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Effect of Different Packaging Films on Postharvest Quality and Selected Enzyme Activities of *Hypsizygus marmoreus* Mushrooms

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Freshly harvested *Hypsizygus marmoreus* mushrooms were packaged using different packaging films, and physiological changes associated with postharvest deterioration, together with the activities of selected enzymes thought to play a role in senescence, were monitored during subsequent storage for 16−24 days at 4 °C and 65−70% relative humidity. A biaxially oriented polypropylene film (BOPP) maintained the postharvest appearance of the mushrooms most effectively by significantly reducing the incidence of unsightly aerial hyphae on the pileal surface and restricting mushroom softening. These samples also exhibited smaller initial decreases in soluble protein, smaller increases in reducing sugar content, and lower levels of malondialdehyde accumulation during early storage. Smallest increases in proteinase activity were recorded in samples wrapped with BOPP and polyoletin packaging, and superoxide dismutase and polyphenol oxidase levels were significantly higher and lower, respectively, in the former. Choice of packaging can significantly affect postharvest quality loss in *H. marmoreus* and improve mushroom shelf life.

KEYWORDS: Mushroom quality; *Hypsizygus marmoreus*; mushrooms; packaging films; postharvest senescence

INTRODUCTION

There has been a huge rise in consumer demand recently for the edible mushroom *Hypsizygus marmoreus*, due to a wider appreciation of its long-recognized organoleptic (*1*) and medicinal attributes (*2*). This, together with improvements in cultivation technology, has led to a dramatic increase in production, which, in the Shanghai municipal area alone, is now in excess of 8 tonnes per day. Traditionally cultivated and consumed in Southeast Asia, countries outside this region, including the United States, have seen a growth in supply and demand for this mushroom. However, *H. marmoreus* mushrooms deteriorate rapidly after harvest due to water loss, browning, softening, stipe elongation and hollowing, pileus expansion and splitting, and the appearance of unsightly aerial hyphae on the pileal surface during refrigeration, all of which greatly reduce consumer acceptability.

Currently, a major problem for mushroom growers in China and elsewhere is to maintain the postharvest quality of their products that often have to be transported over large distances before reaching the market place. Cold-temperature storage is problematic (see above), but a potentially attractive alternative is modified atmosphere packaging (MAP). Previous papers have suggested that this represents a simple, convenient, and economical method for inhibiting physicochemical changes associated with postharvest deterioration and spoilage of fruits and vegetables, thereby maintaining fresh product appearance and extending the shelf life (*3*). MAP has also been applied to mushrooms, although research on the effectiveness of different packaging materials has largely been restricted to the white button mushroom, *Agaricus bisporus* (*4*−*6*), and the oyster mushroom, *Pleurotus* sp. (*7*).

Despite the increasing popularity and commercial importance of *H. marmoreus*, there is a paucity of published data relating to the effects of different packaging materials in prolonging mushroom shelf life and on various physical and biochemical changes associated with quality maintenance and postharvest deterioration. The aim of this study was to determine the effects of five different packaging films on various physical parameters (firmness, weight loss, production of aerial hyphae) associated with postharvest mushroom quality, as well as on selected enzymes generally recognized to be involved in the process of senescence. A better understanding of the effects of packaging films on such changes could lead to more targeted strategies for reducing postharvest quality loss in *H. marmoreus* as well as in other types of fresh edible mushrooms.

MATERIALS AND METHODS

Mushroom Samples. Freshly harvested *H. marmoreus* mushrooms of good commercial quality were obtained from Shanghai Finc Biotech Inc.

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Packaging. Within 4 h of harvesting, mushrooms were precooled, placed in a plastic tray, and wrapped in one of five different packaging films [polyvinyl chloride (PVC, thickness = 11 μm), two types of polyethylene (PE6 and PE11, thickness = 6 and 11 μm, respectively), polyoletin (PO, thickness = 10 μm), and biaxially oriented polypropylene (BOPP, thickness = 20 μm)] while maintained at 4 °C and transported to the cold storage facility of the Shanghai Academy of Agricultural Sciences (SAAS). Samples (140 g each) were then stored at 4 ± 0.5 °C and 65−70% relative humidity for 16 days in the case of PE6- and PE11-wrapped samples (after which time the remaining samples had badly deteriorated and were discarded), 20 days in the case of PO-wrapped samples (similar sample deterioration), and 24 days in the case of samples wrapped in PVC or BOPP. Thirty-five replicates were included in each treatment group and, after 24 h and subsequently every 4 days, five replicates from each treatment group were randomly selected and sampled as described below.

