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The Effect of Modified Atmosphere Packaging and Addition of Calcium Hypochlorite on the Atmosphere Composition, Colour and Microbial Quality of Mushrooms

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The effect of modified atmosphere packaging in combination with the addition of calcium hypochlorite on the atmosphere composition, colour and microbial quality of mushrooms was investigated. A modified atmosphere which slowed down discolouration was obtained in perforated low density polyethylene (LDPE) packages. Addition of calcium hypochlorite did not influence the atmosphere composition of the treatments. Low oxygen concentrations were reached in the PVC treatments which increased browning. No benefit to colour values was obtained with the addition of calcium hypochlorite. Addition of calcium hypochlorite (0.4g/L) reduced all the microbial counts in the PVC treatment with two perforations significantly. The coliform and total plate counts of all the different packaging methods were significantly lower at the end of the storage period with the addition of 0.8g/L calcium hypochlorite.

Introduction

Cultivated mushrooms are highly perishable and tend to rapidly lose the quality attributes such as white colour without spots, tight buttons and crisp texture (1). The loss of mushroom quality after harvesting is determined by its physiological development as well as other post-harvested metabolic changes (such as browning) and microbiological deterioration (1,2).

Modified atmosphere packaging (MAP), involving the change of the relative proportions of CO_2 and O_2 in the atmosphere surrounding the food product, is one method that can be used to extend the shelf-life of perishable products (3). A number of authors reported on the use of MAP in mushroom packaging (4–9). Nichols and Hammond (5) found that PVC films, which permitted an accumulation of CO_2 to about 10 to 12 mg/100 mL and depletion of O_2 to about 2 mg/100 mL, proved to be the best.

Nichols and Hammond found that prepacked mushrooms overwrapped with a film which permitted a high level of respiration when intact, showed a decrease in CO_2 and an increase in O_2 concentrations and some decrease in internal browning at all levels of perforation (6). However, Saxena and Rai found that perforation of packets significantly increased veil opening, weight loss and browning. Temperature had a greater effect on browning, and film perforation on veil opening (8).

Furthermore, Burton et al. (7) reported that overwrapping treatments delayed mushroom development and increasing porosity favoured microorganism growth, which may be suppressed by high CO_2 concentrations. These studies showed that by incorporating microporous film into the film overwrap, excessive anaerobic conditions can be prevented; in this context, oxygen levels below 3 to 4 mg/100 mL.

In experiments by Ballantyne (9), four film types were used for modified atmosphere packaging of mushrooms. A small extension of shelf-life (2 to 3 days) at 5 °C was achieved with KBB film packages. An aerobic equilibrium modified atmosphere between 2 to 8 mL/100 mL O_2 and 4 to 10 mL/100 mL CO_2 was established.

Several reports in the past suggested that spoilage is influenced by the action of bacteria on mushroom tissue (10,11). The use of chemicals such as Oxine (a stabilized form of chlorine dioxide) or calcium hypochlorite and calcium chloride in pre-harvest watering applications, lowered incidence of bacterial blotch (10,12). Washed mushrooms generally deteriorate more rapidly than mushrooms packed unwashed due to the increase in water content, which in turn resulted in increased microbial growth (1). In addition, washing causes bruising due to additional handling, with subsequent accelerated browning (3,12). Addition of chemicals such as oxine, sodium hypochlorite, erythorbate and calcium chloride in wash water was shown to be very effective in controlling bacterial growth and colour retention (1).

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The aim of the study was to determine the effect of MAP packaging in combination with the addition of calcium hypochlorite on the colour and microbial quality of mushrooms, using different perforated and unperforated packaging materials. The effect of spraying the calcium hypochlorite onto the mushrooms and not washing was investigated. The effect of perforation on the atmosphere composition was also studied.

Materials and Methods

Mushrooms of a specific strain, i.e. A 9.3 (first break), were obtained from a commercial mushroom farm (Tongaat Mushrooms Ltd, Deodar farm, Johannesburg, RSA). The mushrooms were picked and kept at 5 °C for 1 day before use.

