African Journal of Agricultural Research Vol. 6(24), pp. 5414-5421, 26 October, 2011
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR11.734
ISSN 1991-637X ©2011 Academic Journals

Full Length Research Paper

Physicochemical properties of mushrooms as affected by modified atmosphere packaging and $CaCl_2$ dipping

Mohammadreza Koushki[1], Sadegh Khoshgozaran Abras[2], Mehrdad Mohammadi[1]*, Zahra Hadian[1], Niloofar Bagheri Poorfallah[1], Parvin Sharayei[2] and Amir Mohammad Mortazavian[1]

[1]Department of Food Technology Research, National Nutrition and Food Technology Research Institute, Faculty of Nutrition Sciences and Food Technology, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
[2]Department of Food Science and Technology, College of Agriculture, Tarbiat Modares University, Tehran, Iran.

Accepted 10 October, 2011

The objective of the present study was to evaluate the effect of modified atmosphere packaging (MAP) in combination with $CaCl_2$ dipping on the shelf-life of common mushrooms (*Agaricus bisporus*). Mushrooms were packaged under MAP and air atmosphere with and without $CaCl_2$ dipping; then all the samples were stored at 4, 10 and 18°C and their physicochemical properties (weight loss, color and glucose contents) were analyzed. The results showed that mushrooms packaged under MAP had the lowest weight loss and L value (brightness), highest degree of overall color change (ΔE) and glucose contents. Overall, low storage temperature and $CaCl_2$ dipping significantly affected the quality of packaged mushrooms ($P<0.01$). Results from the present work suggest that MAP of 5% CO_2 : 10% O_2 (P_2G_2) with $CaCl_2$ dipping (0.3% for 5 min) and storage at 4°C can be used successfully for extending the shelf-life of the mushrooms for more than 11 days.

Key words: Mushroom (*Agaricus bisporus*), $CaCl_2$ dipping, modified atmosphere packaging (MAP), physicochemical properties.

INTRODUCTION

Among 14000 known mushroom species, white button or common mushroom *"Agaricus bisporus*" is one of the most cultivated and consumed edible mushrooms (Chang, 1999; Singh et al., 1999; Boa, 2004). Common mushrooms are rich in various nutrients; several bioactive components and many health benefits have been attributed to mushrooms and the components isolated from them include bioactive polysaccharides (β-glucan, such as lentinan), antioxidants, dietary fibers, ergosterol, vitamins B_1, B_2 and C, folates and minerals (Mattila et al., 2000). Mushrooms are highly perishable and deteriorate within a day after harvest (Antmann et al., 2008). In comparison with other vegetables and fruits, the respiration rate of mushrooms is relatively high which is related to their thin and porous epidermal structure (200 to 500 mg/kg h at 20°C) (Kim et al., 2006). Since mushrooms are fast respiring and highly perishable, prolonging post-harvest storage period while preserving their quality would benefit the mushroom industry as well as consumers.

One of the recent technologies to accomplish this is to use the MA-packaging technique which has been reported as an effective tool for extending the shelf-life of mushrooms (Ares et al., 2006) as well as other type of foods (Alam and Goyal, 2011; Degirmencioglu et al., 2011; Kudachikar et al., 2011; Rai et al., 2011; Sabir et al., 2011; Thippeswamy et al., 2011) along with keeping them fresh. MAP can be defined as a modified atmosphere created by changing the normal air composition in order to provide the desired atmosphere surrounding the packaged product (Antmann et al., 2008). A modified atmosphere composition inside the package depends on various factors such as the rate of respiration, amount of product, proportion of the amount of product to film surface area, permeability of film to gases and storage temperature (Simón et al., 2010). Modified atmospheres, richer in CO_2 and poorer in O_2 than air, are assumed to be able to reduce respiration rate, decay and physiological deteriorations of vegetables, which results in shelf-life extension(Antmann et al., 2008).

*Corresponding author. E-mail: mohammadi@sbmu.ac.ir.

Although many advantages are attributed to low concentration of O_2, less than 2% could cause anaerobic respiration as well as potential growth of anaerobic pathogens (Kim et al., 2006) and the excessive accumulation of CO_2 (>12 kPa) inside the mushroom package can also result in their severe browning (Villaescusa and Gil, 2003).

It has been reported that washing mushrooms before packaging could prevent off-odor development caused by enzymatic and microbial activities (Sapers et al., 1994). Adding $CaCl_2$ to the irrigation water during cropping can delay the cap opening and deterioration of external appearance (Beelman et al., 1987; Beelman et al., 1992). Bartley et al. (1991) reported a significantly improved color of mushrooms irrigated with 50 ppm oxine plus 0.075% $CaCl_2$ prior to harvest and postharvest storage. Furthermore, Solomon et al. (1991) showed that irrigating mushrooms with 0.25% $CaCl_2$ reduced browning but appeared to increase senescence. Kukura et al. (1998) reported a significant relationship between calcium concentration and lightness of common mushrooms.

The present study was undertaken to investigate the effect of MAP in combination with $CaCl_2$ dipping on the physicochemical parameters of common mushrooms in comparison with the ordinary packaging. In order to accomplish this objective, weight loss, color and glucose contents of pre-dipped mushrooms with 0.3% $CaCl_2$ for 5 min, packed under modified atmospheres of 5% CO_2 : 10% O_2 and 6% CO_2 : 2% O_2 and stored at 4, 10 and 18°C were evaluated.