Mushroom Extracts. Frozen *H. marmoreus* tissue (1 g) was ground in a mortar and pestle with 10 mL of 0.05 M phosphate buffer (pH 7.0) containing 10% (w/v) polyvinylpyrrolidone (PVPP) and 0.1 M EDTA. Homogenates were centrifuged (15000*g*, 15 min, 4 °C) and supernatants used for enzyme assays.

Catalase (CAT). CAT activity was assayed according to the method of Kato and Shimizu (*8*) by measuring the initial rate of H_2O_2 disappearance at 240 nm using a Beckman DU-640 UV−vis spectrophotometer (Beckman Inc., Fullerton, CA). Assays were initiated by the addition of 0.1 mL of crude extract to 2.9 mL reaction mixtures containing 0.1 M sodium phosphate buffer (pH 7.0) and 2 mM H_2O_2. Enzyme activity was calculated using ϵ240 for H_2O_2 of 40 mM^{-1} cm^{-1}.

Proteinase. Proteinase activity was assayed using a modified version of the method described in ref *9* using dye-impregnated collagen (azocoll) as substrate. *H. marmoreus* mushroom extract (1.0 mL) was added to 3 mL of azocoll suspension (5 mg/mL) in shaken 50 mL flasks. After incubation at 30 °C for 1 h, residual azocoll was removed by centrifugation, and the absorbance of the supernatant was measured at 520 nm. One unit (U) of proteinase activity was defined as the amount of enzyme catalyzing an increase in absorbance at 520 nm of 0.01/h, and proteinase activity values are presented as U/h/g of fresh weight (fw) of mushroom.

Superoxide Dismutase (SOD). SOD activity was determined by measuring the inhibition of the photochemical reduction of nitroblue tetrazolium (NBT) according to the method of Constantine and Stanley (*10*). Reaction mixtures contained (in a total volume of 3 mL) 13 mM methionine, 0.075 mM NBT, 0.1 mM EDTA, 0.002 mM riboflavin, and 0.1 mL of enzyme extract in 50 mM phosphate buffer (pH 7.8). One unit of SOD activity was defined as the amount of enzyme required to inhibit the rate of NBT photoreduction by 50%, and SOD activity values are presented as unit/h/g of fw of mushroom.

Polyphenol Oxidase (PPO). PPO activity was assayed by measuring the linear increase in absorbance at 410 nm and 30 °C as described by Galeazzi et al. (*11*) using catechol as the substrate. Reaction mixtures contained 2.0 mL of 50 mM phosphate buffer (pH 7.0), 2% (w/v) catechol, and 0.2 mL of extract added to initiate the reaction. One unit (U) of PPO activity was defined as the amount of enzyme catalyzing an increase in absorbance at 410 nm of 0.01/min, and PPO activity values are presented as U/min/g of fw of mushroom.

Soluble Protein. Soluble protein was determined according to the method of Bradford (*12*) using bovine serum albumin as standard.

Respiration Rate. Respiration rates were measured with a Testo 535 CO_2 detector. Approximately 450 g of fw of fruit bodies was placed in a 15 L capacity desiccator maintained at 4 °C together with the detector. Initial CO_2 levels (D_0) were read at time zero and again after 2 h (D_1), and the respiration rate was calculated according to the equation $(D_2 - D_0) \times 10^6 \times V/t \times$ fw and expressed as mL/kg·h.

Reducing and Total Sugar. Reducing sugar and total sugar in samples of powdered, freeze-dried *H. marmoreus* mushrooms were determined according to the methods of Miller (*13*) and Dubois et al. (*14*), respectively.

Malondialdehyde (MDA) Assay. MDA was measured essentially as described previously (*15*). Mushroom extract (1.0 mL) was mixed with 3.0 mL of 15% (w/v) trichloroacetic acid containing 0.5% (w/v) thiobarbituric acid, and the mixture was heated at 100 °C for 18 min. After rapid cooling of the sample to room temperature, and centrifugation at 10000*g* for 10 min at 25 °C, the absorbance of the supernatant was measured at both 532 and 600 nm. The concentration (nmol/g of fw) of MDA was calculated using an extinction coefficient of 155 mM^{-1} cm^{-1} using the formula $(OD_{532} - OD_{600}) \times 40/0.155 \times$ fw).

