td>2.1</td>
</tr>
<tr>
<td>LDPE, 0.05 mm</td>
<td>2.9</td>
<td>2.5</td>
<td>2.0</td>
</tr>
<tr>
<td>LDPE, 0.0375 mm</td>
<td>2.6</td>
<td>2.3</td>
<td>1.8</td>
</tr>
<tr>
<td>LLDPE, 0.015 mm</td>
<td>2.5</td>
<td>1.6</td>
<td>1.2</td>
</tr>
</tbody>
</table>

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**Figure 2**—Effect of magnesium oxide as a carbon dioxide absorber on in-package concentrations of carbon dioxide and oxygen during storage of mushrooms in linear low-density polyethylene (LLDPE) packages at 8 °C and 70% RH.
Discussion

Experiment 1. MAP of perishables requires selecting a packaging material with suitable oxygen and carbon dioxide permeability to establish beneficial in-package concentrations of these gases and to avoid anaerobiosis, thereby to prevent off-odor development (Henig and Gilbert 1975). PP is commonly used for packaging of mushrooms in Sri Lanka. However, PP (0.05 and 0.0375 mm) was found to be unsuitable for packaging of mushrooms in this study as off-odor and off-color development of mushrooms was high.

LDPE, which was recommended by Zagory and Kader (1988) for packaging of most perishable products, was also found to be unsuitable for mushrooms. The subjective quality assessment on off-odor and off-color development revealed that 0.015 mm LLDPE was suitable to package mushrooms.

Mushrooms are also washed before packaging to prevent off-color development caused by enzymatic activities and microbial growth (Sapers and others 1994). Washing of mushrooms with calcium chloride has been shown to be effective in delaying senescence, browning, and suppressing bacterial growth in button mushrooms stored at 4 °C (Barden and others 1990). Similar results have been reported by Roy and others (1995) when button mushrooms were treated with calcium chloride and stored at 12 °C. Kukura and others (1998) showed significant correlation between calcium concentration and lightness of button mushroom, where the $L$ value increased with increase in calcium concentration in irrigation water from 0.5% to 3%. They reported that the addition of calcium chloride to the irrigation water reduced bacterial growth and resulted in light color mushrooms during the postharvest storage. Calcium has good potential as a postharvest treatment for a number of horticultural commodities. The acceptable color of mushroom after 6 d of storage at 8 °C and 70% RH observed when washed with 0.5% citric acid and 0.5% calcium chloride may be due to the antimicrobial effect of the former (Sapers and others 1994) and inhibition of tyrosinase activity by the latter (Barden and others 1990; Kukura and others 1998).

In developing a MAP system, it is required to select a suitable film and film surface area-to-product weight ratio (Talasila and others 1995). The respiration rate of the tissues and the inward and outward gaseous diffusion via the packaging film determines the

and in perforated packages. Weight loss of mushrooms stored in perforated packages was 21.5% on day 2 in storage and was 2.2% and 2.0% when stored in LLDPE and PP, respectively.

Table 3—Gaseous composition and chemical and physical parameters of mushrooms stored at 8 °C and 70% RH under different packaging conditions

<table>
<thead>
<tr>
<th>Condition of packaging</th>
<th>Storage period (d)</th>
<th>CO$_2$ %</th>
<th>O$_2$ %</th>
<th>CH$_3$CHO (ppm)</th>
<th>$L$ value</th>
<th>Weight loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental sample$^b$</td>
<td>12</td>
<td>4.50b</td>
<td>8.5b</td>
<td>37.3b</td>
<td>73.3a</td>
<td>2.2b</td>
</tr>
<tr>
<td>Commercial sample$^c$</td>
<td>6</td>
<td>11.60a</td>
<td>3.2c</td>
<td>42.0a</td>
<td>63.5b</td>
<td>2.0b</td>
</tr>
<tr>
<td>Control$^d$</td>
<td>2</td>
<td>0.05c</td>
<td>20.8a</td>
<td>nd</td>
<td>63.2b</td>
<td>21.5a</td>
</tr>
<tr>
<td>LSD$_{0.05}$</td>
<td>—</td>
<td>1.51</td>
<td>1.9</td>
<td>4.6</td>
<td>3.9</td>
<td>2.0</td>
</tr>
</tbody>
</table>

