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Evaluation of MAP engineering design parameters on quality of fresh-sliced mushrooms

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ABSTRACT

Modified atmosphere packaging (MAP) relies on the interplay between product-respiration and package-film-permeability with the aim of maintaining initial quality and extending shelf-life of fresh produce. This work evaluates the effect of MAP engineering design parameters (amount of product, number of perforations and weight of CO_2 scavenger) on quality of sliced mushrooms. Sliced button mushrooms were packed in a tray, covered with cellophane film, and stored at 10 °C for 3 days. Headspace gas composition and chemical and physical quality parameters (weight loss, pH, firmness and colour) were measured throughout the storage period. All design parameters produced a significant effect ($p < 0.05$) on quality. Addition of CO_2 scavenger in the package increased the deterioration of mushrooms. MAP optimisation design requires consideration of mushroom weight and number of film perforations. The optimal conditions found were 110 g of sliced mushrooms and 2 perforations (0.33 mm diameter) which led to an equilibrium gas composition of 3.6% O_2 and 11.5% CO_2, after 3 days of storage at 10 °C.

1. Introduction

Minimally processed vegetables are ready to use products developed in 1980s to respond to the emerging consumer demand for both convenience and high quality aspects (Del Nobile et al., 2008). Modified atmosphere packaging is a postharvest technology widely used to increase and preserve the shelf-life of fresh produce, improve the product image and reduce waste (Montanez et al., 2010).

MAP of fresh produce relies on the modification of the atmosphere inside the package, achieved by the natural interplay between the respiration of the product and the transfer of gases through the packaging, which leads to an atmosphere richer in CO_2 and poorer in O_2 (passive MAP). MAP design depends of the characteristics of the product, its recommended gas composition and its respiration rate as affected by temperature and headspace gas composition; and the permeability of the packaging materials (perforated or non-perforated polymeric film) and its dependence on temperature (Fonseca et al., 2002; Mahajan et al., 2006, 2009).

MAP also can be achieved by displacing the air of the packaging, with a controlled and desired mixture gases through gas fluxing, or by controlling a specific gas in-package, O_2, CO_2 or ethylene (active MAP) (Robertson, 2006).

An inappropriately designed MAP system may be ineffective or even shorten the storage life of a product: if the desired atmosphere is not established rapidly, the package draws no benefit; if O_2 and O_2/CO_2 levels are not within the recommended range, the product may experience serious alterations and its storage life may be shortened (Fonseca et al., 2002; Mahajan et al., 2006, 2007).

Mushrooms are one of most perishable products. Usually their shelf-life is 1–3 days at ambient temperature, due to high respiration rate (Iqbal et al., 2009) and the inexistence of cuticle (Mahajan et al., 2008). The use of MAP as an adjunct to low temperature storage has been extensively reported to extend shelf-life of mushrooms. Respiration is widely assumed to be slowed down by decreasing O_2, however, the decrease in O_2 concentration and increase in CO_2 concentration must not exceed a certain critical threshold (Parentelli et al., 2007). At very lower O_2 concentrations, anaerobic respiration can occur, leading to the production of off-odours and off-flavours, as well as growth of food borne pathogens, such as *Clostridium botulinum*. Excessive accumulation of CO_2 inside the package can cause physiological injuries to the product, resulting in severe browning, in case of mushrooms (Ares et al., 2006).

A good MAP (passive) should be carefully designed by considering amount of product, film permeability and /or number of perforations and time to achieve the optimum equilibrium atmosphere in order to maintain the initial product quality and extending shelf-life of fresh mushrooms. The present study focus not only on passive MAP but also in active MAP (presence of CO_2 scavenger). Use of CO_2 scavenger in modified atmosphere technology is well documented (Thompson, 1998; Lee et al., 2001; Shin et al., 2002; Cliffe-Byrnes and O'Beirne, 2006). This CO_2 scavenger, calcium

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hydroxide, has been widely used in controlled atmosphere storage for perishable products (Thompson, 1998), and the absorption kinetics of O_2 and CO_2 scavengers was studied by Charles et al. (2006).

The objectives of this work were to determine the effect of the MAP design parameters (amount of product, number of perforations and weight of CO_2 scavenger) on the chemical and physical quality of sliced mushrooms. The optimum MAP conditions were based on an optimum headspace gas composition and aiming to minimise quality changes in order to determine the amount of mushrooms to be packed, the number of perforations and the weight of CO_2 scavenger for maintaining quality and extending the product shelf-life.

2. Materials and methods

2.1. Experimental setup

Button mushrooms (*Agaricus bisporus*) were purchased from a local supermarket (SuperValu, Cork, Ireland) on produce arrival day. Mushrooms were sliced obtaining 0.5 cm of thickness each piece. Sliced mushrooms were placed with a CO_2 scavenger paper bag in a tray ($11.1 \times 15.5 \times 3.4\ cm^3$) and covered with cellophane™ 335 PS film (23.3 μm of thickness, barrier properties: $3\ cc\ m^{-2}\ d^{-1}\ bar^{-1}$ for O_2 at 23 °C and $900\ g\ m^{-2}\ day^{-1}$ for water vapour at 38 °C) supplied by Innovia Films (Innovia Films Ltd., Wigton, Cumbria, CA7 9BG, UK). The film was perforated with a needle of diameter 0.33 mm.