MATERIALS AND METHODS

Sample collection and preparation

Fresh common mushrooms, used in this study, were purchased from Javaneh, Ltd., Kerman Province, Iran. After harvesting, sorting and cutting their stems, they were divided into two groups: with $CaCl_2$ and without $CaCl_2$ dipping ($WCaCl_2$ and $WOCaCl_2$, respectively) and were packaged under ordinary or air and MAP packaging methods, storing at 4, 10 and 18°C for further analysis.

$CaCl_2$ dipping

In order to find appropriate concentrations and time for $CaCl_2$ dipping, three replicates of mushrooms (about 200 to 300 g each) were separated to 6 groups and treated as 1) 0.3% solution for 5 min; 2) 0.3% solution for 10 min; 3) 0.3% solution for 15 min; 4) 3% solution for 5 min; 5) 3% solution for 10 min and 6) 3% solution for 15 min. Initial observations (color, taste and smell) did not show any differences between treatments. Thereby, 0.3% $CaCl_2$ dipping for 5 min was approved due to being time saving and economic.

Packaging methods

Air or ordinary packaging (P_1 as control)

Three replicates of mushrooms (about 150±5 g) with and without $CaCl_2$ dipping were kept in the high density polyethylene (HDPE) (70 µm thickness; 10.6, 35 and 130 [P ($(cm^3.mm)/(s.cm^2.cm.Hg)$)] for O_2, CO_2 and water vapor permeability, respectively) and tray was wrapped into the stretch film prior to heat sealing.

MAP (P_2)

To determine and select appropriate gas conditions, three replicates of mushrooms (about 150±5 g) with and without $CaCl_2$ dipping were packed into polyvinyl chloride (PVC) and polyethylene (PE) as the lower laminated layer (265 µm thickness; 0.053, 0.29 and 14 [P ($(cm^3.mm)/(s.cm^2.cm.Hg)$)] for O_2, CO_2 and water vapor permeability, respectively) and with polyethylene polyamide as the upper laminated layer (70 µm thickness; 0.38, 1.6 and 7000 [P ($(cm^3.mm)/(s.cm^2.cm.Hg)$)] for O_2, CO_2 and water vapor permeability, respectively) in 17.5×11.5×5 cm^3. The packed samples were filled by various gas mixtures carried out by Ross Thermo Form-Fill Seal model 1550 (Germany), which created a vacuum in the packs and flushed the gas mixture before heat sealing.

Different types of applied atmosphere were 1) CO_2 6%: O_2 2%, 2) CO_2 10%: O_2 2%, 3) CO_2 12%: O_2 2% 4) CO_2 6%: O_2 4% 5) CO_2 10%: O_2 4% 6) CO_2 12%: O_2 4% 7) CO_2 6%: O_2 6% 8) CO_2 10%: O_2 6% 9) CO_2 12%: O_2 6% 10) CO_2 5%: O_2 10%. In addition, N_2 was used as a filler gas. Results of preliminary observations (browning, taste, and overall acceptance, presence/absence of surface moisture, mold and yeast inside the packages) showed that gas mixtures number 1 and 10 were appropriate which were named P_2G_1 and P_2G_2, respectively.

Storage and sampling

Packed samples were incubated by Vindon Scientific (U.K) at different storage temperatures (4, 10 and 18°C) and 80% RH. Samples at 4, 10 and 18°C were acceptable for 11, 6 and 3 days, respectively. Samples at 18°C were deleted from further analysis because of the lowest storage capability.

Gas analysis

The composition of gas atmosphere inside the packaged samples was examined by gas chromatography (model 439 Chorompack) with a TCD detector. The used columns were two stainless steel columns (3.2 mm) packed with Molecular Sieve 13X (for separating O_2 and N_2) and Propack Q (for separating CO_2).

Color

The surface color and L-value of mushrooms were measured by a Hunter-Lab Chroma Meter CR-300 (Minolta Corporation, Instrument Systems, Ramsey, NJ). Three random locations were measured on the sliced sites of the cap and they were compared with the ideal mushroom color values of L (brightness)=97, a (greenness) =-2 and b (yellowness) =0 using ΔE as described by the following equation (Kim et al., 2006):

$$\Delta E= [(L-97)^2+ (a-(-2))^2+b^2]^{1/2},$$

where ΔE is degree of overall color change in comparison with color values of an ideal mushroom.

Weight loss

Weight loss was calculated by the following equation:

$$\text{Weight loss (g/100 g)} = (W_0-W_d)/W_0\times 100$$

where W_0 is first day weight and W_d is desired day after storage (Kim et al., 2006).

Glucose contents

Glucose contents were determined based on the Gravimeter-Fehling method (Nigam and Ayyagari, 2008).

Statistical analysis

Data were analyzed by ANOVA one-way parametric test using SPSS 12.1 statistical software (SPSS Inc., Chicago, IL, USA). The Duncan test was used to determine statistically significant differences among means. A 99% ($P< 0.01$) significance level was considered in all the comparisons (Mohammadi et al., 2011).

