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DETERIORATION AND SOME OF APPLIED PRESERVATION TECHNIQUES FOR COMMON MUSHROOMS (*AGARICUS BISPORUS*, FOLLOWED BY *LENTINUS EDODES*, *PLEUROTUS* SPP.)

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ABSTRACT

Mushrooms are consider as a nutritional and health beneficial product. Three most cultivated mushrooms worldwide are *Agaricus bisporus*, *Lentinus edodes* and *Pleurotus* spp. Mushrooms are highly perishable. They tend to lose quality after harvest, mainly because of their high respiration rate and the fact that they have no barrier to protect them from water loss. Mushrooms' shelf-life is limited to a few days under normal refrigeration conditions, which is a constraint on the distribution and marketing of fresh product, making extension of mushroom's shelf life a constant quest. Modified atmosphere packaging provides an affordable packaging system that partly avoids enzymatic browning, fermentation and other biochemical processes by maintaining a controlled gas atmosphere. However, modified atmosphere packaging conditions should be carefully designed. Inappropriate modified atmosphere conditions may be ineffective or even shorten the shelf life of the product due to damage of tissues. Preservation techniques and specially use of MAP, specifically for *Agaricus*, *Lentinus edodes* and *Pleurotus*, is reviewed.

Keywords: Deterioration, preservation, mushroom, *Agaricus bisporus*

INTRODUCTION

Mushroom have been placed in a kingdom of Myceteae and is a "macrofungus with a distinctive fruiting body, which can be either epigeous or hypogeous and large enough to be seen with naked eye and to be picked by hand"**(Cheung, 2008).**The number of recognized mushroom species has been reported to be 14,000, which is about 10% of the total estimated mushroom species on the earth **(Cheung, 2008; Koushki *et al*., 2011)**. Total commercial mushroom production worldwide has increased from about 350,000 tons in 1965 to about 3.4 million metric tons **(Koopman and Laney, 2010).** The most cultivated mushroom worldwide is *Agaricus bisporus*1, followed by Lentinus edodes2, *Pleurotus* spp3, Auricula auricula4, Flamulina velutipes5 and Volvariella volvacea6 **(Aida *et al*., 2009).**

Mushrooms have good quality proteins with lysine and tryptophan. The carbohydrates in the mushrooms are at a level of 4.5 to5.0% but are in the form of glycogen, chitin and hemicellulose instead of starch. The fat contain is as low as 0.3 % but is rich in linoleic acid, an essential fatty acid. Furthermore, Mushrooms are fairly good source of vitamin C and vitamin B complex, particularly thiamine, riboflavin, niacin, biotin and panto *Lentinus edodes* thenic acid. Folic acid and vitamin B12 which are absent in most vegetables are present in the mushrooms which also supply a range of valuable minerals especially potassium and iron **(Mehta *et al*., 2011).**

Mushrooms have been used not only as a source of food but medicinal resource as well (**Aida *et al*., 2009**). About 1800 species of mushrooms with the potential of medicinal properties (**Cheung, 2008**).Numerous studies have reported mushrooms having medicinal attributes including anti-tumor (**Choi *et al*. 2006**). β-Glucan is one of the major structural component of fungal cell walls, have been found to stimulate both the innate and adaptive immunity of the host, followed by a wide range of immunopharmacological activities, particularly antitumor activities, via their cytokine production and signaling cascade (**Moradali *et al*., 2007; Cheung, 2008**). Latest finding by Hearst et al. in 2009 had revealed another benefit of mushrooms. Shiitake and Oyster mushrooms were tested for their antibacterial and antifungal properties. Surprisingly, shiitake extract was found to be effectives as an antimicrobial substance and was significantly more antibacterial than ciprofloxacin. Polysaccharides extracts of medicinal mushrooms act as natural antioxidants and possess immunomodulatory properties (**Kozarski, *et al*., 2011**)

Packaging, coating, refrigeration and dipping in sorbitol and CaCl2 dipping (**Koushki *et al*., 2011**) are the most common methods used for extending the shelf life of mushrooms (**Eissa, 2007**). Appropriate packaging can delay development of deterioration and senescence of mushrooms after harvest (**Taghizadeh *et al*., 2010**). One alternative to extend mushrooms' shelf life during postharvest storage and commercialization is modified atmosphere packaging. (**Koushki *et al*., 2011; Kim *et al*., 2006**).