Calcium hydroxide was used as CO_2 scavenger, absorbing CO_2 from the headspace. Calcium hydroxide reacts irreversible with carbon dioxide producing calcium carbonate (Thompson, 1998).

A label of $10 \times 5\ cm^2$ area was placed on the film, to simulate the labels found in the supermarket packaging. Each tray contained 2 rubber septums in opposite sides for the measurement of headspace gas composition. Packages were stored in an incubator at 10 °C for a short incubation time of only 3 days. No pre-treatment was applied on sliced mushrooms and our previous trials have shown that sliced mushrooms at 10 °C were brown, soft and inedible after 3 days, which would not be acceptable by consumers.

The study involved packing the product under 3 different factors viz, amount of mushrooms, number of perforations in the film and weight of CO_2 scavenger. A full factorial experimental design was used for 3 factors with 3 levels each, performing 27 runs in total, as presented in Table 1.

Changes in package atmosphere composition were evaluated using a gas analyzer (PBI Dansensor, CheckMate 9900, Denmark). O_2 and CO_2 concentrations were determined by extracting gas sample directly from septums of each package. The headspace gas composition was analyzed at regular intervals.

2.2. Analysis of quality parameters

The following quality parameters were determined at the beginning and at the end of the experiment, i. e. 3rd day of storage.

2.2.1. Weight loss

The initial and final weight of sliced mushrooms in each package was measured using an electronic balance (Extend Startorius, ED4202S, Germany). The weight loss was calculated according to Eq. (1):

$$WL = \frac{W_0 - W_f}{W_0} \times 100 \quad (1)$$

where WL is the weight loss (%), W_0 is the initial weight (g) and W_f is the final weight (g) of sliced mushrooms from each package.

Table 1
Factors and levels used for the evaluation MAP design of sliced mushrooms.

Factors	Levels		
Number of perforations	1	3	5
CO_2 scavenger (g)	0	1	2
Amount of mushrooms (g)	80	100	120

2.2.2. pH

Sliced mushrooms (around 10 pieces from each package) were previously homogenised with a grinder and pH of that solution was measured, using a digital pH meter (3310 Jenway, pH Meter, UK). An average of 3 replicates of each solution of homogenised mushrooms from each package was calculated.

2.2.3. Firmness

The firmness of sliced mushrooms was measured with a texture analyzer (Stable Micro System, Texture Analyser, HD plus, UK) equipped with a loadcell (compression platen) of 50 kg f, at a speed return 10 mm s^{-1} and 1 g of contact force. Firmness was expressed as compression force (N). Due to the hardness of stem, this was removed from each piece, measuring only the firmness of the cap. An average of 7 pieces in each package was calculated.

2.2.4. Colour

Hunter colour parameters (L^*, a^*, and b^*) have proved valuable in describing visual colour deterioration and providing useful information for quality control in fruits and vegetables. Generally, visual colour degradation of produce is expressed in terms of parameters colour values (L^*, a^* and b^*) individually or its combination, browning index (BI), total colour difference (ΔE), saturation index or chroma (C^*) and Hue angle (H^*) (Maskan, 2001). In this system, L^* represents lightness (high values) and darkness (low values), $+a^*$ represents redness, $-a^*$ greenness, $+b^*$ yellowness and $-b^*$ blueness (Eissa and Zohair, 2006). Browning index was calculated, according to Eq. (2):

$$BI = \frac{100(x - 0.31)}{0.17} \quad (2)$$

where $x = \frac{a^* + 1.75L^*}{5.645L^* + a^* - 3.012b^*}$. L^*, a^* and b^* parameters of colour were measured with a colour meter (Minolta Chroma Meter, CR-300, Japan). L^*, a^* and b^* experimental database were determined by measuring colour of the cap surface of sliced mushroom and an average of 7 slices of mushrooms from each package was calculated.

2.3. MAP design

MAP design for fresh produce requires an integrated model considering (a) product respiration rate as a function of both gas composition and temperature, (b) amount of product, (c) permeability of packaging to O_2, CO_2, as a function of temperature and (d) packaging geometry and size, amongst other product characteristics (Mahajan et al., 2006, 2009). Assuming that there is no gas stratification inside the package and that the total pressure is constant, the differential mass balance equations that describe O_2 and CO_2 concentration changes in a package containing a respiring product (Mahajan et al., 2007) are given in Eqs. (3) and (4).

$$V_f \times \frac{d(y_{O_2})}{dt} = \frac{P_{O_2}}{e} \times A \times (y_{O_2}^{out} - y_{O_2}) - R_{O_2} \times M \quad (3)$$

$$V_f \times \frac{d(y_{CO_2})}{dt} = \frac{P_{CO_2}}{e} \times A \times (y_{CO_2}^{out} - y_{CO_2}) + R_{CO_2} \times M \quad (4)$$

where V_f is the headspace (free volume) in the package, y is the gas concentration (in molar fraction), e is the thickness of polymeric film, P is the permeability of the package expressed in volume of

gas exchanged per unit time and area and R is the respiration rate expressed in volume of gas generated/consumed per unit time and weight of the product (M); the subscripts O_2 and CO_2 refer to oxygen and carbon dioxide, respectively.