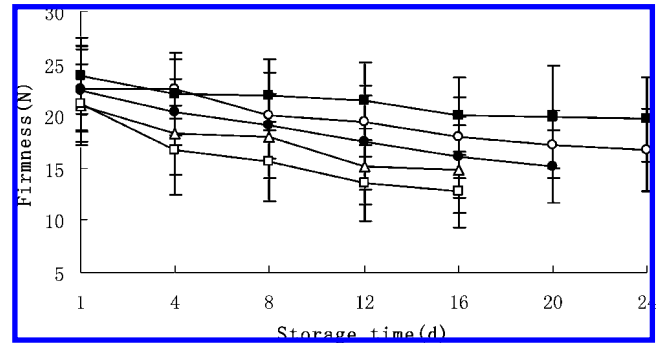

Figure 1. Effect of packaging film on *H. marmoreus* mushroom firmness during storage at 4 °C: PVC (○); PE6 (□); PE11 (△); PO (●); BOPP (■). Vertical bars represent standard deviation about the mean (n = 5); no bars indicate SD < 10%.

Fruit Body Firmness. The firmness of *H. marmoreus* mushrooms was calculated from the first force peak on a texture profile analysis (TPA) curve obtained using a TA.XT-plus texture analyzer (Stable Micro Systems Ltd., Godalming, U.K.) fitted with a HDP/BSK blade set (*16*). Tests were carried out using 90 replicates (1 mushroom pileus = 1 replicate) at each sampling time during the storage period. The operating parameters were as follows: test mode, compression; pretest speed, 2 mm/s; test speed, 2 mm/s; post-test speed, 10 mm/s; target mode, 10 mm distant from probe; trigger type, 5.0 g of autoforce. Firmness values are expressed in newtons.

Formation of Aerial Hyphae on Pileal Surface. The extent of aerial hyphal growth on the pileal surface was estimated (as percent coverage) by three independent assessors after 24 h and subsequently every 4 days using a scale ranging from 0% (no hyphal growth) to 100% (complete coverage of the pileal surface). Each assessor assigned a hyphal index to each sample calculated as follows: Σ (percentage estimates of hyphal cover)/10 (number of replicates). The mean ± SD values of the three hyphal indices assigned to each sample were then plotted.

Statistical Analysis. All extractions and determinations were carried out at least in triplicate, and the data were subjected to analysis of variance using DPS (version 7.05). Duncan's multiple range test was employed to determine the statistical significance (P = 0.05) of the differences between the means.

RESULTS

Effect of Packaging on Overall Mushroom Quality. Throughout the storage period, all of the mushroom samples exhibited a gradual decrease in firmness (**Figure 1**). However, compared to mushrooms packed in PVC, PE11, PO, and PE6, the softening effect was significantly (P < 0.05) less evident in samples packaged in BOPP film, with which a 15.2% decrease in hardness was recorded after 24 days of storage. This compared with the fastest softening rate measured in mushrooms packed in PE6 film (40.1% after 16 days) (**Figure 1**).

Low levels (<5%) of aerial hyphae were detectable on the pilei of all samples after 4 days except for BOPP-packaged mushrooms, for which hyphal incidence levels never exceeded 2% throughout 24 days of storage (**Figure 2**). The incidence of aerial hyphae on PE6-packaged mushrooms increased markedly between 4 and 8 days (from ~5% to 40%), whereas more gradual increases in hyphal growth were observed on PO-, PVC-, and PE11-packed samples. However, a marked increase (from ~18 to 62%) in the incidence of aerial hyphae on the

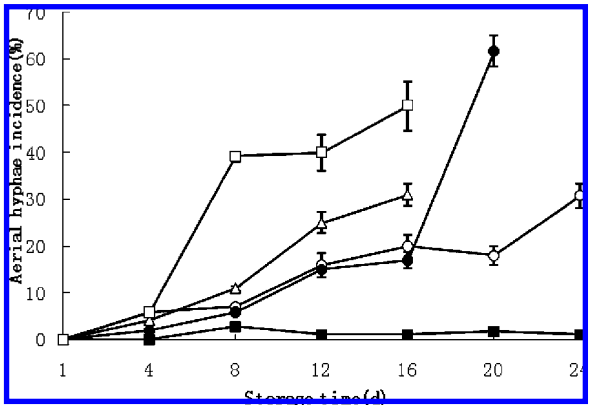

Figure 2. Effect of packaging film on the incidence of aerial hyphae on *H. marmoreus* mushroom pilei during storage at 4 °C: PVC (○); PE6 (□); PE11 (△); PO (●); BOPP (■). Vertical bars represent standard deviation about the mean ($n = 5$); no bars indicate SD < 10%.