Two experiments were carried out. Variables used in the two experimental groups were the following:

Experiment 1

Treatment 1: LDPE, 4 perforations, MAP, sprayed with $CaCl_2O_2$ (0.4 g/L)
Treatment 2: LDPE, 4 perforations, MAP, without $CaCl_2O_2$
Treatment 3: PVC, no perforations, AIR, without $CaCl_2O_2$
Treatment 4: PVC, no perforations, AIR, sprayed with $CaCl_2O_2$ (0.4 g/L)
Treatment 5: PVC, 2 perforations, AIR, sprayed with $CaCl_2O_2$ (0.4 g/L)
Treatment 6: PVC, 2 perforations, AIR, without $CaCl_2O_2$
(Tray A was used in samples 3 to 6 and tray B in samples 1 and 2 respectively)

Experiment 2

Treatment 1: LDPE, 4 perforations, MAP, sprayed with $CaCl_2O_2$ (0.8 g/L)
Treatment 2: LDPE, 4 perforations, 10 mg/100 mL, MAP without $CaCl_2O_2$
Treatment 3: PVC, no perforations, AIR, sprayed with $CaCl_2O_2$ (0.8 g/L)
Treatment 4: PVC, no perforations, AIR, without $CaCl_2O_2$
Treatment 5: PVC, 2 perforations, AIR, sprayed with $CaCl_2O_2$ (0.8 g/L)
Treatment 6: PVC, 2 perforations, AIR, without $CaCl_2O_2$
(Tray A was used in samples 3 to 6 and tray B in samples 1 and 2 respectively)

Solutions of 0.4 g/L and 0.8 g/L$CaCl_2O_2$ (general purpose) were used for the chemical treatment of the samples. To avoid excessive wetting of the samples, the samples were not washed in water containing chemicals, but instead, the chemical solutions were sprayed onto the mushrooms with a hand spray bottle with a fine mist spray. By weighing, it was established that 1 g (±0.2 g) of the chemical solution remained on 200 g of product.

The mushrooms were packed in a tray whereafter it was placed in a bag of low density polyethylene (LDPE), gas flushed and sealed in a 'VACPACK' vacuum/gas packaging machine (when LDPE was used) or overwrapped (when PVC was used). Gas bottles containing the specific gas mixtures were used and connected to the packaging machine. Packaging materials used were LDPE 30 μm) with four 1 mm perforations and PVC cling wrap with and without two 1 mm perforations. The mushrooms were packed in two types of trays, i.e. a polystyrene tray with dimensions of 180 × 120 × 25 mm (tray A) and a clear PVC tray with dimensions of 170 × 115 × 55 mm (tray B). The gas mixture used was 10 mg/100 mL O_2: 10 mg/100 mL CO_2, supplied by Air Products SA, Pty Ltd.

All the packages contained 200 ± 5 g mushrooms. At least six replicate samples were packed for each treatment in both experiments. The samples were stored at 5 ± 1 °C.

The headspace composition of at least two replicate samples from each treatment were analysed for O_2 and CO_2 concentration, at various intervals during the storage period. The gas samples were taken through silicon septums on the packages using a syringe. The samples were injected through another septum onto a 8-port valve on a Varian 3400 gas chromatograph with a thermal conductivity detector and helium as carrier gas. A 2 m × 2.2 mm Porapac N and a 2 m × 2.2 mm Molecular sieve 13× column were used for the carbon dioxide and oxygen analyses, respectively. A column temperature of 100 °C and a gas flow rate of 30 cm^3/min were used.

A Gardner XL 23 Tri-Stimulus Colorimeter was used to obtain Hunter *L*-values of the samples during regular intervals during the storage period. A small sample aperture place of 10 mm diameter was used. Six different measurements were made on the cap of each mushroom. At least six mushrooms from each treatment were measured in this way.

The microbial counts included Total plate count (Tryptone glucose yeast agar, PCA), *coliforms* (Violet red bile glucose agar, VRB) and *Pseudomonas* sp. (*Pseudomonas* agar base with 5 mL glycerol and CN supplement). The methods and agar preparation are described by Bridson (13). All the microbial results were expressed as cfu/g (colony forming units per gram product).

The data in the graphs and tables are calculated average values of the replicates of each treatment in the experimental groups. Statistical analyses was done using the *F*-test to test for significant differences between all the sample means in one experiment. When the *F*-test showed significant differences between sample means, Scheffe's paired comparison test was used to determine which of the sample means differed significantly from each other (14). In the discussion of the results, significant differences refer to the results obtained with this statistical analysis. A confidence level of 95% was used for the analyses of all the experiments.