RESULTS AND DISCUSSION

Packaging atmosphere composition

Changes of MAP atmosphere composition are presented in Figure 1. Packaging atmosphere surrounding the product in all treatments altered over storage time. The decrease and increase were observed in O_2 and CO_2 concentrations, respectively which were reported by other researchers previously (Ares et al., 2006; Parentelli et al., 2007; Antmann et al., 2008; Simón et al., 2010). Accordingly, high respiration rate of mushrooms and packaging film permeability to gasses were proposed as a possible reason for gaseous alternations (Exama et al., 1993; Lopez-Briones et al., 1993). Furthermore, it was observed that samples dipped with $CaCl_2$ in comparison with samples without $CaCl_2$ dipping had lower CO_2 and higher O_2 concentrations, which indicates that $CaCl_2$ dipping was efficient in retarding respiration rate of mushrooms. Roy et al. (1995) demonstrated the effectiveness of $CaCl_2$ dipping by lowering the rate of gas mixture rate. However, results obtained by Kuyper et al. (1993) showed that calcium hypochlorite treatment did not influence the atmosphere composition significantly. Cliffe-Byrnes and O'Beirne (2008) found no significant relationship between in-package gas composition and washing mushrooms before packaging with ClO_2 and H_2O_2.

In addition, increasing storage temperature from 4 to 10°C resulted in lower O_2 and higher CO_2 concentrations. These findings confirmed the results reported by Cliffe-Byrnes and O'Beirne (2008) in which the effect of storage temperature on atmosphere evolution was mentioned as lower O_2 and higher CO_2 concentrations at 8°C compared with 4°C. Similarly, Masson et al. (2002) indicated that, in case of CO_2 and O_2, rate of change was greater at 10°C than at 5°C.

Weight loss

Weight loss was significantly affected by storage time and temperature ($P<0.01$). The amount of weight loss increased during the storage period and increase in storage temperature resulted in increase in weight loss (Tables 1, 2 and 4) which could be expected because of previous results reported by Tano et al. (1999), Villaescusa and Gil (2003) and Antmann et al. (2008) who mentioned the effect of higher temperature on accelerating weight loss and found the lowest weight loss at 4 and 0°C, corresponding to fall in vapor transmission of films, transpiration and respiration rate of the mushrooms (Roy et al., 1995). As far as $CaCl_2$ dipping is concerned, samples with $CaCl_2$ dipping had lower weight loss in comparison with without $CaCl_2$ dipping (Table 1) which indicated that $CaCl_2$ dipping was efficient in reducing weight loss. This may be associated to the contribution of calcium to maintain the cellular organization and to regulate enzymatic activities, thereby retarding the moisture loss caused by the senescence (Jayathunge and Illeperuma, 2005). Comparing mushrooms under MAP with air-packaged showed that the samples with modified atmosphere presented less weight loss (Table 2). These results demonstrated that MAP is a potential means for decreasing weight loss as one of the deteriorating factors for mushroom quality.

Moreover, the combined use of MAP and $CaCl_2$ dipping significantly declined the rate of weight loss (Table 3). However, Roy et al. (1995) who irrigated the mushroom field by the water containing $CaCl_2$ and Kim et al. (2006) who treated the mushrooms with hard water before packaging did not find $CaCl_2$ dipping effective in reducing weight loss. Evaluating the interactive effect of packaging atmosphere, storage time and $CaCl_2$ dipping (Table 4) showed that the samples under MAP, in comparison with air packaging had the weight loss less than 10%, more than which is considered unacceptable for the packaged products (Antmann et al., 2008), and $CaCl_2$ dipping samples with P_2G_2 stored at 4°C had the lowest weight loss (6.163) which was approximately two times lower than the samples in ordinary packaging without $CaCl_2$ dipping kept at 10°C (12.47) at the end of the storage.

Color

Storage time and temperature are two important factors in color deterioration of mushrooms. As expected, L values and ΔE decreased and increased over the storage time, respectively, and increasing the storage temperature intensified the changes in these variants (Tables 1, 2 and 4). Comparing the samples with $CaCl_2$ dipping with the mushrooms without $CaCl_2$ dipping showed that this dipping significantly affected their color and resulted in higher L value (brighter mushrooms) and lower ΔE ($P<0.01$) (Table 1), which is due to the potential of calcium in imparting stability to vacuole membranes and further slowing the enzymatic browning (Roy et al., 1996). Additionally, obtained results, which demonstrated

