ACTA Acta Sci. Pol., Technol. Aliment. 8(2) 2009, 53-60
ISSN 1644-0730 (print) ISSN 1889-9594 (online)

QUALITY MAINTENANCE IMPROVEMENT OF *PLEUROTUS OSTREATUS* MUSHROOMS BY MODIFIED ATMOSPHERE PACKAGING

Maria Sapata, Ana Ramos, Armando Ferreira, Luis Andrada, Manuel Candeias
Instituto Nacional dos Recursos Biológicos L-INIA in Oeiras, Portugal

Background. Modified atmosphere packaging (MAP) is an important technology to extend mushrooms shelf-life, with maintenance the characterisation as "fresh product", since allows reducing losses and maintaining quality, once they belong to highly perishable commodities. The aim of this study was to evaluate the potential storage conditions on the properties of fresh cultivated mushrooms – *Pleurotus ostreatus* when placed in polyethylene trays heatsealed with different polymeric films, passive modification mode, at 4°C.
Material and methods. The process was carried out using fresh mushrooms of the first flush, produced under controlled conditions. Investigations were conducted for 11 days. The mushrooms shelf-life was assessed through quality parameters, namely physiological, physicochemical, microbial and sensorial analysis. The marketability was assessed by visual appearance and sensory characteristics change, namely, softening and off-odours and off-flavours development.
Results. The factorial discriminate analysis allowed observing the influence of the different polymeric films permeability on the mushrooms storage. On the second day, similar mushrooms behaviour, with all film packages, was observed. From the seventh to the eleventh day, the packages showed an identical storage state, two to two, just the ninth day. This behaviour is related with O_2 levels (A and B films) and with CO_2 levels (C and D films).
Conclusions. The results leads to conclude that PE 65S Cryovac (C) and PD 961 Cryovac (D) films, improve storage mushrooms preservation with good stability during 11 days, showing the beneficial effect of MAP conditions. It is a valuable starting point in order to design a commercial application of modified atmosphere packaging technology with these products.

Key words: mushrooms, polymeric films, quality, stability

Corresponding author – Adres do korespondencji: Maria Sapata, I.P. Instituto Nacional dos Recursos Biológicos L-INIA, Quinta do Marquês, 2784-505 Oeiras, Portugal, e-mail: margarida.lobo@gmail.com

INTRODUCTION

Nowadays the oyster mushrooms (*Pleurotus* spp.) have a very successful and great consumer's demand, due to their high nutritive content, peculiar taste and texture, unique flavour and medicinal properties. Fresh mushrooms are known as a very perishable commodity, with a short shelf life, of 3-4 days when compared to most vegetables at ambient temperature, due to high respiration rate and low ethylene production, once they have no cuticle to protect them from physical or microbial changes or water loss [Villaescusa and Gil 2003]. The minimal processing using modified atmosphere package (MAP) in combination with cold chain storage, in post-harvest mushrooms preservation, is an important technology to reduce losses and maintain quality, considerably extending the effect of low temperature storage [Choi and Kim 2003, Luckasse and Polderduk 2003].

The high relative humidity in the atmosphere surrounding the product, and the controlled O_2 and CO_2 levels inside package can potentially reduce respiration rate and decay, generally represented by physiological disorders with dehydration, firmness loss, enzymatic browning and/or bacterial damages., with the resulting benefit of extending product life [Kader et al. 1989, Kader 1992, Roy et al. 1995, Salvador et al. 2002]. So, during storage, inside package intended obtain an optimal atmosphere composition that is due to a dynamic equilibrium between vegetable respiratory activity and gas diffusion through semi permeable plastic films packaging [Salvador et al. 2002, Tano et al. 1999].

However, sometimes minimally processed mushrooms storage shows spoilage problems, in distribution circuits, since it is often difficult to ensure constant temperature and applied adequate films barrier properties, observing moisture condensation inside packages, off-odour development and off-colour [Jayathunge and Illeperuma 2005]. The aim of this study was to evaluate the quality and safety of *Pleurotus ostreatus* mushrooms minimally processed, when modified atmosphere packed in polyethylene trays, heatsealed with different polymeric films, through physiological, physical, chemical, microbiological and sensorial parameters, in order to determine the shelf-life of this product for its convenient use.