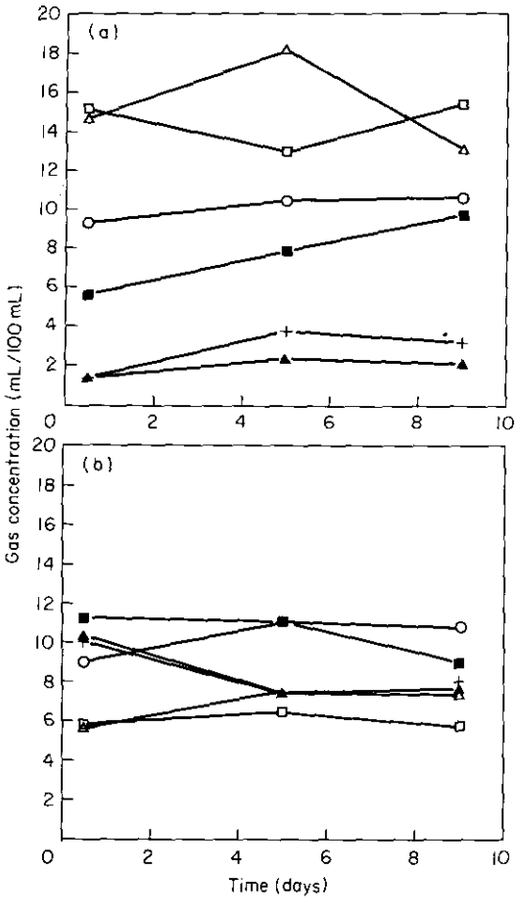

Fig. 1(a) Changes in O_2 concentration (mL/100 mL) of treatments packed in perforated and unperforated PVC and LDPE (experiment 1) with and without the addition of 0.4 g/L $CaCl_2O_2$. (■) LDPE, four perforations, MAP, with $CaCl_2O_2$ (treatment 1); (○) LDPE, four perforations, MAP (treatment 2); (▲) PVC, no perforations, AIR (treatment 3); (+) PVC, no perforations, AIR, with $CaCl_2O_2$ (treatment 4); (□) PVC, two perforations, AIR, with $CaCl_2O_2$ (treatment 5); (△) PVC, two perforations, AIR (treatment 6). **(b)** Changes in CO_2 concentration (mL/100 mL) of treatments, packed in perforated and unperforated PVC and LDPE (experiment 1) with and without the addition of 0.4 g/L $CaCl_2O_2$. (■) LDPE, four perforations, MAP, with $CaCl_2O_2$ (treatment 1); (○) LDPE, four perforations, MAP (treatment 2); (▲) PVC, no perforations, AIR (treatment 3); (+) PVC, no perforations, AIR, with $CaCl_2O_2$ (treatment 4); (□) PVC, two perforations, AIR, with $CaCl_2O_2$ (treatment 5); (△) PVC, two perforations, AIR (treatment 6)

Results and Discussion

Experiment 1

Gas analysis (**Fig. 1**). The atmosphere composition of treatments 1 and 2 (LDPE with four perforations, MAP with and without $CaCl_2O_2$) was modified initially by gas flushing and changed slightly during storage due to respiration and permeability of the packaging material. The atmosphere composition of treatments 1 and 2 (LDPE with four perforations) were 9.7 mg/100 mL O_2: 9.0 mg/100 mL CO_2 and 10.6 mg/100 mL O_2: 10.8 mg/100 mL CO_2 on day 9 and was thus in the desired range according to Ballantyne (9). Atmosphere modification was also observed in treatments 5 and 6 (PVC with two perforations) when modified atmosphere compositions of 15.4 mg/100 mL O_2: 5.8 mg/100 mL CO_2 and 13.1 mg/100 mL O_2: 7.3 mg/100 mL CO_2, respectively, were reached on day 9 of the storage period, but the O_2 concentration was slightly higher than desired. Addition of calcium hypochlorite did not influence the atmosphere composition of the treatments significantly.