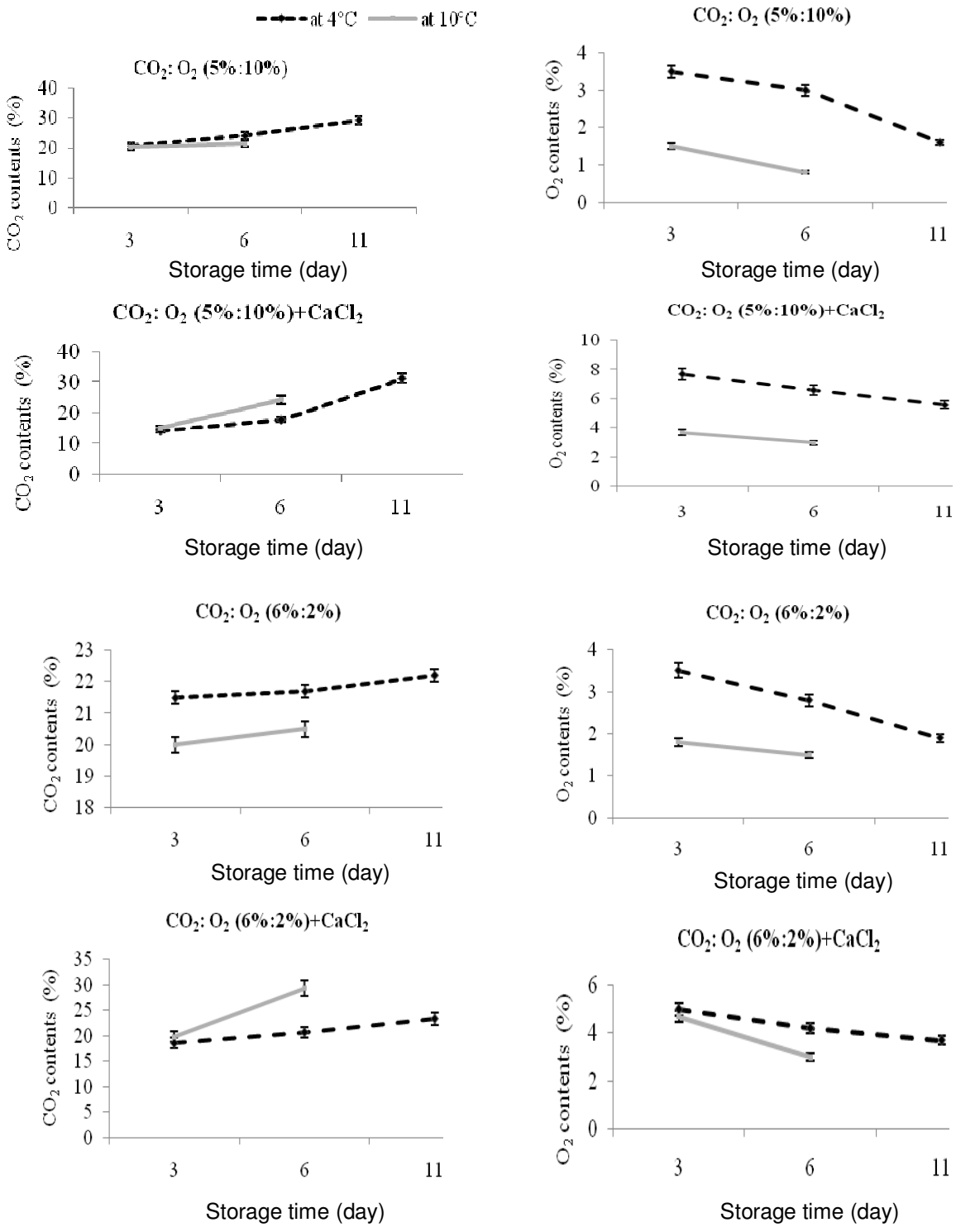

Figure 1. O_2 and CO_2 contents of storage atmosphere of the samples, with and without $CaCl_2$ dipping. Vertical bars represent the standard error.

that MAP was able to retard discoloration and the samples under MAP showed lower increase in ΔE and lower decrease in L value. However, there was no significant difference between P_2G_1 and P_1 in L value and ΔE by the end of storage (Table 2). Retarding discoloration in the mushrooms packaged under the modified atmosphere may be attributed to the suppression of enzymatic browning and reduction of comparison with the

Table 1. Interactive effect of storage time and CaCl2 treatment at 4 and 10°C.

Parameter		Day 3		Day 6		Day 9		Day 11	
		$WOCaCl_2$	$WCaCl_2$	$WOCaCl_2$	$WCaCl_2$	$WOCaCl_2$	$WCaCl_2$	$WOCaCl_2$	$WCaCl_2$
Weight loss, %	4°C	4.023^{F}	3.339^{G}	5.776^{D}	4.724^{E}	8.358^{B}	6.987^{C}	10.57^{A}	8.820^{B}
	10°C	5.060^{B}	4.171^{B}	7.447^{A}	6.712^{A}	NA	NA	NA	NA
Glucose content, %	4°C	0.347^{AB}	0.351^{A}	0.337^{C}	0.344^{B}	0.324^{D}	0.334^{C}	0.303^{F}	0.316^{E}
	10°C	0.307^{AB}	0.310^{A}	0.298^{B}	0.301^{B}	NA	NA	NA	NA
L value	4°C	86.74^{D}	90.56^{A}	84.94^{E}	89.22^{B}	84.40^{E}	88.50^{C}	83.44^{F}	88.02^{C}
	10°C	85.81^{B}	88.75^{A}	82.46^{D}	85.05^{C}	NA	NA	NA	NA
ΔE	4°C	24.33^{C}	17.36^{F}	25.02^{B}	20.26^{E}	25.92^{B}	21.50^{E}	26.66^{A}	22.64^{D}
	10°C	25.49^{B}	21.34^{C}	30.77^{A}	25.12^{B}	NA	NA	NA	NA

Each value is a mean of 3 replicates (n=3) and different letters in the respective row are significantly different at α=0.01; WOCaCl2: without CaCl2 treatment; WCaCl2: with CaCl2 treatment; NA: not analyzed (or unacceptable).