MATERIAL AND METHODS

Samples

The process was carried out using fresh *P. ostreatus* mushrooms (INRB/L-INIA culture collection) of the first flush produced and harvested from the L-INIA unit, under controlled conditions. Mushrooms were selected by appearance and size. Damaged and extremely large or small ones were discarded to minimize the biological variability. After washed and disinfected with H_2O_2 solution (5%) 30 sec. [Sapers and Simmons 1998], they were drained with paper towelling, placed (about 120 g) in polyethylene trays B-12 H47 Ovarpack (PS-EVOH-PE of 230 × 144 × 47 mm, thickness 550 µm) containing a moisture absorber MP-Ovarpack (12 × 18 cm). These were heatsealed with polymeric films of different permeability (Table 1) with a heat-sealing machine MGM SAV Vuoto gas.

Table 1. Characteristics of the packaging polymeric films

Code	Plastic polyethylene	Thickness µm	O_2 Permeability $mL/m^2 \cdot 24\ h \cdot atm$	CO_2 Permeability $mL/m^2 \cdot 24\ h \cdot atm$	Commercial denomination
A	low density	10	≈9 550	≈28 000	Freshmate Vileda*
B	low density	90	2 250	8 000	PE-52 LV Amcor**
C	low density and chlorinated vinilidene	65	3 000-4 000	11 000-15 000	PE65S Cryovac
D	low density	31	6 000-8 000	19 000-22 000	PD-961 Cryovac

*Data calculated in specifications of the film PE (data of the catalogue of Amcor-Flexibles).
**Microperfurated film for packing of this product type – 1 microperfuration/14 cm^2 (the manufacturer's responsibility).

The gaseous mixture used was normal air – passive modification mode. The mushrooms packs were stored at 4°C. Samples, in duplicated, were accomplished for the physiological, physiochemical, microbial and sensorial analyses at 0, 2, 4, 7, 9 and 11 days.

Quality analysis

The stability evaluation was determined by: Gas composition inside the packs (volume % of O_2 and CO_2) was analysed immediately after the closing of the packs and in each sampling day in duplicate, with a gas analyser PBI Dansensor, Checkmate 9900. Soluble solids contents (SSC) was evaluated for each of the samples with a hand-held digital sugar refractometer ATAGO PR-1, with the results expressed as degree Brix. pH values determined with a potentiometer Crisonmicro pH 2002 provided with a penetration electrode.

Weight loss was monitored by the weight of the package content before and after storage period; moisture absorbed amount through the mass difference between the dry and moistened absorber, relatively to the fresh mushroom mass. Exudates determination was performed in duplicate [Carlin et al. 1990]. Amount of liquid freed from approximately 4 g of mushroom when placed between two discs of filter paper (papers qualitative circles, 150 mm and pressed with a weight of 10 kg (Salles Torres), during 10 seconds. Results were expressed as g of released juice/100 g of mushroom. Colour was measured by reflectance using a colorimeter Minolta Chroma 200b calibrated with a standard tile and observed under International System L*, a* and b*; ten measures were performed for each sample.

Texture was evaluated using the texturometer Stable Microsystems TA-Hdi, with a load cell of 50 N, using a puncture, with a probe inox P6 (Ø 6 mm), at 20°C; ten measures were performed for each sample. The microbial control, reported as colony forming units per gram of fresh mushrooms (CFU g^{-1}), and expressed as logarithmic units, consisted of: aerobic mesophilic and psicrotrophics bacterial count (Plate Count Agar, 30°C, 48 hours and 4°C, 10 days), yeasts and moulds count (Rose Bengal Chloramphenicol, 25°C, 5 days), total coliforms (Violet Red Bile Lactose Agar, 30°C, 48 hours), *Pseudomonas* (Pseudomonas Agar Base, 30°C, 48 hours) and sporulated forms (Plate Count Agar, 30°C, 48 hours).