2.4. Analysis of experimental data

Statistical evaluation of the results was performed using a 3^3 factorial design. Analysis of variance was carried out to find effects ($p < 0.05$) of number of perforations, CO_2 scavenger and amount of mushrooms on headspace gas composition and mushrooms quality, by using the Statistica software (release 7, Statsoft, USA). Non regression linear using Levenberg–Marquandt method was used to fitting polynomial models to O_2 and CO_2 database, by using the Statistica software. The performance of the fitting was determined and evaluated by using the coefficient of determination (R^2).

3. Results and discussion

3.1. Headspace gas composition

Examples of O_2 and CO_2 concentrations within packages during storage time are shown in Fig. 1. Mushrooms have high respiration rate, creating a modified atmosphere, and equilibrium was achieved quickly (Iqbal et al., 2009). After 3 days of storage and for a packaging containing 3 perforations and 100 g of sliced mush-

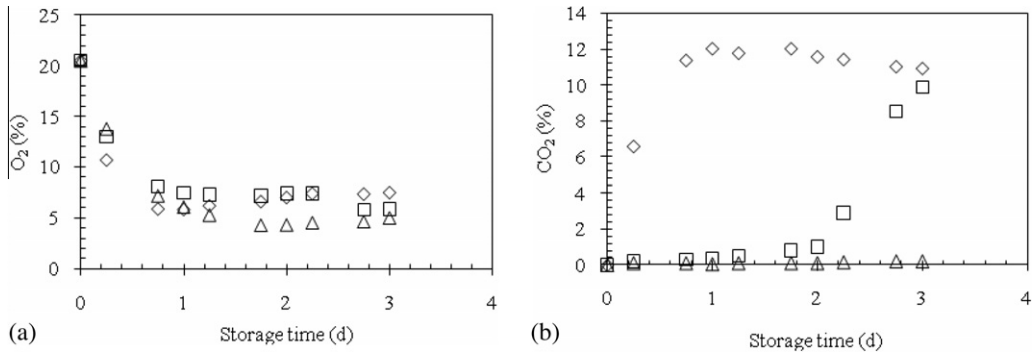


Fig. 1. Examples of profiles of (a) O_2 and (b) CO_2 concentrations inside of the packages, during storage time at 10 °C, for the specified conditions. The amount of CO_2 scavenger: ◇ 0 g scavenger; □1 g scavenger; △2 g scavenger; number of perforations and weight of sliced mushrooms remain constant (3 and 100 g, respectively).