Table 2. Interactive effect of storage time and packaging atmosphere at 4 and 10°C.

Parameter		Day 3			Day 6			Day 9			Day 11		
		P_2G_2	P_2G_1	P_1	P_2G_2	P_2G_1	P_1	P_2G_2	P_2G_1	P_1	P_2G_2	P_2G_1	P_1
Weight loss, %	4°C	1.688^{G}	1.815^{G}	7.540^{D}	3.096^{F}	3.372^{F}	9.281^{G}	5.217^{E}	7.017^{D}	10.78^{B}	7.324^{D}	9.798^{C}	11.97^{A}
	10°C	2.531^{E}	2.940^{E}	8.376^{B}	4.363^{D}	5.550^{C}	11.320^{A}	NA	NA	NA	NA	NA	NA
Glucose content, %	4°C	0.352^{A}	0.351^{A}	0.344^{ABC}	0.346^{AB}	0.343^{BC}	0.333^{D}	0.337^{CD}	0.332^{D}	0.319^{EF}	0.323^{E}	0.315^{F}	0.291^{G}
	10°C	0.314^{A}	0.309^{AB}	0.302^{BC}	0.306^{AB}	0.300^{BC}	0.293^{C}	NA	NA	NA	NA	NA	NA
L value	4°C	90.34^{A}	87.71^{C}	87.89^{C}	88.52^{B}	86.85^{D}	85.87^{E}	87.23^{C}	86.50^{D}	85.42^{EF}	86.31^{DE}	85.56^{F}	85.32^{F}
	10°C	87.67^{A}	87.44^{B}	86.73^{C}	84.41^{D}	83.33^{E}	83.52^{E}	NA	NA	NA	NA	NA	NA
ΔE	4°C	19.39^{H}	21.33^{F}	21.82^{E}	20.59^{G}	21.67^{E}	25.66^{B}	22.45^{E}	22.66^{DE}	26.02^{A}	23.30^{D}	24.01^{C}	26.64^{A}
	10°C	21.99^{E}	24.01^{D}	24.23^{D}	26.67^{C}	27.66^{B}	29.51^{A}	NA	NA	NA	NA	NA	NA

Each value is a mean of 3 replicates (n=3) and different letters in the respective row are significantly different at α=0.01; NA: not analyzed (or unacceptable); P_1: Air atmosphere; P_2G_1: Gas atmosphere of 6% CO_2 : 2% O_2; and P_2G_2: Gas atmosphere of 5% CO_2 : 10% O_2.

air-packaged samples with or without $CaCl_2$ dipping (Table 3).

In line with this study's findings, Ahvenainen (2003) reported that higher L value and lower ΔE can be obtained using MAP in packaging mush-rooms in comparison with the samples stored in

Table 3. Interactive effect of packaging atmosphere and $CaCl_2$ treatment at 4 and 10°C.

Parameter		P_1		P_2G_1		P_2G_2	
		$WCaCl_2$	$WOCaCl_2$	$WCaCl_2$	$WOCaCl_2$	$WCaCl_2$	$WOCaCl_2$
Weight loss, %	4°C	9.080^{B}	10.710^{A}	5.153^{D}	5.848^{C}	3.669^{E}	4.994^{D}
	10°C	9.316^{A}	10.390^{A}	3.993^{BC}	4.497^{B}	3.016^{C}	3.878^{BC}
Glucose content, %	4°C	326.8^{C}	316.1^{D}	339.5^{AB}	330.8^{C}	342.3^{A}	336.0^{B}
	10°C	298.8^{C}	295.8^{BC}	306.3^{ABC}	302.8^{ABC}	311.5^{A}	308.0^{AB}
L value	4°C	88.87^{B}	83.86^{E}	88.97^{B}	84.44^{D}	89.96^{A}	86.82^{C}
	10°C	86.63^{B}	83.63^{E}	86.35^{C}	84.43^{D}	87.71^{A}	84.36^{D}
ΔE	4°C	21.06^{D}	28.34^{A}	20.08^{E}	24.56^{B}	19.12^{F}	23.07^{C}
	10°C	24.03^{D}	29.71^{A}	23.56^{D}	28.11^{B}	22.09^{E}	26.57^{C}

Each value is a mean of 3 replicates (n=3) and different letters in the respective row are significantly different at α=0.01; $WOCaCl_2$: without $CaCl_2$ treatment; $WCaCl_2$: with $CaCl_2$ treatment.

Table 4. Interactive effect of packaging atmosphere, storage time and $CaCl_2$ treatment at 4 and 10°C.