The mushrooms marketability was assessed by visual appearance and sensory characteristics change, namely, softening and off-odours and off-flavours development. The results were treated with the Statistical V.6 program, for Principal Components Analysis (PCA) and Factorial Discriminate Analysis (FDA).

RESULTS AND DISCUSSION

During storage the minimally processed mushrooms, packed with A and B films, presented similar behaviour, typical of a product packaged with high gas permeability film, submitted to the active modification mode. In these packs, the O_2 level quickly decrease from the first to second day, from which, became constant, till the end of the storage, meaning that the balance was reached from the second day. The CO_2 concentration increased in the second day, refusing since then, for constant values.

With samples packaged with C and D films, it was observed behaviour similar a passive modification mode, with lower O_2 level and high CO_2 level, due to the films characteristics conjugation with the respiration rate of the product. So, it was verified that the balance point was reached, between the second and the third day, in the samples packaged with the C film, while in case D film that become at the third day (Fig. 1).

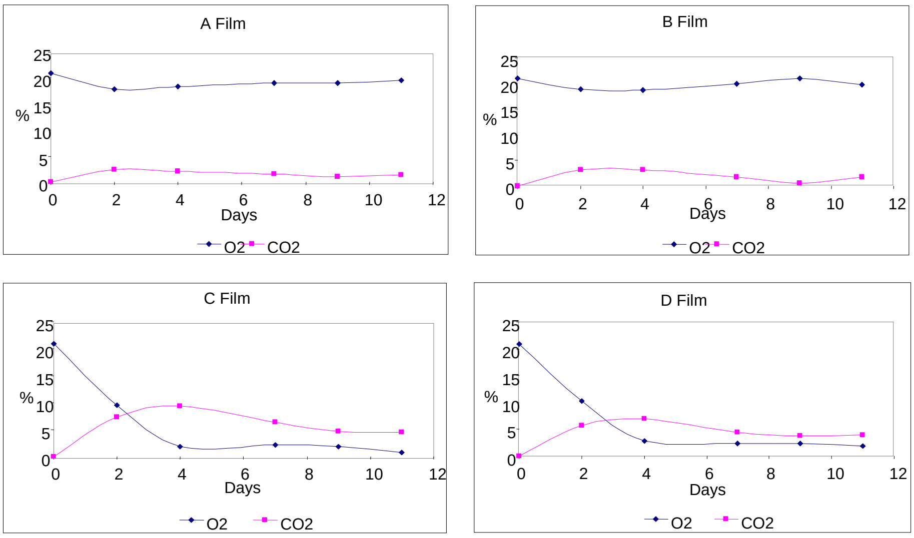

Fig. 1. Atmosphere composition evolution inside packages for each film type (A, B, C and D)

In all polymeric films, a quick increase was observed in SSC, from 0.33 to 0.60. Exudates, moisture and pH variations were not verified, with the exudates values about 50%, the moisture with values of 96% and pH about 6.25 for 7.49. In expect weight loss and water freed (absorbing) by the mushrooms, it was observed a relationship between

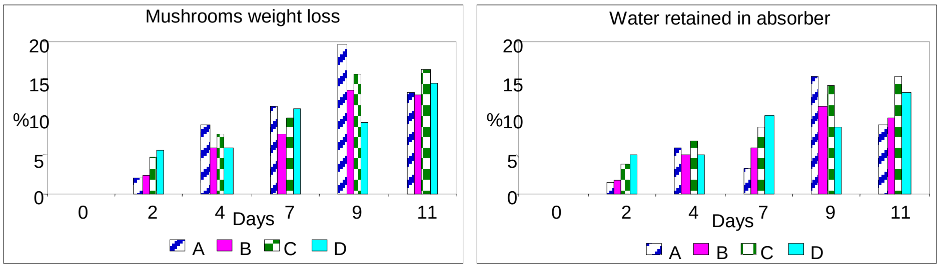

Fig. 2. Evolution of mushrooms weight loss and water retained in the absorber for package films (A, B, C and D)

the weight loss (3.62% to 14.25%) and the water retained in the absorber (3.09% to 12.00%) in the films (Fig. 2).