Low O_2 concentrations (1.4 mg/100 mL) were reached in treatments 3 and 4 (with no perforations), 4 to 5 h after packaging through the action of respiration. The O_2 concentration of these treatments increased slightly during the rest of the storage period to 2.2 and 3.2 mg/100 mL due to the permeability of the packaging material. It is undesirable to obtain anaerobic conditions, since it can accelerate browning due to physiological damage, as seen from the colour analyses, and increase the risk of growth of anaerobic pathogens.

Colour analysis (**Table 1a**). On day 5, the *L*-value of treatment 2 (LDPE, four perforations, MAP, no $CaCl_2O_2$) was significantly higher (mushrooms whiter) than treatment 4 (PVC, no perforations, AIR, with $CaCl_2O_2$). The sample means of treatment 2 were significantly different from treatments 1 and 4 on day 9. The modified atmosphere created in the samples packed in LDPE with four perforations improved the colour of the treatment and the anaerobic conditions in the PVC packages without perforations increased browning.

Table 1(a) Hunter *L*-values for different treatments packed in perforated and unperforated PVC and LDPE, with and without the addition of 0.4 mg/mL $CaCl_2O_2$

	Time (days)				
	0.5	5		9	
Treatment					
1	44.6	40.6	ab	37.1	b
2	44.6	42.4	a	41.0	a
3	44.6	40.9	ab	38.5	ab
4	44.6	39.3	b	37.2	b
5	44.6	41.7	a	40.8	a
6	44.6	41.1	ab	40.2	ab

Means with the same letter in columns do not differ significantly.
Treatment 1 = LDPE (four perforations), MAP, with $CaCl_2O_2$; treatment 2 = LDPE (four perforations), MAP; treatment 3 = PVC (no perforations), AIR; treatment 4 = PVC (no perforations), AIR, with $CaCl_2O_2$; treatment 5 = PVC (two perforations), AIR with $CaCl_2O_2$; treatment 6 = PVC (two perforations), AIR.

Two treatments with added calcium hypochlorite (treatment 1: LDPE, 4 perforations; treatment 4: PVC, no perforations) had significantly lower *L*-values than the treatments without calcium hypochlorite on day 9. This could be due to a too low concentration of calcium hypochlorite to prevent enzymatic browning and microbial growth, or accelerated bacterial growth due to the addition of water. The difference in colour values of the two treatments in perforated PVC (with and

Table 1(b) Microbial counts (cfu/g) of treatments packed in perforated and unperforated PVC and LDPE, with and without the addition of 0.4 mg/mL $CaCl_2O_2$

	Treatments						
	Time (days)	1	2	3	4	5	6
PCA	1	8×10^4	5×10^5	5×10^5	8×10^4	8×10^4	5×10^5
	5	$>3 \times 10^7$ a	$>3 \times 10^7$ a	$>3 \times 10^7$ b	2×10^7 b	5×10^6 b	$>3 \times 10^7$ a
	9	5×10^7 cb	3×10^8 a	1×10^7 b	1×10^6 c	2×10^6 cb	1×10^5 d
VRB	1	6×10^4	6×10^4	6×10^4	6×10^4	6×10^4	6×10^4
	5	2×10^6 a	9×10^6 a	1×10^6 a	2×10^6 b	1×10^6 c	6×10^6 a
	9	2×10^7 d	$>3 \times 10^8$ a	5×10^7 b	4×10^6 dc	6×10^6 c	4×10^5 e
CN	1	2×10^4	8×10^5	8×10^5	2×10^4	2×10^4	8×10^5
	5	4×10^5 ab	1×10^6 a	6×10^4 cd	9×10^4 c	2×10^4 d	4×10^5 b
	9	1×10^5 b	5×10^6 a	4×10^5 b	1×10^5 b	2×10^5 b	1×10^5 b

Means with the same letter in columns do not differ significantly.
PCA, total plate count; VRB, total coliforms; CN, *Pseudomonas* spp. Treatment 1 = LDPE (four perforations), MAP, with $CaCl_2O_2$; treatment 2 = LDPE (four perforations), MAP; treatment 3 = PVC (no perforations), AIR; treatment 4 = PVC (no perforations), AIR, with $CaCl_2O_2$; treatment 5 = PVC (two perforations), AIR with $CaCl_2O_2$; treatment 6 = PVC (two perforations), AIR.

without calcium hypochlorite) was not significant. No benefit to colour values was obtained with the addition of calcium hypochlorite.