Treatment	T, °C	Weight loss, %	Glucose content, %	L value	ΔE
$P_1D_3WCaCl_2$	4	6.624^{FG}	0.348^{ABC}	90.86^{AB}	17.64^{L}
	10	7.069^{B}	0.304^{ABC}	NA	22.06^{G}
$P_1D_3WOCaCl_2$	4	8.455^{D}	0.340^{BCD}	84.93^{H}	25.99^{C}
	10	9.054^{B}	0.300^{ABC}	NA	26.40^{D}
$P_2G_1D_3WCaCl_2$	4	1.773^{J}	0.352^{A}	89.50^{CD}	17.54^{L}
	10	2.687^{EF}	0.311^{AB}	NA	21.98^{G}
$P_2G_1D_3WOCaCl_2$	4	1.856^{J}	0.350^{AB}	85.92^{G}	25.13^{E}
	10	3.194^{EF}	0.308^{ABC}	NA	26.04^{D}
$P_2G_2D_3WCaCl_2$	4	1.618^{J}	0.353^{A}	91.31^{A}	16.90^{M}
	10	2.130^{F}	0.316^{A}	NA	19.96^{H}
$P_2G_2D_3WOCaCl_2$	4	1.759^{J}	0.350^{AB}	89.37^{D}	21.88^{I}
	10	2.932^{EF}	0.312^{AB}	NA	24.03^{F}
$P1D_6WCaCl2$	4	8.051^{DE}	0.338^{BC}	88.01^{E}	22.46^{H}
	10	10.93^{A}	0.294^{C}	NA	25.99^{D}
$P_1D_6WOCaCl_2$	4	10.51^{BC}	0.328^{EF}	83.74^{IJ}	28.86^{B}
	10	11.72^{A}	0.292^{C}	NA	33.02^{A}
$P_2G_1D_6WCaCl_2$	4	3.247^{HI}	0.346^{ABC}	89.40^{D}	20.25^{J}
	10	5.299^{CD}	0.302^{BC}	NA	25.13^{E}
$P_2G_1D_6WOCaCl_2$	4	3.498^{HI}	0.339^{BC}	84.30^{HI}	23.10^{G}
	10	5.801^{C}	0.298^{BC}	NA	30.18^{B}
$P_2G_2D_6WCaCl_2$	4	2.873^{I}	0.348^{ABC}	90.25^{BC}	18.08^{L}
	10	3.902^{DE}	0.302^{ABC}	NA	24.23^{F}

Table 4. Contd.

$P_2G_2D_6WOCaCl_2$	4	3.320^{HI}	0.343^{ABC}	86.79^{F}	23.10^{G}
	10	4.825^{CD}	0.304^{ABC}	NA	29.10^{C}
$P_1D_9WCaCl_2$	4	10.18^{C}	0.324^{GH}	NA	NA
$P_1D_9WOCaCl_2$	10	11.39^{B}	0.312^{IJ}	NA	NA
$P_2G_1D_9WCaCl_2$	4	6.765^{FG}	0.337^{C}	NA	NA
$P_2G_1D_9WOCaCl_2$	10	7.269^{EF}	0.327^{FG}	NA	NA
$P_2G_2D_9WCaCl_2$	4	40.020^{H}	0.340^{BC}	NA	NA
$P_2G_2D_9WOCaCl_2$	10	6.413^{FJ}	0.333^{D}	NA	NA
$P_1D_{11}WCaCl_2$	4	11.47^{B}	0.297^{K}	87.73^{E}	23.10^{G}
$P_1D_{11}WOCaCl_2$	10	12.47^{A}	0.285^{L}	82.90^{J}	30.18^{A}
$P_2G_1D_{11}WCaCl_2$	4	8.828^{D}	0.323^{GH}	88.01^{E}	22.46^{H}
$P_2G_1D_{11}WOCaCl_2$	10	10.77^{BC}	0.307^{JK}	83.11^{J}	25.55^{D}
$P_2G_2D_{11}WCaCl_2$	4	6.163^{C}	0.328^{EFG}	88.32^{E}	22.37^{H}
$P_2G_2D_{11}WOCaCl_2$	10	8.485^{D}	0.318^{HI}	84.29^{HI}	24.23^{F}

Each value is a mean of 3 (n=3) replicates and different letters in the respective column are significantly different at α=0.01; NA: not analyzed (or unacceptable); $WOCaCl_2$: without $CaCl_2$ treatment; $WCaCl_2$: with $CaCl_2$ treatment; D_3: day 3, D_6: day 6, D_9: day 9, D_{11}: day 11; P_1: Air atmosphere; P_2G_1: Gas atmosphere of 6% CO_2 : 2% O_2; and P_2G_2: Gas atmosphere of 5% CO_2 : 10% O_2.

conventional packages (non-MAP). Barden et al. (1990) found that $CaCl_2$-irrigated mushrooms were whiter at harvest and had a slower rate of browning during the post-harvest storage in conventional packages. However, Roy et al. (1995) reported that no significant color differences were observed between the treatments for conventional or $CaCl_2$ irrigated mushrooms. As can be seen in Table 4, all the treatments (for L value) were higher than 80, more than which is acceptable for wholesalers and less than 70 would be rejected by consumers (Kim et al., 2006). The highest L value (88.32) and lowest ΔE (22.37) scores were given to $CaCl_2$ dipping samples under P_2G_2 and stored at 4°C. However, no significant difference was observed between the samples with $CaCl_2$ dipping under P_2G_1 (22.46) and P_1 (23.10).