Some mushrooms water freed was condensed in the packages walls or on the involving film, then the difference was observed between the mushrooms weight loss and the weight gain by moisture absorbers. In all different films packages a decrease of the mushrooms texture, about 3.68 N for 1.90 N (48.40%), was verified, values related with the firmness loss, observed at visual level. The L* values increased from 48.59 to 51.85, indicating that the mushrooms became clearer, C* from 11.21 to 17.53, showing a more brilliant colour and the H°, didn't present variation, where the mushrooms became yellow or lightly brown.

During storage, independently the polymeric film type used, it was observed an increase in all microbial counts, namely:

– total mesophilic – 2 cycles (6.806 to 8.975 log CFU/g)
– psycrophilic bacterial – 2 cycles (6.322 to 8.880 log CFU/g)
– yeasts and moulds – 2 cycles (6.602 to 8.762 log CFU/g)
– total coliforms – 3 cycles (5.531 to 8.515 log CFU/g)
– *Pseudomonas* – 4 cycles (4.097 to 8.546 log CFU/g)
– sporulated forms – 1 cycle for the A packages (2.653 to 3.204 log CFU/g), 3 cycles for the B and C packages (2.653 to 5.620 log CFU/g) and 2 cycles for the D packages (2.653 to 4.064 log CFU/g).

With a principal component analysis performed on all data, 80,09% of the total variance could be explained by the first two components (Fig. 3). In the score plot of PC1 the variables weight loss, texture, pH, moisture, C*, total mesophilic count, *Pseudomonas*, yeasts and moulds, psycrophilics and coliforms are strongly linked to the first component (65.28% of explain variance) explaining the influence that these parameters had in the mushrooms spoilage evolution during storage. The connection was observed among the microbial component, with contrary sign, to the texture and O_2. This phenomenon is due to the microbial spoilage, in O_2 presence, commit the texture of the mushrooms. The PC2 (14.81% of explain variance) is explained by O_2 and CO_2 levels, in opposite position.

By factorial discriminate analysis (Fig. 4) the influence can be observed of the different polymeric films permeability on the mushrooms storage. So on the second day, with all film packages, similar mushrooms behaviour was observed, with in opposite

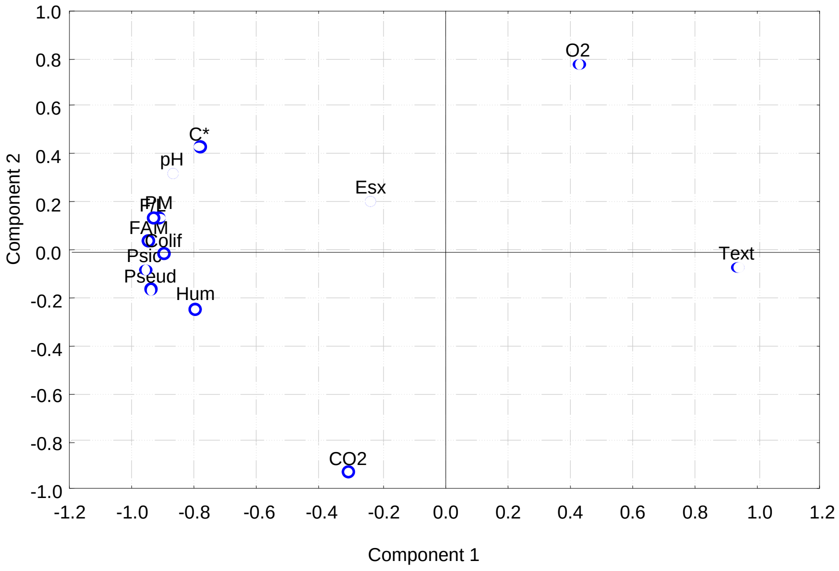

Fig. 3. Principal Component Analysis (PCA): O_2 – oxygen, CO_2 – carbon dioxide, PM – weight loss, Text – texture, pH, Exs – exsudate, C* – chroma, Hum – moisture, FAM – mesophilic flora, Pseud – pseudomons, Psic – psycrophilic flora, Colif – coliforms, F/L – yeasts and moulds