The purpose of this paper is to review deterioration, shelf life, nutritional value and use of modified atmosphere packaging for keeping three kind of fresh mushrooms (*Agaricus bisporus*, Lentinus edodes, and *Pleurotus* spp) better.

Mushroom Deterioration

Mushrooms are highly perishable and their shelf-life depends on processing, package properties and environmental conditions during storage and distribution. The main processes which contribute to loss in mushroom quality after harvest are (i) discoloration, (ii) browning, (iii) loss of closeness, (iv) weight loss and (v) texture changes (**Aguirre *et al*., 2009**).

Browning in vegetables and fruits which is caused by tyrosinase is an undesirable reaction. This unfavorable darkening from enzyme oxidation generally results in a less attractive appearance and a loss in nutritional quality. It becomes a major problem in the food industry. Tyrosinase (EC 1.14.18.1) is a bifunctional enzyme, which catalyzes o-hydroxylation of monophenols (Cresolase activity) and oxidation of catechols to the corresponding o-quinones. Tyrosinases are responsible for many biologically essential functions, such as pigmentation, sclerotization, primary immune response and host defense (**Saboury, 2009**).

Tyrosinase inhibitors have been established as important constituents of depigmentation agents and have potential uses as food preservatives (**Han *et al*., 2008**).Furthermore Salicylic acid has also been shown to have an inhibitory effect on browning of some fruits and vegetables (**Peng and Jiang, 2006**). In a study by Zhang et al. in 2006 indicated that salicylic acid is a competitive inhibitor of mushroom tyrosinase. Cinnamic and salicylic, could be added to the Sodium chlorite solution to achieve greater inhibition of browning than obtained with citric acid in sliced apple samples (**Lu *et al*., 2007**). The results showed that 4-

[1] Button mushroom; White Button Mushroom; WBM
[2] Xiang gu in Chinese and shiitake in Japanese
[3] Oyster mushrooms
[4] Wood ear mushroom
[5] Winter mushroom
[6] Straw mushroom

chlorosalicylic acid could strongly inhibit both monophenolase activity and diphenolase activity (**Han *et al*., 2008**).

Mushrooms have a short postharvest shelf life compared to most vegetables, due to a very high metabolic activity and high water content, making them prone to microbial spoilage and to exhibit enzymatic browning. After harvest the mushroom colour gradually changes from white to brown, due to the appearance of browning and possibly bacterial blotching, while the growth of the stipe and the cap continues. The cap growth results in gradual opening of the mushroom cap (**Aguirre *et al*., 2009**).

Presence of more than 90% moisture content of mushrooms indicated that, they are highly perishable and start deteriorating immediately after harvest. They develop brown colour on the surface of the cap due the enzymatic action of phenol oxidase, this results in shorter shelf life (**Mehta *et al*., 2011**).

The intact mushrooms lose their commercial value within a few days, due to senescence, water loss, microbial attack and browning. Mushroom browning occurs as a result of two distinct mechanisms of phenol oxidation: (a) activation of tyrosinase, an enzyme belonging to the polyphenoloxidase (PPO) family; (b) and/or spontaneous oxidation (**Nerya *et al*., 2006**).

Enzymatic browning is a consequence of PPO catalyzed oxidation of phenolic substrates into quinones, which undergo further reactions to dark pigments called melanins. The major PPO enzyme responsible for browning in mushrooms appears to be tyrosinase (**Jiang *et al*., 2011**).

The effects of a-cyano-4-hydroxycinnamic acid (HCCA) on the activity of mushroom tyrosinase have been studied. Results showed that HCCA could inhibit both the monophenolase activity and diphenolase activity of mushroom tyrosinase (**Qiu *et al*., 2009**).