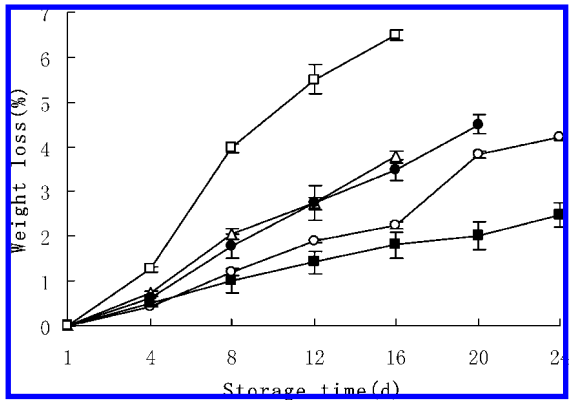

Figure 3. Effect of packaging film on weight loss in *H. marmoreus* mushrooms during storage at 4 °C: PVC (○); PE6 (□); PE11 (△); PO (●); BOPP (■). Vertical bars represent standard deviation about the mean ($n = 5$); no bars indicate SD < 10%.

pilei of PO-packed mushrooms, accompanied by a general deterioration in mushroom quality, was recorded between 16 and 20 days.

Highest and lowest weight losses were recorded in PE6- (6.7% in 16 days) and BOPP-packaged (2.5% in 24 days) mushrooms, respectively (**Figure 3**). PVC film was also relatively effective in preventing weight loss over the first 16 days of storage (2.3%), whereas weight losses of 3.8 and 3.5% were recorded in PE11- and PO-packaged mushrooms, respectively, over this same period (**Figure 3**).

Effect of Packaging on Soluble Protein, Total Sugar, and Reducing Sugar Contents of *H. marmoreus* Mushrooms during Storage at 4 °C. Soluble protein levels in all samples remained relatively constant (~4.3−4.9 mg/g of mushroom) during the first 8 days of storage but, after 12 days, levels in the two polythene-packaged mushrooms (PE6 and PE11) had decreased to ~65% of initial levels. However, soluble protein detected in samples wrapped in BOPP and PVC packaging unexpectedly increased by 92 and 54%, respectively, between 20 and 24 days (**Figure 4A**).

Total sugar concentrations in all samples except mushrooms packaged in PE6 film remained relatively unchanged for the first 4 days of storage and then progressively decreased. Total sugar levels in BOPP-wrapped mushrooms decreased at a much slower rate (~13% after 24 days) relative to mushrooms packaged in other films and constituted 56.6% of the total dry weight at this point, a significantly higher value ($P < 0.05$) compared to other samples. A decrease in the total sugar content of mushrooms wrapped in PE6 film was recorded even after the first 4 days of storage, and levels in these samples dropped by ~21% after just 16 days (**Figure 4B**).

The reducing sugar content of mushrooms packaged in PVC, PO, and the two polyethylene films all increased throughout the storage period, whereas levels in BOPP-wrapped mushrooms remained stable for the first 4 days before increasing at a significantly slower rate ($P < 0.05$) compared to the other four samples (**Figure 4C**). The largest increase in reducing sugar content (67% after 16 days) was recorded in mushrooms packaged in PE6 compared to an increase of only 43% after 24 days observed in BOPP-wrapped samples.

Effect of Packaging on MDA Levels in *H. marmoreus* Mushrooms during Storage at 4 °C. The effects of different packaging materials on MDA levels in *H. marmoreus* mushrooms during storage at 4 °C are shown in **Figure 4D**. Marked increases in MDA levels were observed during the first 4 days of storage in all samples except those wrapped in BOPP film. Levels then remained relatively constant for the next 4 days in mushrooms packaged in PVC, PO, and PE11 before increasing again during the latter part of the storage period (especially in the case of PO-packaged samples), whereas the increase was continuous in PE6-wrapped mushrooms. After 16 days, MDA levels in PE6- and PE11-packaged samples increased 4.6- and 3.8-fold, compared with 2.4-, 2.9-, and 3-fold increases recorded in mushrooms wrapped in PO, PVC, and BOPP films, respectively.