Glucose contents

Glucose contents were affected significantly by the storage time and temperature ($P<0.01$). A reduction was observed in glucose contents over the storage time and glucose consumption was enhanced by increasing storage temperature (Tables 1, 2 and 4). In addition, $CaCl_2$ dipping influenced the glucose contents significantly ($P<0.01$). The samples dipped with $CaCl_2$ contained higher glucose contents than without dipping (Table 1). It can be concluded that it is due to lower respiration rate in $CaCl_2$ dipped samples. As shown in Table 2, the comparison of glucose contents of the mushrooms showed lower reduction in MA packaging than the packaging with air atmosphere (P_1: 0.344 to 0.291 at 4°C; 0.302 to 0.293 at 10°C). $CaCl_2$ dipping combined with MAP resulted in reduction in glucose consumption (Table 3). Ooraikul and Stilles (1991) demonstrated that packaging mushrooms under modified atmosphere affected mushrooms glucose contents and suggested decrease of respiration rate as a possible reason. However, Jiang et al. (2010) reported that reducing sugar levels increased in all samples during a 20-day storage period and observed that relatively small increases occurred in reduction of sugar contents of the samples treated with gamma irradiation (1.0 k Gray) + MAP in comparison with the stand-alone MAP samples. Glucose contents of mushrooms under P_2G_2 with $CaCl_2$ dipping and storage at 4°C (0.328) were slightly higher.

However, there was no significant difference between the mushrooms packed under P_2G_1 (0.323) and P_1 (0.297) both with $CaCl_2$ dipping kept at the same storage temperature after 11 days of storage (Table 4). Finally, Common mushrooms are highly perishable and their shelf-life is 1 to 3 days. Therefore, extending shelf-life would benefit both producers and consumers. The results of the present study showed that MAP in combination with $CaCl_2$ dipping was effective in extending shelf-life of the packaged mushrooms. Furthermore, this study demonstrated the possibility of prolonging the shelf-life of the mushrooms packaged with the gas mixture of 5% CO_2: 10% O_2 (P_2G_2) with $CaCl_2$ (0.3% for 5 min) dipping stored at 4°C up to more than 11 days; since P_2G_2 ha d the weight loss of less than 10% and L value of more than 80 by the end of the research.

REFERENCES

Ahvenainen R (2003). Novel food packaging techniques. Woodhead Publishing limited, CRC Press, pp. 424-425.

Alam T, Goyal G (2011). Effect of MAP on microbiological quality of Mozzarella cheese stored in different packages at 7±1°C. J. Food Sci. Technol., 48(1): 120-123.