Yi and others in 2009 studied on inhibitory effects of vitamin C esters 1 and 2 on the diphenolase activity of mushroom tyrosinase. The results showed that compounds 1 and 2 inhibited tyrosinase with IC50 values of 0.58 and 0.16 mM, respectively. The dose–response curves demonstrated that compounds 1 and 2 not only lengthened the lag time, but also decreased the steady-state rate.

Koushki et al. in 2011 evaluate that MAP in combination of CaCl2 dipping had effective in extending shelf life of the packaged mushrooms.

Although Modified atmosphere packaging (MAP) is one of a number of technologies available to control product deterioration, providing an appropriate protective atmosphere around the product (**Zhang *et al*., 2006**) and it is a suitable way for mushroom preservation and after some suitable results, in recent years, some researchers study on Integrated application of MAP and other techniques to improve mushrooms quality (**Jiang *et al*., 2011, 2010**)

Respiration rate

Short shelf-life of mushrooms is due to their high respiration rate, tendency to turn brown and lack of physical protection to avoid water loss or microbial attack and which is the major cause of quality losses that accounts for reduction in market value (Mohapatra et al., 2008). Therefore, mushrooms need special attention to retain freshness (**Kim, 2006**). There are several indicators that determine the quality of mushrooms, such as visual appearance, size, colour, maturity stage, development stage, microbial growth and weight loss (**Aguirre *et al*., 2008**).The main processes responsible for mushrooms sensory quality loss are browning and texture changes (Ares et al. 2006). The shorter shelf life of mushrooms is due to its very high respiration rate-of about 28.2-43.6 mg CO2 per kg fresh weight per hour at 0°C and 280 mg CO2 per kg fresh weight per hour at 19°C (**Rai and Arumuganathan, 2008**).

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Respiration rate of fresh mushrooms under air at 10oC ranges from 17.8 to 178 CO2 kg-1 s-1, depending on mushroom species considered (**Ares *et al*. 2006; Parentelli *et al*. 2007**). Respiration is widely assumed to be slowed down by decreasing available O2 and increasing CO2. Furthermore, if O2 concentrations are too low or CO2 too high physiological damages might occur to the product. Therefore modified atmosphere packages should be carefully designed since a system incorrectly designed may be ineffective or even shorten the shelf life of the product (**Ares *et al*., 2007**). The influence of CO2 in respiration rate depends on the type and developmental stage of the commodity, CO2 concentrations and time of exposure (**Parentelli *et al*. 2007**).

Shitake mushrooms showed a higher respiration rate and a higher susceptibility to high Co2 concentration than other mushrooms varieties (**Ares *et al*., 2006**).

Browning

An important cause of loss of Mushroom quality during postharvest storage is browning (**Ares *et al*. 2006; Parentelli *et al*. 2007**). Mushrooms have a short postharvest shelf life compared to most vegetables, due to a very high metabolic activity and high water content, making them prone to microbial spoilage and to exhibit enzymatic browning (**Mehta *et al*., 2011**).

The activity of tyrosinase, responsible for mushroom browning was dependent on O2 concentration (**Antmann *et al*., 2008**). Also showed that the relative humidity also affected the transition process from ‘‘white” to ‘‘brown” and storage of mushrooms in an abused situation produced an increase of the brow spotting from the beginning of the storage which was constant in the entire storage time (**Aguirre *et al*., 2009**).

PPOs also known as tyrosinase, catechol oxidase, catecholase, phenolase, monophenol oxidase, and cresolase were first discovered in 1856 in mushrooms. Tyrosinase oxidizes some monophenols to o-diphenols and then the former are oxidized to quinines, which spontaneously polymerize to form brown, black or red pigments (**Nerya *et al*. 2006**).

Texture changes

One of the main changes associated with mushrooms deterioration are changes in their texture (**Ares *et al*. 2006; Parentelli *et al*. 2007**).

Mushroom texture can be affected by various factors like heat treatment and storage in pH ranges and showed that shear force exhibited similar trend to firmness but with distinguishable differences (**Caglarirmak, 2007**).