Effect of Packaging on Proteinase, SOD, PPO, and CAT Activities in *H. marmoreus* Mushrooms during Storage at 4 °C. Proteinase activity in mushrooms packaged in PVC, PO, and PE11 increased sharply during the first 4 days of storage and exhibited smaller fluctuations between 4 and 12 days, before increasing again to peak levels on day 16 (**Figure 5A**). No significant changes in enzyme activity were observed in samples wrapped in PE6 and BOPP during the first 4 days, but levels then more than doubled in the former after 8 days and remained high, whereas activity in the latter increased by ~45% between 4 and 8 days of storage before gradually falling to ~70% of initial levels after 24 days.

SOD activity in all samples except those packaged in BOPP exhibited a general downward trend and, after 12 days of storage, enzyme levels had decreased to 67, 73, 76, and 81% of initial values recorded in mushrooms packaged in PE6, PE11, PO, and PVC films, respectively (**Figure 5B**). SOD levels in BOPP-packed mushrooms remained unchanged after 4 days of storage and then decreased, but at a lower rate compared with the other samples. After 12 days, levels had fallen only 3% compared with initial levels, and ~83% of the initial activity was recorded after 24 days of storage.

Sharp initial increases in PPO, to peak values of 41.1, 46.1, and 48.8 U/g of fw after 8 days of storage, were recorded in mushrooms packaged in PVC, PE11, and PO films, respectively (**Figure 5C**). Enzyme activity in PE6-wrapped samples remained virtually unchanged after 4 days but then increased almost 300% during the next 4 days to a peak value 58.8 U/g of fw. PPO levels in BOPP-packaged mushrooms fell slightly after 4 days of storage, almost doubled (to ~19 U/g of fw) during the next 4 days, and then increased more rapidly to reach a peak value of ~43 U/g of fw on day 12, 4 days later than all of the other samples. PPO activity then decreased in all samples throughout the remaining storage period, to below initial levels in the case of PVC- and BOPP-wrapped mushrooms (**Figure 5C**).