$^a$Each value represents the mean of 3 replications and same letter following the value within the same column was not significantly different at $P < 0.05$. nd = not detectable.
$^b$Washed with 0.5% citric acid (CA) + 0.5% CaCl$_2$ and packaged in 0.015-mm linear low-density polyethylene (LLDPE) with carbon dioxide scavenger (3 g MgO).
$^c$Washed with water and packaged in 0.05-mm polypropylene.
$^d$Washed with 0.5% CA + 0.5% CaCl$_2$ and packaged in perforated (0.378 cm$^2$/100 cm$^2$) LLDPE with carbon dioxide scavenger (3 g MgO).
in-package atmosphere (Yuen 1993). The diffusion rates of gases are proportional to the area of the film (Lopez-Briones and others 1993). The commercial mushroom samples packaged at a surface film area-to-product weight ratio of 2:1 were found to be unsuitable as reflected by off-odor and off-color development (Table 2). The in-package oxygen and carbon dioxide concentrations of mushrooms packaged in 2:1 pouches was 3.1% and 9.8%, respectively, on day 6 in storage. Moreover, the L value of the mushrooms was lower than 70, the value recommended for mushrooms (Gomley 1975). In-package concentrations of oxygen and carbon dioxide were 9% and 3%, respectively, in 4:1 packages. The L value of mushrooms in the same packages was 72. There was no significant difference in oxygen or carbon dioxide concentrations and the L value of samples in 3:1 and 4:1 packages. Based on these results, a surface area-to-product weight ratio of 3:1 can be recommended for packaging and storage of mushrooms at 8 °C.

Experiment 2. The importance of selecting a suitable storage temperature and establishing an optimum gaseous composition in MAP has been identified for extending the postharvest life of mushrooms (Tano and others 1999). In-package oxygen and carbon dioxide concentrations of 5% to 10% and 2.5% to 5%, respectively, have been reported to optimize the marketing conditions for mushrooms (Lopez-Briones and others 1993). In this study, in-package concentrations of carbon dioxide and oxygen were within these limits when packaged in 0.015-mm LLDPE with 3 g or 5 g of magnesium oxide. Equilibrium oxygen and carbon dioxide concentrations of 8% to 15% and 1% to 2%, respectively, were established when button mushrooms were packaged in PVC films and stored at 2 °C (Nichols and Hammond 1973). Packaging of button mushrooms in MA containers (750 g of mushrooms in 4-L containers) has resulted in steady-state oxygen and carbon dioxide concentrations of 5% and 10%, respectively, during storage for 12 d at 4 °C (Tano and others 1999). Extension of the postharvest life of oyster mushroom up to 12 d may be due to reduction of the respiration rate at 8 °C and the environment of less than 8.5% oxygen and 4.5% carbon dioxide established in LLDPE packages. Reduction of the respiration rate by 50% has been reported for button mushrooms that were stored at 4 °C for 12 d in MA containers (Tano and others 1999). Similar observations were made by Ajlouni (1993) when button mushrooms were packaged in linear polyethylene trays overwrapped with PVC films and stored at 12 °C for 4 d. In-package oxygen concentration dropped below and carbon dioxide concentration increased above the injury levels identified by Lopez-Briones and others (1993) after 6 d in storage. Therefore, the postharvest life of commercial samples was limited to 6 d at 8 °C and 70% RH.

Fermentative reactions and off-flavor developments are enhanced in many vegetables when the in-package oxygen concentration was reduced below the desirable level (Brimlow and Vadehra 1991). Generally, it is recommended to maintain an oxygen concentration of 2% or above as most vegetables develop an alcoholic flavor at 1% oxygen (Brimlow and Vadehra 1991). Tano and others (1999) reported 30.3 ppm ethanol in button mushrooms stored for 12 d at 4 °C that were exposed to carbon dioxide and oxygen concentrations of 15% and 1.5%, respectively. Under similar conditions, the acetaldehyde concentration of button mushrooms was 6 to 8 ppm. The findings of this study are in agreement with the results reported by Tano and others (1999) where ethanol concentration increased with increase in carbon dioxide concentration. The ethanol concentration of samples increased with the increase in magnesium oxide content. This indicates that magnesium oxide is effective in reducing the levels of ethanol concentration by maintaining the carbon dioxide and oxygen concentrations within the required levels identified by Lopez-Briones and others (1993).