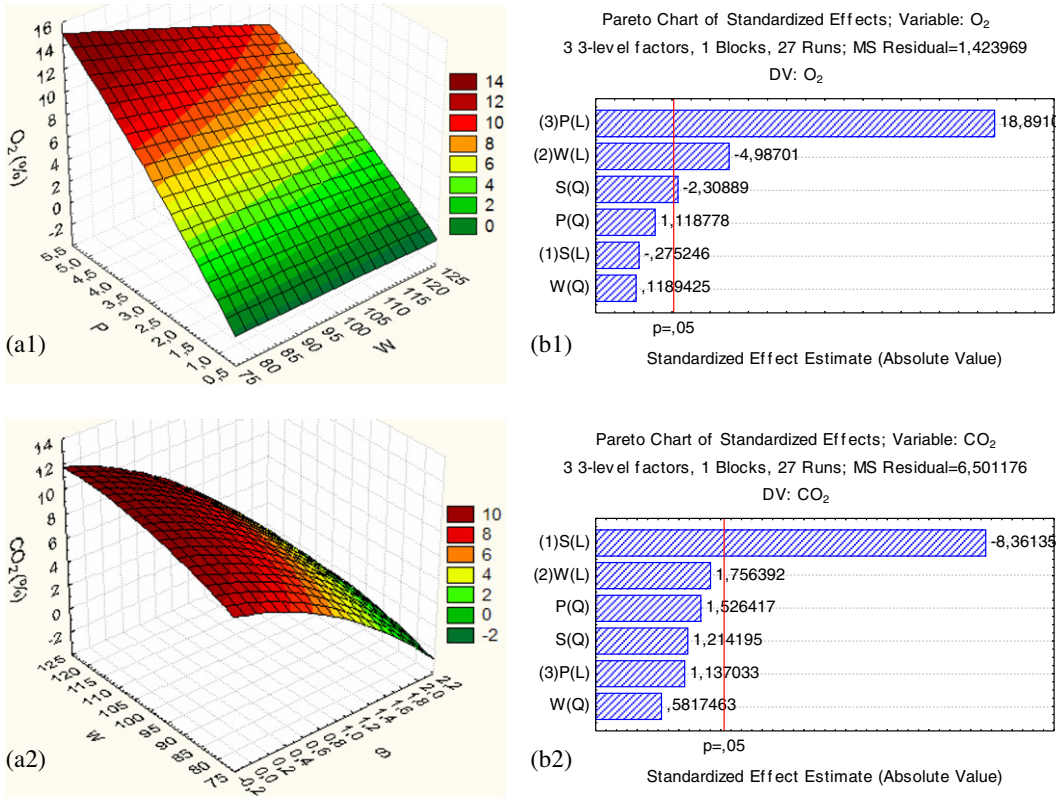


Fig. 2. (a) Surface plots with effects of number of perforations (P), weight of CO_2 scavenger (S) and amount of mushrooms (W) on (1) headspace O_2 composition and (2) headspace CO_2 composition, after 3 days at 10 °C. (b) Pareto charts of standardised effects for number of perforations, weight of CO_2 scavenger and amount of mushrooms on (1) headspace O_2 composition and (2) headspace CO_2 composition, at 95% significance level, indicated as a vertical dashed line.

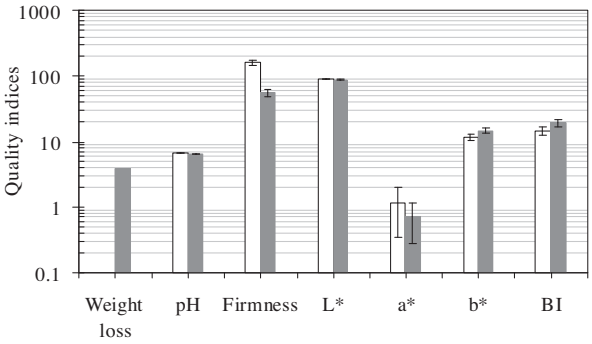
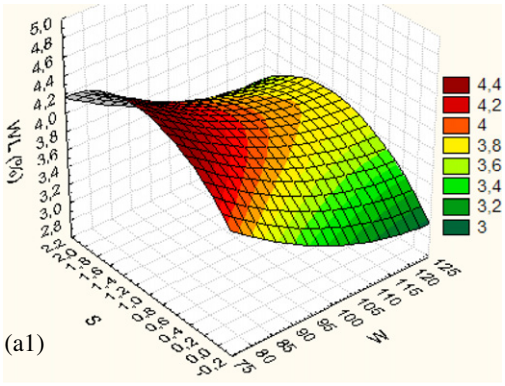
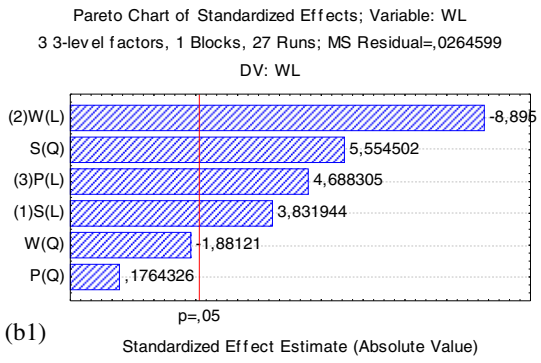
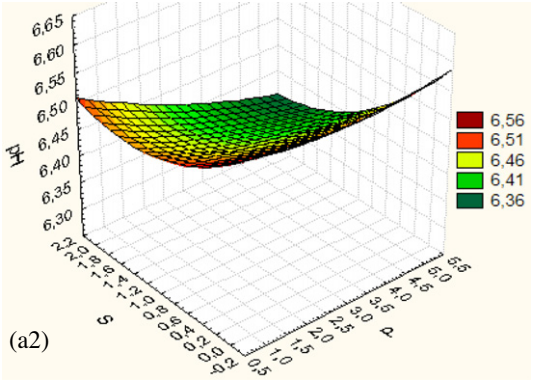


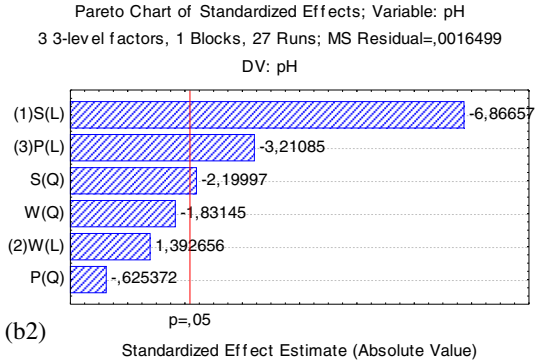
Fig. 3. Changes in quality parameters of sliced mushrooms stored at 10 °C in a package with 3 film perforations, 1 g of CO_2 scavenger and containing 100 g of sliced mushrooms. (empty bar: day 0; filled bar: day 3).