Microbial analysis (**Table 1b**). The initial *Pseudomonas* and total plate counts of treatments treated with calcium hypochlorite (treatments 1, 4 and 5) were significantly lower than treatments without calcium hypochlorite (treatments 2, 3 and 6). No significant difference in initial coliform counts were observed between treatments with and without calcium hypochlorite treatment. Addition of calcium hypochlorite reduced the initial *Pseudomonas* and total plate counts of the samples but not the coliform counts on the mushrooms.

No significant differences in microbial counts of the LDPE treatments with four perforations and the treatments in PVC with no perforations (with and without calcium hypochlorite) were obtained on day 5.

On day 9, at the end of the storage period, the coliform and total plate counts of the treatments packed in LDPE (four perforations) and PVC (no perforations) were lower in treatments treated with calcium hypochlorite than without. In the treatment packed in PVC (no perforations) higher counts were found in the treatment containing calcium hypochlorite.

On days 5 and 9, addition of calcium hypochlorite reduced all the microbial counts in the PVC treatment with two perforations significantly. This can be due to the positive influence of the addition of calcium hypochlorite and the modified atmospheres created in treatments.

Calcium hypochlorite addition in experiment 1 resulted in a lowering of the initial microbial counts. The addition of calcium hypochlorite to the PVC treatment with two perforations reduced microbial growth. No effects or increases occurred in the other samples.

Experiment 2

Gas analysis (**Fig. 2**). The O_2 concentration in the PVC treatments with two perforations was initially modified to 4 to 7 mg/100 mL, but increased suddenly towards day 8, whereas the O_2 concentrations in treatments 1 and 2 (LDPE, 4 perforations, MAP, with and without $CaCl_2O_2$) were 15.1 and 13.9 mg/100 mL, respectively. None of the treatments resulted in a desirable atmosphere composition. The sudden increase in O_2 concentration in the PVC treatments with two perforations toward day 8 after an initial O_2 concentration of 4 to 7 mg/100 mL, could be due to leakages in the packages. Higher O_2 concentrations were reached on day 8 in the samples packed in LDPE with four perforations in this experiment than in experiment 1. This could be due to variations in raw material quality and respiration rate.

The atmosphere composition of the PVC treatments with no perforations was modified to low O_2 concentrations (<2 mg/100 mL) through the action of respiration. Addition of calcium hypochlorite did not influence the atmosphere composition of the treatments.

Colour analysis (**Table 2a**). On day 5, the *L*-value of treatment 5 (PVC with 2 perforations, treated with calcium hypochlorite (0.8 g/L) were significantly lower (mushrooms browner) than the treatment without calcium hypochlorite, showing a disadvantage of the use of a higher concentration calcium hypochlorite compared to experiment 1. The differences between *L*-values of the other treatments were not significant.