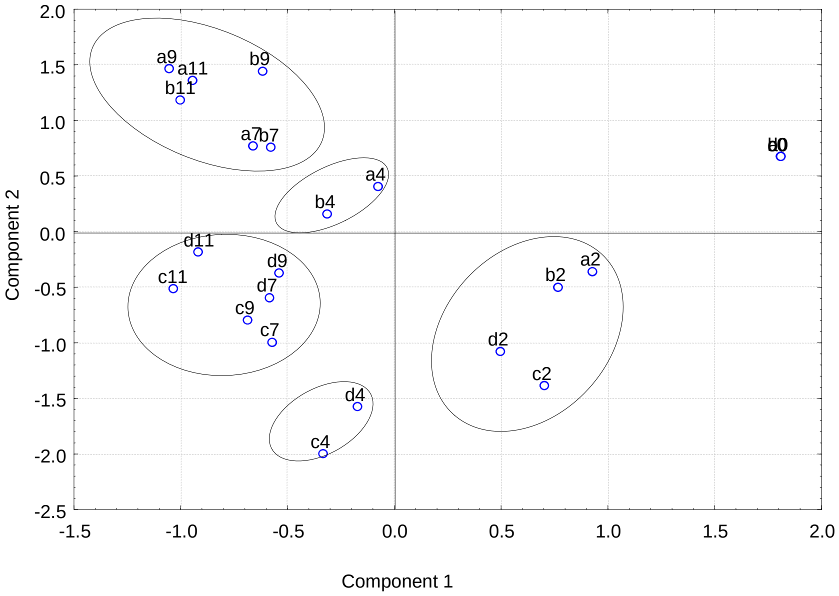

Fig. 4. Factorial Discriminate Analysis (FDA): a – Vileda Freshmate film, b – PE 52 LV Amcor film, c – PE65S Cryovac film, d – PD-961 Cryovac film

senses diverge, from the fourth day. This behaviour is related with O_2 levels, in case of films A and B and with CO_2 levels in case of films C and D. From the seventh to the eleventh day, the packages showed an identical storage state, two to two, just the ninth day. However, due the O_2 level inside the C and D packages, these films were appropriated to obtain a better product stability and storage.

A sensorial analysis was performed to evaluate the market quality. The visual quality of *Pleurotus* was very good. Comparing with C and D packages, modifications of firmness and unpleasant off-odours and off-flavours development were noticed for all A and B packages, after the seventh day of storage. The colour changed after storage, with a discolouration.

CONCLUSIONS

The effects of these storage conditions on *Pleurotus ostreatus* mushrooms quality were assessed and it was observed that they were affected by the CO_2 and O_2 levels inside the packages, with weight decrease, firmness and color losses, and an increase on microbial count. By the global aspects, the present study leads to conclude that PE 65S Cryovac (C) and PD 961 Cryovac (D) films, improve storage mushrooms preservation with good stability during 11days, showing the beneficial effect of MAP conditions.

Results represent a valuable starting point in order to design a commercial application of modified atmosphere packaging technology with these products, since packaging is essential for reducing respiration rate and maintaining quality. However, packaging film must be environmentally adapted to the O_2 requirement of the commodity, which largely depends on the storage temperature and proper internal package humidity.

This study intends to contribute to the improvement of the knowledge of the behaviour of these minimally processed products, in way to increase the competitiveness in the industrial sector.

Acknowledgements

The authors thank the National Institute of Agricultural Research (INIA) under the Ministry of Agriculture, Research Project PIDDAC: “Improving shelf-life of fresh *Pleurotus* mushrooms by modified atmosphere packaging”, which enabled us to write this article.