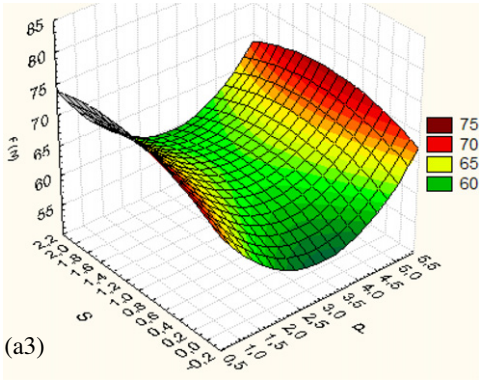
rooms, O_2 decreased to 7.5%, 5.9% and 5.1% in the packages containing 0, 1, and 2 g of CO_2 scavenger, respectively. Equilibrium gases composition in headspace was achieved after, approximately, 1 day, except CO_2 in a package with 1 g scavenger. Decrease in O_2 concentration with time was similar in package containing 0, 1 or 2 g of CO_2 scavenger. However, the amount of CO_2 scavenger showed significant differences in CO_2 concentrations with time. Sliced mushrooms packed without CO_2 scavenger showed increase in CO_2 concentration with time reaching 11%, after 3 days. With scavenger, CO_2 was absorbed by a mechanism reaction of CO_2 scavenger, eliminating it from headspace. In packages with 1 g of scavenger, CO_2 remained almost null until 40 h after which it increased rapidly to 10% by the end of the storage period. It showed that 1 g of scavenger reached saturation limit in 40 h. In packages with 2 g of scavenger, CO_2 concentration remained null in headspace indicating that the scavenger was still active after 3 days of storage. It is











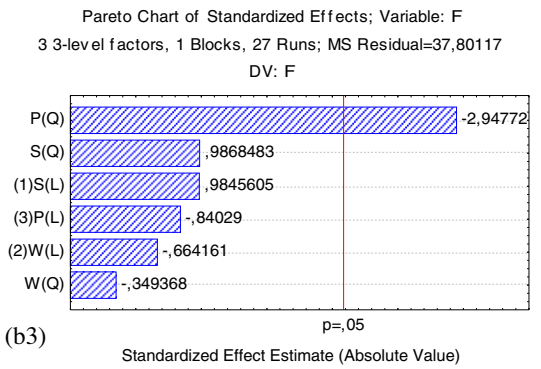
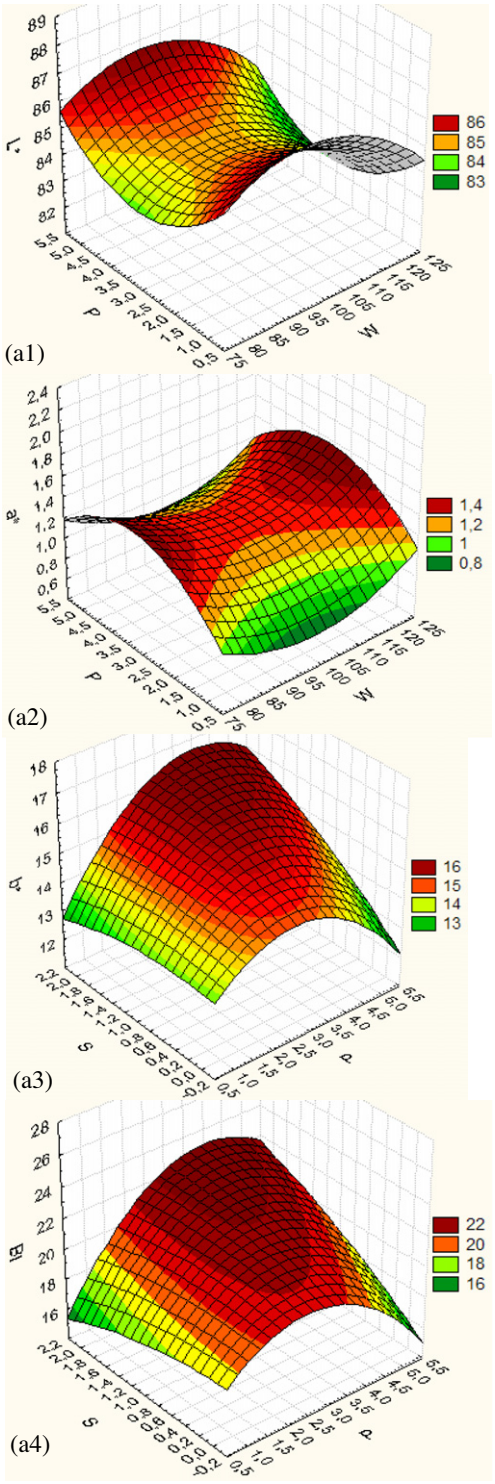


Fig. 4. (a) Surface plots with effects of number of perforations (*P*), weight of CO_2 scavenger (*S*) and amount of mushrooms (*W*) on (1) weight loss, (2) pH and (3) firmness of mushrooms, after 3 days at 10 °C. (b) Pareto charts of standardised effects for number of perforations, weight of CO_2 scavenger and amount of mushrooms on (1) weight loss, (2) pH and (3) firmness of mushrooms, at 95% significance level, indicated as a vertical dashed line.

interesting to note that the amount of CO_2 scavenger had no significant effect on the equilibrium concentration of O_2 in the package.