Modified atmosphere packaging (MAP)

Modified atmosphere packaging (MAP) is a technique used for prolonging the shelf-life period of fresh or minimally processed foods. In this preservation technique the air surrounding the food in the package is changed to another composition (**Sandhya, 2010**). The use of modified atmosphere packaging to extend the shelf life of mushrooms has been extensively reported (**Sandhya, 2010**) and it is one of the most effective and economical ways to maintain freshness (**Simón and Gonzalez-Fandos, 2011**). Two of the most important factors in determining deterioration rate during modified atmosphere storage are temperature and gas composition (**Ares *et al*., 2007**).

Modified atmosphere is created in a sealed package of a fresh horticultural produce as a result of exchange of respiratory gases namely O2 intake and CO2 evolution. When the rate of gas permeation through the packaging material equals respiratory gas exchange, consequently an equilibrium concentration of O2 and CO2 are established (**Rai and Arumuganathan, 2008**).

One of the primary effects of MAP is a lower rate of respiration, which reduces the rate of substrate depletion. Ethylene (C2H4) is a natural plant hormone and plays a central role in the initiation of ripening, and is physiologically active in trace amounts (0.1 ppm). C2H4 production is reduced by about half at O2 levels of around 2.5%. This low O2 retards produce ripening by inhibiting both the production and action of C2H4. Modified atmosphere packaging of kohlrabi stem also showed improvement in quality (Escalona et al., 2006). Recommended gas mixtures for MAP are shown below (Table 1).

Table 1 Recommended gas mixtures for MAP

Product	O2%	CO2%	N2%
Mushrooms	3-21	5-15	65-92

Mushrooms are conventionally packed in plastic trays over-wrapped with perforated PVC films and stored under refrigeration temperature and also PVC over-wraps were efficient in reducing weight loss, in retaining the vitamin C content and in reducing browning during storage (**Mota *et al*. 2006**).

MAP (*Agaricus bisporus*)

In some research showed that storage in 1 or 2% O2 + 0 or 4% CO2 was best in keeping their quality and firmness. High CO2 prevented cap opening at 12°C but also found that atmospheres with high CO2 concentration resulted in more cap browning, although O2 concentration did not have any effect on colour change. Although Colour deterioration was inhibited by storage at 0°C and also that low O2 and 10% CO2 inhibited cap opening and internal browning but caused a ‘yellowing’ of the cap surface. Furthermore 10% CO2 could delay deterioration, but levels of over 10% could cause a ‘pinkish’ discoloration (**Thompson, 2010**).

MAP (*Lentinus edodes*)

Sorbitol and sodium chloride were used to modify the in-package relative humidity (IPRH) of fresh mushrooms (water irrigated and CaCl2 irrigated) stored in a modified atmosphere package (MAP) at 12 c. No differences were observed for maturity index and microbial population between mushrooms stored in modified atmosphere package (MAP) with or without moisture absorbers. Normally grown mushrooms with 10 and 15g sorbitol and the best color no improvements in quality were found with moisture absorbers with normally grown mushrooms (**Antmann *et al*. 2008**).

Parentelli *et al*. in 2007 Studied the influence of modified-atmosphere packaging under microbiological and sensory quality of shitake mushrooms

(Lentinula edodes) mushrooms were packaged under atmospheric air (passive modified atmosphere) and initial gas mixture of 5% O2 and 2.5 % Co2 (active modified atmosphere), in bags of two different films : low-density polyethylene (PE) and polypropylene (PP). Sensory analysis showed that mushrooms stored under modified atmosphere (active and passive) had a higher deterioration rate than those stored in PP macroperforated films and lower sensory quality values during the entire storage time (**Parentelli *et al*., 2007**).