REFERENCES

Carlin F., Ngugen-The C., Chambroy Y., Reich M., 1990. Effects of controlled atmospheres on microbial spoilage, electrolyte leakage and sugar content of fresh ready-to-use grated carrots. Int. J. Food Sci. Techn. 25, 110-119.

Choi H., Kim G.H., 2003. Quality changes in *Pleurotus ostreatus* during modified atmosphere storage as affected by temperatures and packaging material. Acta Hort. 628, 357-362.

Jayathunge L., Illeperuma C., 2005. Extention of postharvest life of oyster mushroom by modified atmosphere-packaging technique. J. Food Sci. 70, 9, 573-578.

Kader A., 1992. Modified atmospheres during transport and storage. In: Postharvest technology of horticultural crops. Ed. A.A. Kader. Univ. Calif. DANR, Oakland (CA), 85-92.
Kader A., Zagory D., Karbel E.L., 1989. Modified atmosphere packaging of fruits and vegetables. Crt. Rev. Food Sci. Nutr. 28, 1-30.
Luckasse L.J.S., Polderduk J.J., 2003. Predictive modelling in post-harvest quality evolution in perishables applied to mushrooms. J. Food Eng. 59, 191-198.
Roy S., Anantheswaran R.C., Beelman R.B., 1995. Fresh mushrooms quality as affected by modified atmosphere packaging. J. Food Sci. 67, 2, 334-340.
Salvador M.L., Jaime P., Oria R., 2002. Modeling of O_2 and CO_2 exchange in modified atmosphere packaging of burlat cherries. J. Food Sci. 67, 231-240.
Sapers G.M., Simmons G.F., 1998. Hydrogen peroxide disinfections of minimally processed fruits and vegetables. Food Technol. 52, 2, 48-52.
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.
Villaescusa R., Gil M.I., 2003. Quality improvement of *Pleurotus* mushrooms by modified atmosphere packaging and moisture absorbers. Postharv. Biol. Techn. 28, 169-179.

UTRZYMANIE JAKOŚCI OWOCNIKÓW *PLEUROTUS OSTREATUS* PRZEZ PAKOWANIE W ATMOSFERZE MODYFIKOWANEJ

Wprowadzenie. Grzyby należą do łatwo psujących się towarów. Pakowanie w atmosferze zmodyfikowanej (MAP) jest metodą przedłużania trwałości owocników, pozwalającą zachować cechy świeżego surowca. Celem badania była ocena wpływu warunków przechowywania na właściwości świeżych owocników grzybów uprawnych – *Pleurotus ostreatus* po umieszczeniu w opakowaniach polietylenowych i przechowywaniu w temperaturze 4°C.
Materiał i metody. W doświadczeniu określono wpływ potencjalnych warunków przechowywania na cechy świeżych owocników boczniaków umieszczonych na tackach polietylenowych, owiniętych dwoma rodzajami folii i przechowywanych w temperaturze 4°C. Trwałość owocników była oceniana na podstawie parametrów jakościowych – fizjologicznych, fizykochemicznych, mikrobiologicznych – i analizy sensorycznej.
Wyniki. Analiza skupień pozwoliła zaobserwować wpływ przepuszczalności różnych folii polimerowych na przechowywanie świeżych grzybów. Do drugiego dnia przechowywania nie zauważono różnic, niezależnie od sposobu pakowania. Statystycznie istotne zmiany stwierdzono dopiero po 11 dniach przechowywania.
Wnioski. Pakowanie w atmosferze MPA pozwala na przedłużenie trwałości owocników *Pleurotus ostreatus.* Jest to cenny punkt wyjścia do projektowania komercyjnego stosowania pakowania w atmosferze MPA tych produktów.

Słowa kluczowe: boczniak, grzyby, folie polimerowe, jakość, trwałość

Accepted for print – Zaakceptowano do druku: 12.03.2009

For citation – Do cytowania: Sapata M., Ramos A., Ferreira A., Andrada L., Candeias M., 2009. Quality maintenance improvement of Pleurotus ostreatus mushrooms by modified atmosphere packaging. Acta Sci. Pol., Technol. Aliment. 8(2), 53-60.