Antmann G, Ares G, Lema P, Lareo C (2008). Influence of modified atmosphere packaging on sensory quality of shiitake mushrooms. Postharvest Biol. Technol., 49(1): 164-170.
Ares G, Parentelli C, Gámbaro A, Lareo C, Lema P (2006). Sensory shelf life of shiitake mushrooms stored under passive modified atmosphere. Postharvest Biol. Technol., 41(2): 191-197.
Barden CL, Beelman RB, Bartley CE, Schisler LC (1990). The effect of calcium chloride added to the irrigation water on quality and shelf life of harvested mushrooms. J. Food Prot., 43: 759-762.
Bartley CE, Beelman RB, Winnet JR (1991). Factors affecting colour of cultivated mushrooms (Agaricus bisporus) prior to harvest and during postharvest storage. Mushroom Sci., 13: 689-694.
Beelman RB, Bartley CL, Mau JL, Miklus MB, Solomon JM, Royse DJ, Winner JR, Muthersbaugh HR (1992). Irrigation water treatments to improve quality and shelf life of Agaricus mushrooms. Mushrooms News, 40: 18-23.
Beelman RB, Quinn JJ, Okereke A, Schisler LC, Muthersbaugh HR, Evenson K (1987). Effect of peat casing layer and the addition of calcium chloride to watering treatments on quality and shelf life of fresh mushrooms. In Developments in Crop Science 10. Cultivating edible fungi, P. J. Wuest, D. J. Royse, R. B. Beelman (Ed.), Elsevier Publ. Co., Amsterdam, pp. 271-282.
Beelman RB, Guthrie BD, Royse DJ (1989). influence of bacterial populations on the postharvest deterioration of fresh mushrooms. Mushroom Sci., 11 (2): 655-665.
Boa E (2004). Wild edible fungi a global overview of their use and importance to people. FAO, Rome, p. 148.
Chang ST (1999). World production of cultivated edible and medicinal mushrooms in 1997 with emphasis on Lentinus edodes (Berk.) Sing. in China. Int. J. Med. Mushrooms, 1: 291-300.
Cliffe-Byrnes V, O'Beirne D (2008). Effects of washing treatment on microbial and sensory quality of modified atmosphere (MA) packaged fresh sliced mushroom (*Agaricus bisporus*). Postharvest Biol. Technol., 48(2): 283-294.
Degirmencioglu N, Göcmen D, Inkaya AN, Aydin E, Guldas M, Gonenc S (2011). Influence of modified atmosphere packaging and potassium sorbate on microbiological characteristics of sliced bread. J Food Sci Technol., 48(2): 236-241.
Doores S, Kramer M, Beelman RB (1987). evaluation of bacterial populations associated with fresh mushrooms *(Agaricus bisporus)*. In Developments in Crop Science, 10, Cultivating Edible Fungi P. J. Wuest, D. J. Royse, R. B. Beelman (Ed.). Elsevier Publishing Co, Amsterdam, pp. 283-294.
Exama A, Arul J, Lencki RW, Lee LZ, Toupin C (1993). Suitability of plastic films for modified atmosphere packaging of fruits and vegetables. J. Food Sci., 58(6): 1365-1370.
Jayathunge L, Illeperuma C (2005). Extension of Postharvest Life of Oyster Mushroom by Modified Atmosphere Technique. J. Food Sci., 70(9): E573-E578.
Jiang T, Luo S, Chen Q, Shen L, Ying T (2010). Effect of integrated application of gamma irradiation and modified atmosphere packaging on physicochemical and microbiological properties of shiitake mushroom (Lentinus edodes). Food Chem., 122(3): 761-767.
Kim KM, Ko JA, Lee JS, Park HJ, Hanna MA (2006). Effect of modified atmosphere packaging on the shelf-life of coated, whole and sliced mushrooms. LWT-Food Sci. Technol., 39(4): 365-372.
Kudachikar V, Kulkarni S, Prakash MNK (2011). Effect of modified atmosphere packaging on quality and shelf life of 'Robusta'banana (Musa sp.) stored at low temperature. J. Food Sci. Technol., 48(3): 319-324.
Kukura JL, Beelman RB, Peiffer M, Walsh R (1998). Calcium chloride added to irrigation water of mushrooms *(Agaricus bisporus)* reduces postharvest browning. J. Food Sci., 63(3): 454-457.
Kuyper L, Weinert IAG, McGill AEJ (1993). Effect of modified atmosphere packaging and addition of calcium hypochlorite on the atmosphere composition, colour and microbial quality of mushrooms. Food Sci. Technol. 26(1): 14-20.
Lopez-Briones G, Varoquaux P, Bureau G, Pascat B (1993). Modified atmosphere packaging of common mushroom. Int. J. Food Sci. Technol., 28(1): 57-68.
Masson Y, Ainsworth P, Fuller D, Bozkurt H (2002). Growth of Pseudomonas fluorescens and Candida sake in homogenized mushrooms under modified atmosphere. J. Food Eng., 54(2):125-131.
Mattila P, Suonpää K, Piironen V (2000). Functional properties of edible mushrooms. Nutrition, 16(7-8): 694-696.
Mohammadi M, Abedi A, Azizi MH, Seyed Ahmadian F, Pouraram H (2011). Development of fortified biscuit using NaFeEDTA. J. Sci. Food Agric., 91(11): 1984-1989.
Nigam A, Ayyagari A (2008). Lab manual in biochemistry, immunology and biotechnology. McGraw-Hill Education. New Delhi.
Ooraikul B, Stilles ME (1991). Modified atmosphere packaging of fruits and vegetables. In: Modified atmosphere packaging of food. Ellis Horwood, London.
Parentelli C, Ares G, Corona M, Lareo C, Gámbaro A, Soubes M, Lema P (2007). Sensory and microbiological quality of shiitake mushrooms in modified atmosphere packages. J. Sci. Food Agric., 87(9): 1645-1652.
Rai DR, Chadha S, Kaur MP, Jaiswal P, Patil RT (2011). Biochemical, microbiological and physiological changes in Jamun (Syzyium cumini L.) kept for long term storage under modified atmosphere packaging. J. Food Sci. Technol., 48(3): 357-365.
Roy S, Anantheswaran RC, Beelman RB (1996). Modified Atmosphere and Modified Humidity Packaging of Fresh Mushrooms. J. Food Sci., 61(2): 391-397.
Roy S, Anantheswaran RC, Beelman RB (1995). Fresh mushroom quality as affected by modified atmosphere packaging. J. Food Sci., 60 (2): 334-340.
Sabir A, Sabr FK, Kara Z (2011). Effects of modified atmosphere packing and honey dip treatments on quality maintenance of minimally processed grape cv. Razaki (*V. vinifera* L.) during cold storage. J. Food Sci. Technol., 48 (3): 312-318.
Sapers GM, Miller RL, Miller FC, Cooke PH (1994). Enzymatic browning control in minimally processed mushrooms. J. Food Sci., 59(5): 1047-1047.
Simón A, González-Fandos E, Vázquez M (2010). Effect of washing with citric acid and packaging in modified atmosphere on the sensory and microbiological quality of sliced mushrooms (*Agaricus bisporus L.*). Food Control. 21 (6): 851-856.
Singh AK, Sharma HK, Kumar P, Singh B (1999). Physico-chemical changes in white button mushroom (Agaricus bisporus) at different drying temperatures. Mushroom Res., 8(2): 27-30.
Solomon JM, Beelman RB, Bartley CE (1991). Addition of calcium chloride and stabilized chlorine dioxide to irrigation water to improve quality and shelf life of Agaricus bisporus. Mushroom Sci., 13: 695-701.
Tano K, Arul J, Doyon G, Castaigne F (1999). Atmospheric composition and quality of fresh mushrooms in modified atmosphere packages as affected by storage temperature abuse. J. Food Sci., 64(6): 1073-1077.
Thippeswamy L, Venkateshaiah BV, Patil SB (2011). Effect of modified atmospheric packaging on the shelf stability of paneer prepared by adopting hurdle technology. J. Food Sci. Technol., 48(2): 230-235.
Villaescusa R, Gil M (2003). Quality improvement of Pleurotus mushrooms by modified atmosphere packaging and moisture absorbers. Postharvest Biol. Technol., 28(1): 169-179.