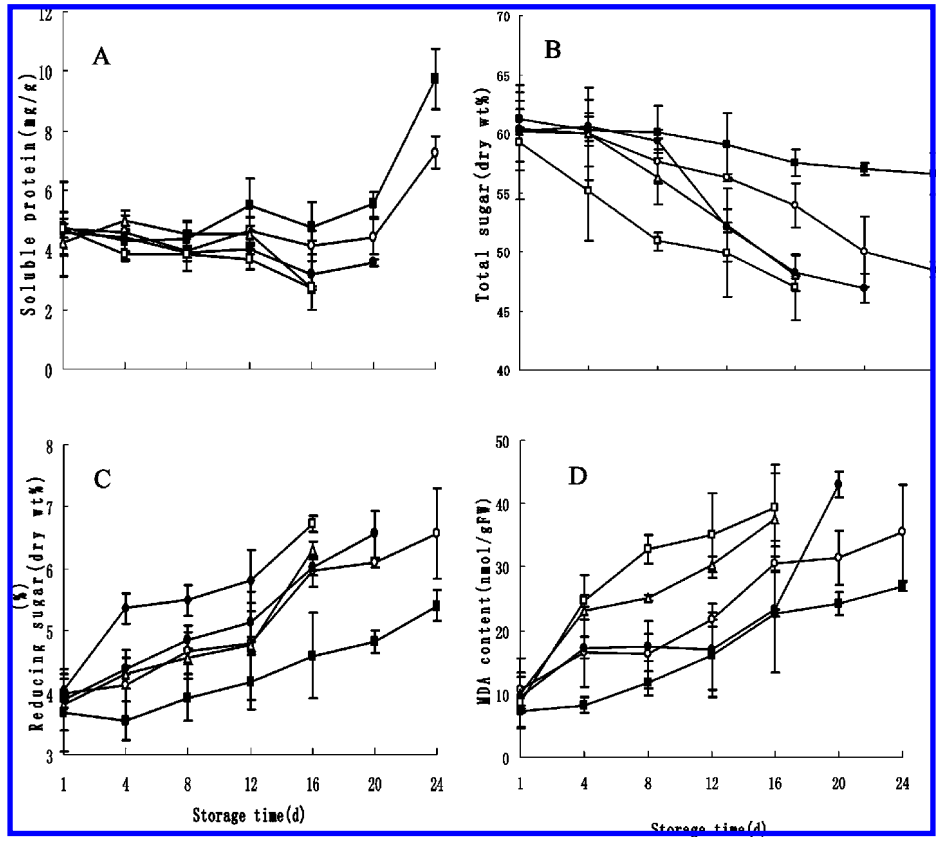

Figure 4. Effect of packaging film on the content of selected chemical components of *H. marmoreus* mushrooms during storage at 4 °C: (**A**) soluble protein; (**B**) total sugar; (**C**) reducing sugar; (**D**) malondialdehyde (MDA); PVC (○); PE6 (□); PE11 (△); PO (●); BOPP (■). Vertical bars represent standard deviation about the mean ($n = 5$); no bars indicate SD < 10%.

CAT activity decreased significantly in all samples except those wrapped in BOPP film during the first 8−12 days of storage but then increased, especially in mushrooms packed in PVC (**Figure 5D**), for which peak levels recorded after 16 days were 1.7-fold higher compared with initial values (~100 U/mL). Enzyme activity in BOPP-wrapped samples remained virtually constant (90−100 U/mL) for the first 12 days, increased sharply during 12−16 days to 205 U/mL, and then decreased to 118 U/mL at the termination of the experiment.

Effect of Packaging on the Respiration Rate of *H. marmoreus* Mushrooms during Storage at 4 °C. Respiration rates of all the test samples decreased during the first 4 days of storage, by ~90% of initial values in the case of BOPP-wrapped mushrooms, compared with ~60% in samples packed in PVC and PO, and ~40% in mushrooms packaged in the two PE films (**Figure 6**). Respiration levels then increased sharply between 8 and 12 days, peaking between 8 and 26% above initial rates in samples packaged in PVC, PO, PE6, and PE11 and at 22% below in the case of BOPP-wrapped mushrooms. Respiration rates of mushrooms packed in PVC, PO, and BOPP films peaked a second time after 20 days of storage before decreasing again during the last 4 days of storage.

DISCUSSION

Modified atmosphere packaging represents a highly beneficial storage method for agroproducts postharvest, especially in cases of continuing metabolic activity. MAP is effective in prolonging the shelf life of horticultural commodities by decreasing O_2 and increasing CO_2 concentrations in the package atmosphere, achieved via the interaction between respiratory O_2 uptake and CO_2 evolution by the packaged produced and gas transfer between the packaging film (*17*). The influence of MAP on the marketing quality of prepacked button mushrooms (*A. bisporus*) was assessed in several earlier studies by measuring the external and internal color, firmness, and microbial growth (*18*). More recently, Kim et al. (*19*) determined the effects of packaging in PVC wrap or two polyolefin (PD-941 and PD-961) films on the shelf life of whole and sliced button mushrooms, uncoated or after coating with $CaCl_2$ and chitosan. The whiteness of whole mushrooms varied significantly with the type of coating (the extent of darkening was greater in coated whole mushrooms than in sliced ones), but not with the type of films. Weight loss occurred in all packages although, due to a lower permeability, PD-961 was most effective in lowering weight loss and the maturity index for both whole and sliced mushrooms, thereby extending the shelf life.

Beit-Halachmy and Mannheim (*20*) concluded that MAP may be beneficial for maintaining the quality of fresh *A. bisporus*, but if batches of mushrooms respired more quickly than predicted or were exposed to large temperature fluctuations, MAP could have a damaging effect. MAP was also reported to be beneficial for maintaining acceptable quality of *Pleurotus ostreatus* (*7, 21*). However, as far as we are aware, this is the first assessment of the effects of MAP on general features associated with the postharvest quality of *H. marmoreus* mushrooms during storage and on selected biochemical changes associated with postharvest senescence.