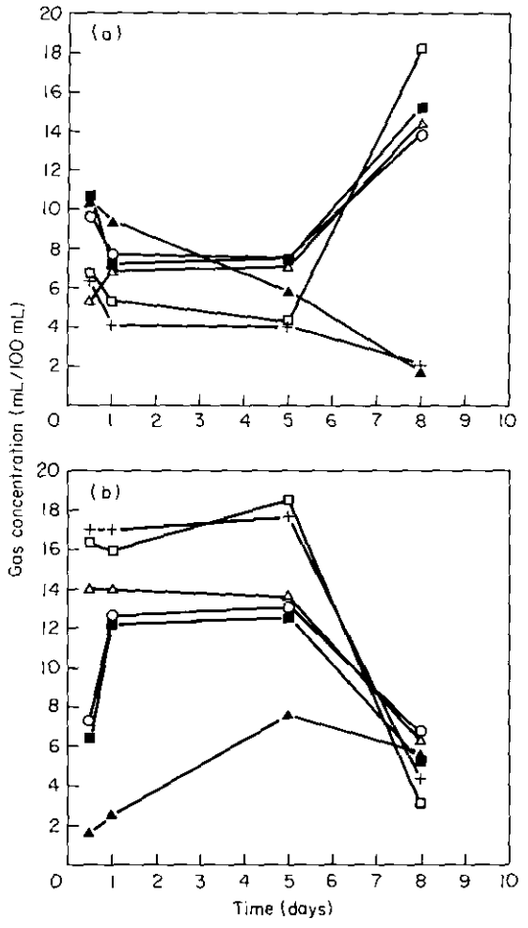

Fig. 2(a) Changes in O_2 concentration (mL/100 mL) of treatments packed in perforated and unperforated PVC and LDPE (experiment 1) with and without the addition of 0.4 g/L $CaCl_2O_2$. (■) LDPE, four perforations, MAP, with $CaCl_2O_2$ (treatment 1); (○) LDPE, four perforations, MAP (treatment 2); (▲) PVC, no perforations, AIR, with $CaCl_2O_2$ (treatment 3); (+) PVC, no perforations, AIR (treatment 4); (□) PVC, two perforations, AIR, with $CaCl_2O_2$ (treatment 5); (△) PVC, two perforations, AIR (treatment 6). **(b)** Changes in CO_2 concentration (mL/100 mL) of treatments, packed in perforated and unperforated PVC and LDPE (experiment 1) with and without the addition of 0.4 g/L $CaCl_2O_2$. (■) LDPE, four perforations, MAP, with $CaCl_2O_2$ (treatment 1); (○) LDPE, four perforations, MAP (treatment 2); (▲) PVC, no perforations, AIR, with $CaCl_2O_2$ (treatment 3); (+) PVC, no perforations, AIR (treatment 4); (□) PVC, two perforations, AIR, with $CaCl_2O_2$ (treatment 5); (△) PVC, two perforations, AIR (treatment 6)

On day 9, the differences between *L*-values of the treatments with and without calcium hypochlorite were not significant. The addition of a higher concentration calcium hypochlorite did not increase the discoloration towards the end of the storage period as in experiment 1. This could be a result of a slight bleaching effect obtained with calcium hypochlorite which counteracted the negative effect of the increased water content.

The *L*-values of the treatments in LDPE with four perforations were significantly higher than those of the treatments in PVC (no perforations), showing an advantage of an aerobic atmosphere compared to anaerobic conditions.

Microbial analysis (**Table 2b**). On day 5, total plate count of the treatments in PVC (no perforations) with calcium hypochlorite were significantly lower than the counts of treatments in PVC without calcium hypochlorite and the rest of the treatments. Differences between all the perforated PVC and LDPE treatments, with and without calcium hypochlorite, were not significant. The coliform counts in all the treatments in the different packaging materials with added calcium hypochlorite were significantly lower than the treatments in the same packaging material without added calcium hypochlorite. No significant difference in *Pseudomonas* counts were observed between samples with calcium hypochlorite and without.

On day 9, the coliform and total plate counts of the all different packaging materials were significantly lower on day 9 with the addition of 0.8 g/L calcium hypochlorite. For example, the total plate counts of the samples in LDPE were 1×10^6 (with $CaCl_2O_2$) and 9×10^6 (without $CaCl_2O_2$). Thus, an advantage of spraying with 0.8 g/L calcium hypochlorite on the microbial quality of the samples was observed on day 9 of the storage period.

On day 9, the *Pseudomonas* and total plate counts of treatment 3 (PVC, no perforations, with $CaCl_2O_2$) were significantly lower than treatment 1 (LDPE, four perforations with $CaCl_2O_2$). At the same time, the *Pseudomonas* and total plate counts of treatment 4 (PVC, no perforations, no $CaCl_2O_2$) were significantly lower than treatment 2 (LDPE, four perforations, no $CaCl_2O_2$). The higher *Pseudomonas* and total plate counts in the perforated LDPE samples compared to the unperforated PVC samples could be a result of the aerobic conditions and the high humidity conditions created inside the LDPE samples.