Lopez-Briones and others (1993) reported that packaging of button mushrooms in microporous-oriented polypropylene films was beneficial in maintaining color during storage for 8 d at 4 °C. Tano and others (1999) reported that brightness given by the L value decreased from 84 to 76 during storage at 4 °C for 12 d. The results of this study revealed that the mushroom color was acceptable even on day 12 when packaged in LLDPE with magnesium oxide. This is probably due to the ability of magnesium oxide to keep the in-package carbon dioxide concentration below 10%, above which brown color development was observed in button mushrooms stored at 2 °C (Nichols and Hammond 1973). The findings of this study were in agreement with the work of Nichols and Hammond (1973), in which samples packaged without magnesium oxide containing 11% carbon dioxide showed the lowest L value. Mushroom packaged in PP also showed an L value of 65.3, which is below the acceptable level of 70 identified by Gomley (1975). The low L value may be associated with the high in-package carbon dioxide concentration of 11.6%.

It was evident that weight loss of mushrooms packaged with 3 g and 5 g of magnesium oxide was higher than those packaged with 1 g of magnesium oxide and without magnesium oxide on day 12. Weight loss increased during storage, and there was no significant difference between mushrooms packaged with different quantities of magnesium oxide. However, the weight loss of mushrooms packaged with 1 g of magnesium oxide was 1.9% on day 12 and was below the maximum limit of 2% identified by Sveeine and others (1967) for mushrooms. Tano and others (1999) reported a 1% to 8% weight loss of mushrooms when stored at 4 °C for 12 d in MA containers. The weight loss of button mushrooms stored in PVC films was 7.5% after 9 d in storage at 12 °C and 80% RH (Roy and others 1995). Ajlouni (1993) also observed an 8.4% weight loss when button mushrooms were packaged in linear polyethylene trays overwrapped with PVC films and stored at 12 °C for 10 d. Nichols and Hammond (1973) observed an 8% weight loss after 5 d in storage at 2 °C when button mushrooms were packaged in PVC films. There was no significant difference between the samples packaged in LLDPE and PP in terms of weight loss, probably due to the similar water vapor permeability properties of these materials at 8 °C. Compared with previously reported work, the weight loss observed in this study was rather low, indicating low moisture loss. This may probably be due to the calcium chloride treatment as calcium helps in maintaining the cellular organization and regulating enzyme activities, thereby reducing moisture loss associated with senescence (Jones and Lunt 1967). The samples packaged in perforated packages showed 21.5% weight loss. It may probably due to high moisture loss associated with low RH of 70%. Nichols and Hammond (1973) reported a weight loss of 50% when unwrapped button mushrooms were stored at 2 °C for 5 d.

The results revealed that 0.015-mm LLDPE is a more suitable material than 0.05-mm PP for mushrooms as indicated by lower carbon dioxide and ethanol concentrations and higher oxygen concentration and L value, and longer shelf life when mushrooms were packaged in the former than in the latter. Mushrooms packaged in 0.05-mm PP had a postharvest life of 6 d at 8 °C and 70% RH. Under similar conditions, the postharvest life of mushrooms packaged in 0.015-mm LLDPE was 12 d. Washing with 0.5% calcium chloride and 0.5% citric acid followed by packaging in a 0.015-mm LLDPE with 3 g of magnesium oxide may have contributed to the long postharvest life of oyster mushroom. These experiments were conducted using passive MAP and to speculate that active MAP using an initial flush of the packages with the expected steady-state gas concentrations, as normally done in commercial MAP operations, would be likely to further improve the postharvest life of these mushrooms.
Conclusions

Washing of oyster mushroom with 0.5% citric acid and 0.5% calcium chloride followed by packaging in 0.015-mm LLDPE in a 3:1 surface area–to–product weight ratio (600 cm²/200 g) with 3 g of magnesium oxide as a carbon dioxide scavenger was successful in extending the postharvest life from 6 d in commercial samples to 12 d at 8 °C and 70% RH.

References