Of the five types of MAP examined, BOPP film was clearly superior in terms of maintaining overall quality as measured in terms of those parameters important to consumers, that is, mushroom firmness, lower weight loss (i.e., less drying out and shriveling), and fewer unsightly aerial hyphae on the mushroom pilei. PVC was also relatively effective in reducing weight losses

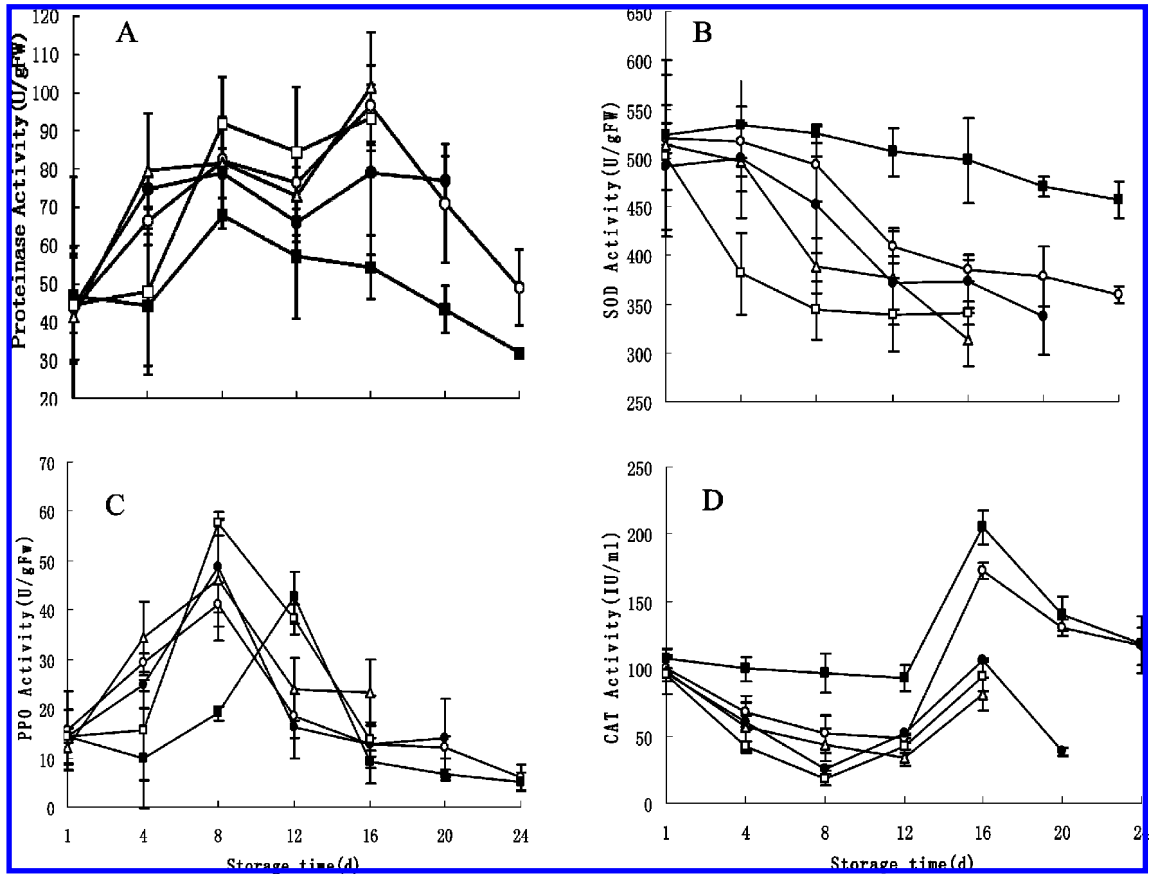

Figure 5. Effect of packaging film on selected enzyme activities in *H. marmoreus* mushrooms during storage at 4 °C: (**A**) proteinase; (**B**) superoxide dismutase (SOD); (**C**) polyphenol oxidase (PPO); (**D**) catalase (CAT); PVC (○); PE6 (□); PE11 (△); PO (●); BOPP (■). Vertical bars represent standard deviation about the mean ($n = 5$); no bars indicate SD < 10%.

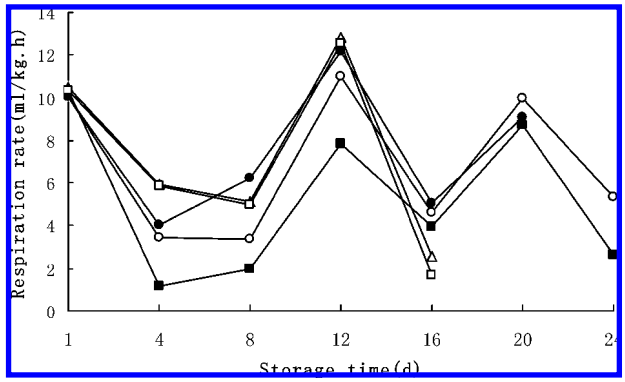

Figure 6. Effect of packaging film on the respiration rate of *H. marmoreus* mushrooms during storage at 4 °C: PVC (○); PE6 (□); PE11 (△); PO (●); BOPP (■). Vertical bars represent standard deviation about the mean ($n = 5$); no bars indicate SD < 10%.

and delaying the onset of aerial hyphae, whereas PE-6 film was least effective under the test conditions.