The effect of number of perforations, weight of CO_2 scavenger and amount of sliced mushrooms on headspace gas composition is shown in Fig. 2. There was a significant effect of number of perforations ($p < 0.05$) on headspace O_2 composition. Number of perforations in the film increased the gas exchange, for example, a package containing 120 g of sliced mushrooms with 1 perforation yielded 0.08% of O_2 and 10.8% of CO_2, whereas a package with 5 perforations yielded 9.5% of O_2 and 10.0% of CO_2. This might be due to increased mass transfer through micro-perforations (Eqs. (3) and (4)). In packages with 1 perforation, O_2 concentration after



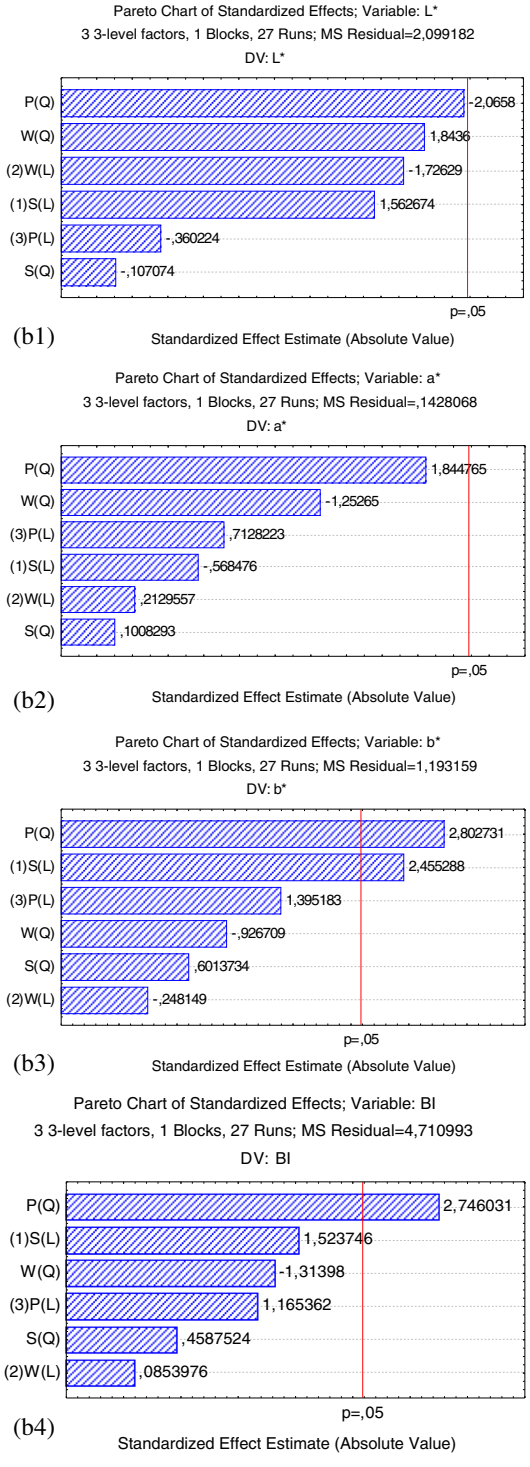


Fig. 5. (a) Surface plots with effects of number of perforations (P), weight of CO_2 scavenger (S) and amount of mushrooms (W) on parameters of colour (1) L^*, (2) a^*, (3) b^* and (4) browning index of mushrooms, after 3 days at 10 °C. (b) Pareto charts of standardised effects for number of perforations, weight of CO_2 scavenger and amount of mushrooms on parameters of colour (1) L^*, (2) a^*, (3) b^* and (4) browning index of mushrooms, at 95% significance level, indicated as a vertical dashed line. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

3 days, was null (0.2%), in packages with 3 perforations, was on average 6.0%, and in packages with 5 perforations, O_2 concentration reached 10.8%. In packages with 1 perforation, respiration rate of sliced mushrooms was higher than the entry rate of O_2 through perforated packaging film. This could lead to anaerobic respiration of sliced mushrooms (Parentelli et al., 2007). Amount of sliced mushrooms also had effect ($p < 0.05$) on O_2 concentration in headspace, which decreased while increasing weight of mushrooms. Mushrooms consume O_2, and the increase of the amount of mushrooms led to consume more O_2 from the less headspace of the package. Pareto chart shows that the presence of CO_2 scavenger had no significant effect on package O_2 concentration; on the contrary it had a significant effect on package CO_2 concentration.

3.2. Weight loss

A weight loss of 3.8% obtained in the package with 3 perforations in the film, 1 g of CO_2 scavenger and 100 g of sliced mushrooms is shown in Fig. 3. After 3 days, weight loss varied from 2.9% to 4.8%, which was found to be below the limit of acceptance, 5% (Mahajan et al., 2008). Antmann et al. (2008) reported a weight loss less than 5% for whole shiitake mushrooms, after 5 days at 5 °C, and remained constant after 15 days in packages with a non perforated film and in packages with small number of perforations in the film. Whereas, in packages with a higher number of perforations in the film, Antmann et al. (2008) observed a weight loss around 10% after 3 days, and around 35% after 15 days, at 5 °C, concluding that high relative humidity inside packages might increase mushroom deterioration and softening; and referred to the necessity of the use of moisture absorbers. A very high humidity, created by the transpiration rate of mushrooms and poor water vapour permeability of the film, causes condensation inside the package, increases the microorganism growth and discoloration. However, a very high water vapour permeability of the film leads to loss of weight and undesirable textural changes (Mahajan et al., 2008). In this experiment, it was observed that cellophane™ 335 PS film had water vapour permeability adequate for mushrooms, during 3 days of storage.