Table 2(a) Hunter *L*-values for different treatments packed in perforated and unperforated PVC and LDPE, with and without the addition of 0.8 mg/mL $CaCl_2O_2$

	Time (days)		
Treatment	0.5	5	9
1	44.3	42.3 ab	43.0 a
2	44.3	42.1 ab	43.1 a
3	44.3	40.9 ab	40.0 b
4	44.3	40.4 b	41.2 ab
5	44.3	41.6 ab	42.0 ab
6	44.3	42.9 a	42.3 a

Means with the same letter in columns do not differ significantly.
Treatment 1 = LDPE (four perforations), MAP, with $CaCl_2O_2$; treatment 2 = LDPE (four perforations), MAP; treatment 3 = PVC (no perforations), AIR, with $CaCl_2O_2$; treatment 4 = PVC (no perforations), AIR; treatment 5 = PVC (two perforations), AIR with $CaCl_2O_2$; treatment 6 = PVC (two perforations), AIR.

Conclusions

In experiment 1, the atmosphere composition of treatments in LDPE with four perforations were in the

Table 2(b) Microbial counts (cfu/g) of treatments packed in perforated and unperforated PVC and LDPE, with and without the addition of 0.8 mg/mL $CaCl_2O_2$

	Treatments						
	Time (days)	1	2	3	4	5	6
PCA	1	1×10^5	1×10^5	1×10^5	1×10^5	1×10^5	1×10^5
	5	1×10^6	1×10^6	1×10^3	1×10^4	1×10^5	1×10^6
		a	a	a	b	a	a
	9	1×10^6	9×10^6	1×10^5	3×10^6	4×10^5	2×10^6
		b	a	d	b	c	ab
VRB	1	2×10^4	2×10^4	2×10^4	2×10^4	2×10^4	2×10^4
	5	2×10^5	7×10^6	$<10^3$	4×10^4	$<10^3$	2×10^5
			b	a	c	b	cb
	9	6×10^6	6×10^6	7×10^4	1×10^6	4×10^5	2×10^6
		a	a	e	c	d	b
CN	1	6×10^4	6×10^4	6×10^4	6×10^4	6×10^4	6×10^4
	5	4×10^5	3×10^5	1×10^3	2×10^3	3×10^4	5×10^4
		a	a	c	c	b	ab
	9	5×10^6	6×10^6	7×10^4	1×10^6	4×10^5	2×10^6
		a	a	d	bc	c	ab

Means with the same letter in columns do not differ significantly.
PCA, total plate count; VRB, total coliforms; CN, *Pseudomonas* spp. Treatment 1 = LDPE (four perforations), MAP, with $CaCl_2O_2$; treatment 2 = LDPE (four perforations), MAP; treatment 3 = PVC (no perforations), AIR, with $CaCl_2O_2$; treatment 4 = PVC (no perforations), AIR; treatment 5 = PVC (two perforations), AIR with $CaCl_2O_2$; treatment 6 = PVC (two perforations), AIR.

desired range on day 9 and this atmosphere slowed down discolouration of the samples compared to the rest of the treatments. In experiment 2, the atmosphere of these samples were more aerobic but a benefit of aerobic conditions compared to anaerobic conditions (in unperforated PVC) was still obtained. The difference in atmosphere composition could be due to variations in raw material quality and respiration rate. In both experiments 1 and 2, addition of calcium hypochlorite did not influence the atmosphere composition of the treatments.

In experiments 1 and 2, low O_2 concentrations were reached in the PVC treatments, which increased browning compared with the rest of the samples. No benefit to colour values was obtained with the addition of calcium hypochlorite in both experiments.

In experiment 1, addition of calcium hypochlorite caused an increase in browning of the mushrooms towards the end of the storage period, while in experiment 2, the addition of a higher concentration calcium hypochlorite did not increase the discolouration. This could be a result of a slight bleaching effect obtained with calcium hypochlorite which counteracted the negative effect of the increased water content.

In experiment 1, addition of calcium hypochlorite reduced the initial *Pseudomonas* and total plate counts of the treatments, but not the coliform counts, on the mushrooms. On days 5 and 9, addition of calcium hypochlorite reduced all the microbial counts in the PVC treatment with two perforations significantly. This can be due to the positive influence of the addition of calcium hypochlorite and the modified atmospheres created in this treatment.

In experiment 2, the coliform and total plate counts of all the different packaging methods were significantly lower on day 9 with the addition of 0.8 g/L calcium hypochlorite. In addition, the *Pseudomonas* and total plate counts in the perforated LDPE samples were higher than the unperforated PVC samples on day 9, which could be as a result of the aerobic conditions and the high humidity conditions created inside the LDPE samples.

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