H. marmoreus mushrooms used in this study contained substantial amounts of soluble protein (~5.0 mg/g of fw) which, after harvesting, serve as a nutrient source to support continuing metabolic activity. The maintenance of relatively high levels of soluble protein in mushrooms packaged in BOPP and PVC indicated a positive effect because a decline in soluble protein concentration is considered to be an important indicator of tissue senescence (*22*). BOPP and PVC were also most effective in slowing both the rate of total sugar disappearance from mushrooms and the rate of increase in reducing sugar levels. Lower total sugar and higher soluble sugar concentrations in harvested agriproducts are also considered to be important indicators of postharvest deterioration (*23*). Further evidence that MAP using BOPP and, to a lesser extent, PVC films served to retain mushroom quality is provided by the lower MDA concentrations recorded in mushrooms packaged in these materials. MDA is widely applied as an index of lipid peroxidation, usually resulting from oxidative stress (*24*), which in turn, causes a reduction in membrane integrity, increases membrane leakage and enhances cell senescence (*25*). The lower MDA concentrations in BOPP- and PVC-packaged mushrooms correlated well with the higher levels of SOD and CAT found in these samples. SOD and CAT protect cells from the damaging effects of reactive oxygen species and represent key components of cellular antioxidant defense systems. SOD catalyzes the dismutation of superoxide anions to produce hydrogen peroxide, which is then removed by CAT, and the two enzymes are thought to extend food freshness by protecting the integrity of membranes. In *A. bisporus*, SOD has been associated with stress tolerance, and the gene encoding the enzyme is reported to be up-regulated in postharvest sporophores.

BOPP packaging was highly effective in maintaining proteinase activity in mushrooms at relatively low levels throughout the storage period. Proteinases appear to play a key role in the postharvest deterioration of edible mushrooms including *A. bisporus* (*22, 26, 27*), *Lentinus edodes* (*28*), *Volvariella volvacea* (*29*), and *Pleurotus* spp. (*29, 30*). A 12-fold increase in proteinase activity was reported in parts of *A. bisporus* pilei after harvesting (*27*), and delaying the onset of postharvest peak proteinase activity in *V. volvacea* and *Pleurotus cornucopiae* using different temperature treatments also prolonged mushroom freshness (*29*). Metalloproteinases and serine proteinases were shown to be the

predominant proteinases (*31*), and accumulation of a serine proteinase in senescent sporophores of *A. bisporus* (*22*) and increased postharvest expression of serine proteinase transcripts (*27*) were subsequently reported. No significant changes in enzyme activity were observed in samples wrapped in PE6 and BOPP during the first 4 days, but levels then more than doubled in the former after 8 days and remained high, whereas activity in the latter increased by ~45% between 4 and 8 days of storage before gradually falling to ~70% of initial levels after 24 days.

Although PPO in all of the samples increased to similar peak values during the storage period, there was a significant delay (~4 days) in the onset of this increase in mushrooms packaged in BOPP film. PPOs are widely distributed in fungi and are the most important factor in the browning of fresh white edible fungi caused by the oxidation of *o*-diphenols to *o*-quinones, which then polymerize to form brown products (*32*). The strain of *H. marmoreus* used in this study produced gray-brown mushrooms, and browning was not a major concern. However, our data are expected to have major implications for the postharvest treatment of white strains of this mushroom that have been developed recently and which are rapidly becoming increasingly popular with consumers.

Production of *Hypsizygus* in China increased 11-fold (from 21,000 to 242,500 tonnes) during 1998−2003 (*33*), due largely to a wider recognition of the nutritional, organoleptic, and health-promoting qualities of this mushroom. However, although the mushroom industry in general has witnessed major advances in cultivation technology and strain improvement, short shelf life is still a major problem facing mushroom producers in terms of distribution and marketing of the fresh products. Therefore, extending the postharvest storage period remains a high priority. Our data show that certain types of MAP have a clear beneficial effect on the postharvest appearance of harvested *H. marmoreus* mushrooms and on various biochemical activities previously linked to postharvest deterioration.

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