All the factors studied presented a significant effect ($p < 0.05$) on weight loss of mushrooms, as shown in Fig. 4. The presence of CO_2 scavenger increased weight loss. In MAP, a decrease in respiration rate may be mainly attributed to low O_2 and high CO_2 concentrations. CO_2 is an inhibitor of respiration rate; in its absence, the respiration rate of produce increases as well as the transpiration rate. Relatively to the amount of mushrooms, increasing the ratio of CO_2/O_2, the weight loss decreased, due to less O_2 per g of mushrooms and consequently respiration and transpiration rates were lower. Number of perforations also had effect on weight loss of mushrooms. Perforations in the film allow a higher exchange of gases. Therefore, increasing the number of perforations, dehydration increased and consequently weight loss of mushrooms, in agreement with report by Antmann et al. (2008).

3.3. pH

Initial pH of fresh sliced mushrooms was 6.6 and it decreased slightly, after 3 days of storage, ranging between 6.3 and 6.6. Masson et al. (2002) obtained an initial pH of homogenised mushrooms of 6.5, similar to the pH obtained in the present study. The pH is associated to microorganisms growth and its production of organic acids (Heard, 2002). Number of perforations and weight of CO_2 scavenger had a significant effect ($p < 0.05$) on pH, as shown in Fig. 4. Number of perforations in the film had influence on pH, since O_2 concentration varied from 0.2% to 10.8%, with a variation of number of perforations from 1 to 5. In packages with low levels of O_2, anaerobic respiration of mushrooms could occur, as well as the potential growth of pathogens, such as *Clostridium botulinum* (Parentelli et al., 2007), but, higher O_2 concentrations within the packages could contribute for a higher growth rate of aerobic commodities. The film with 1 perforation showed the best result, showing a pH close to the initial pH. Relatively to the presence of CO_2 scavenger (causing absence of CO_2 within the package), this not only could contribute to an increase of respiration rate, but also to the growth of certain microorganisms, such as aerobic bacteria, yeast and moulds. Weight of mushrooms within the package did not present effect on pH.

3.4. Firmness

At harvest, mushrooms are firm, crisp (resist deformation), and tender (easy to shear or crew), but during postharvest deterioration starts and they soften and toughen. Firmness decreased from 161.0 N to a range of 52.7–79.2 N, after 3 days of storage. Loss of firmness is caused by chitin synthesis in cell walls, leading to toughening; protein and polysaccharide degradation; and loss of cell turgency due to changes in cell membrane permeability, leading to softening of mushrooms (Eskin and Robinson, 2000; Parentelli et al., 2007). The number of perforations had a significant effect on firmness of mushrooms, as shown in Fig. 4. However, results were not clear, and high mean square residual was obtained, and it is recommended to perform higher number of replications (more than 7) for obtaining a more accurate determination.

3.5. Colour

Initial L^* of fresh sliced mushrooms was 88.5 and it decreased slightly after 3 days, initial a^* was 1.2 and did not vary significantly, and initial b^* obtained was 11.6 and it increased, after 3 days of storage. Browning index increased after 3 days, from 14.7 to a range of 16.1–26.3, as a consequence of a decrease in L^* parameter and of an increase in b^* parameter. Mushrooms lost luminosity and turn dark with decrease of L^*, and became yellow with increase of b^*, with time. This discoloration was induced by bruising, slicing, storage and physiological disorders and the very high polyphenol oxidase (PPO) content and phenolic compounds make them very susceptible to enzymatic browning. Browning is attributed mainly due to the oxidation of phenolic compounds catalysed by tyrosinase (Heard, 2002).

All factors did not show significant effect ($p > 0.05$) on L^* and a^*, as shown in Fig. 5. Whereas, b^* was significantly affected ($p < 0.05$) by number of perforations and CO_2 scavenger; it increased with number of perforations and CO_2 scavenger, leading to yellowness in sliced mushrooms. Similar to firmness, it would be recommended to use high number of replications (more than 7), for decreasing mean square residual. Browning index was significantly affected ($p < 0.05$) by the number of perforations, and it increased with number of perforations, since this allowed higher entry of O_2 and browning enzymatic reactions could occur effectively (Lamikanra, 2002).

Table 2
Parameters values of polynomial equation for O_2 and CO_2 concentrations, and respective coefficient of determination.

Parameters	$O_2 \pm SE$	$CO_2 \pm SE$
β_0	7.13 ± 0.28	10.98 ± 0.12
β_1	−1.24 ± 0.15	0.58 ± 0.07
β_2	5.44 ± 0.15	−1.39 ± 0.07
β_{12}	−0.81 ± 0.19	1.04 ± 0.08
β_{11}	−0.08 ± 0.26	−0.32 ± 0.11
β_{22}	−1.44 ± 0.26	−0.69 ± 0.11
R^2	0.996	0.992

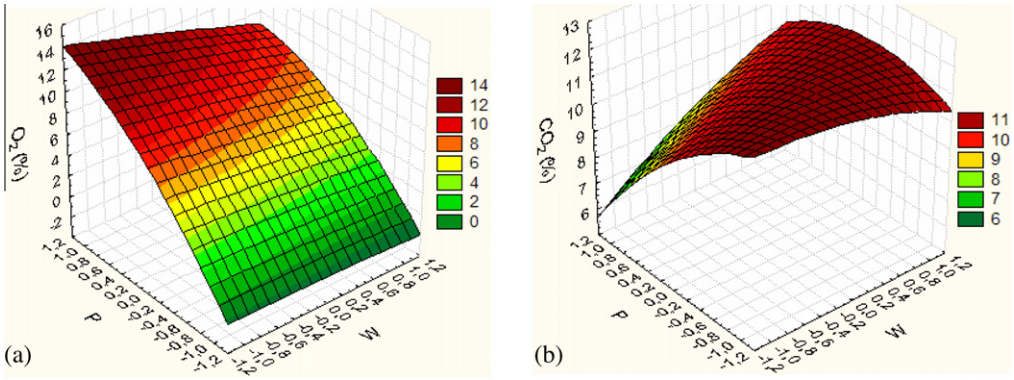


Fig. 6. Surface plots of headspace (a) O_2 and (b) CO_2 composition as a function of number of perforations (P) and amount of mushrooms (W), after 3 days at 10 °C.

3.6. Optimisation of MAP conditions

Optimisation of MAP design considers the optimum headspace gas composition and aims at minimising the changes in quality parameters of the product. Sveine et al. (1967) reported that 0.1% of O_2 and 5% of CO_2 were optimum conditions for prolonging shelf-life of mushrooms (Kim et al., 2006). In fact, this work showed that at lower O_2 in the headspace composition, obtained in packages with 1 perforation, the quality changes were smaller. Low O_2 reduced respiration rate and retarded cap development, reduced aerobic deterioration, weight loss and decreased tyrosinase activity reducing enzymatic browning. Although a low O_2 may have many advantages, O_2 less than 2% can cause anaerobic microbial growth, such as *C. botulinum* and *Staphylococcus aureus* (Kim et al., 2006). For safety reasons, it has been recommended that O_2 should not drop below 2% in MAP design of produce (Varoquaux et al., 1999). Ares et al. (2006) and Parentelli et al. (2007) reported that in MAP the concentration of O_2 should be kept low, 3 to 5%, and CO_2 concentrations cannot be higher than 12%, since excessive accumulation of CO_2 can cause physiological injuries in mushrooms.

In order to optimise MAP conditions, polynomial equation was fitted to O_2 and CO_2 concentrations of experimental data of packages without CO_2 scavenger (9 runs), at $t = 3$ days, as a function of coded weight of sliced mushrooms to be packed and coded number of perforations for their optimisation (Eq (5)).

$$y_{O_2,CO_2} = \beta_0 + \beta_1 W + \beta_2 P + \beta_{12} WP + \beta_{11} W^2 + \beta_{22} P^2 \quad (5)$$

where, y_{O_2} is O_2 concentration (%), y_{CO_2} is CO_2 concentration (%), βs are constant parameters, W is coded weight of mushrooms, and P is coded number of perforations. The optimisation results are presented in Table 2. Coefficient of determination (R^2) revealed a good fit of polynomial equation to experimental data. The optimum MAP conditions required for the sliced mushrooms were predicted by using Eq. (5). The variation of headspace O_2 and CO_2 composition as a function of number of perforations and amount of mushrooms is presented in Fig. 6.

The optimum packaging conditions obtained were 110 g of sliced mushrooms and 2 perforations in the film (0.5 coded for weight of mushrooms and −0.5 coded for perforations), leading to 3.6% of O_2 and 11.5% of CO_2 in the headspace gas composition, after 3 days at 10 °C.

4. Conclusions

An engineering design of a MAP system for sliced mushrooms should always consider the amount of product, its recommended gas composition and its respiration rate as affected by temperature and headspace gas composition, the permeability of the packaging materials (perforated or non-perforated polymeric film) and its dependence on temperature. This work showed the importance of an optimised MAP design, requiring the consideration of weight of sliced mushrooms to be packed and number of perforations in the film, in order to achieve the best headspace gas composition in acceptable length, for maintaining quality and extending shelf-life of fresh sliced mushrooms. Addition of CO_2 scavenger in the package increased the deterioration of mushrooms, showing that active packaging was not beneficial; therefore a less costly packaging solution is recommended for achieving an optimum quality of sliced mushrooms. The optimum packaging conditions obtained were 110 g of sliced mushrooms and 2 perforations in the film, leading to 3.6% of O_2 and 11.5% of CO_2 in the headspace gas composition, after 3 days at 10 °C.

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