MAP (*Pleurotus ostreatus*)

However, mushrooms such as *Pleurotus ostreatus* undergo rapidly deterioration during storage and distribution. Many studies on maintaining freshness of mushrooms have been reported on modified atmosphere packaging (MAP), controlled atmosphere (CA), chill storage , coating treatment , radiation treatment, ozone treatment and moisture absorber treatment (Lee et al, 2007) .
Passive modified atmosphere packaging of *Pleurotus ostreatus* stored at 4oC in bags of LDPE, PVC and a microperforated film. After 7 days of storage, the better visual quality was obtained for mushrooms in PVC packages (Ares et al., 2007).

CA storage was shown to have little effect on increasing storage life at either 1.0 or 3.5 °C, but at 8 °C with a combination of 10% CO2±2% O2, 20% CO2±21% O2 or 30% CO2±21% O2 the oyster mushrooms had a reduced respiration rate and retained their quality for longer than those stored in air. Recommended storage at 1°C and 94% RH in 30% CO2±1% O2 was about 10 days, and 5% CO2±1% O2 for 21 days (Thompson, 2010).

Integrated Application of MAP along with other techniques to improve mushrooms quality

In 2008 Cliffe-Byrne and O'Beirne studied on The effects of different washing treatments combined with modified atmosphere packaging (MAP) on the quality and storage life of sliced mushrooms were determined. There were no additional benefits to the sensory and microbial quality from using a two-stage wash versus a single wash of either H2O2 or ClO2 combination anti-microbial/browning treatments using H2O2 and sodium D-isoascorbate monohydrate had beneficial effects on quality, with better acceptability of appearance and colour and significant microbial reduction. A spray application of sodium D-isoascorbate monohydrate, proved even better than a washing treatment, probably due to minimal water uptake. Spray applications of H2O2 above 1% were damaging. Overall, washing had significant effects on the quality and storage life of MA packaged sliced mushroom.

In 2010 Jiang and others had a research on effect of integrated application of gamma irradiation and MAP on physicochemical and microbiological properties of shiitake mushroom. Shiitake (Lentinula edodes) mushroom is the second most cultivated edible mushroom in the world, comprising of about 25% of the worldwide production. Its production has increased faster than any other mushroom species. Shiitake mushrooms were packed in biorientated polypropylene (BOPP) bags and exposed to different doses of gamma irradiation (1.0, 1.5, and 2.0 kGy) within the packaging, heat sealed and stored at 4 _C for 20 d. Of the three doses, 1.0 kGy was most effective in maintaining a high level of firmness. Samples treated with 1.0 kGy also exhibited smaller initial declines in soluble protein, higher increases in total sugar content and lower levels of malondialdehyde accumulation. Furthermore, 1.0 kGy promoted the accumulation of phenolics compound and showed higher antioxidant ability during storage. At higher doses, 2.0 kGy resulted in a higher microbial reduction, but showed negative effects on texture, chemical properties and functional components. It is evident from this study that integrated treatments of gamma irradiation (1.0, 1.5, and 2.0 kGy) + MAP was more effective in reducing microbial counts than stand-alone MAP.

In another research on effect of integrated application of nitric oxide and modified atmosphere packaging to improve quality retention of button mushroom, Nitric oxide (NO) is a highly reactive free radical gas that was initially notable as an industrial pollutant but is now known to be involved in resisting vegetative stress and senescence of horticultural products (**Jiang, 2011**). Short-term exposure to a low concentration of NO gas or its donor compounds has been shown to extend the post-harvest life of various intact fresh fruits and vegetables (**Wills *et al*., 2007; Zhu and Zhou, 2007**). It has been shown that they delayed ripening (**Zhu and Zhou, 2007**), inhibited ethylene biosynthesis (**Eum *et al*., 2009; Zhu *et al*., 2**008), inhibited cut-surface browning (**Pristijono *et al*., 2006; Wills *et al*., 2008**), and enhanced resistance to post-harvest diseases (**Zhu & Zhou, 2007**). *Agaricus bisporus* were dipped for 10 min in different concentrations (0.5, 1, and 2 mM) of 2,20-(hydroxynitrosohydrazino)-bisethanamine (DETANO), a nitric oxide donor, then packed in biorientated polypropylene (BOPP) bags, heat sealed and stored at 4 ◦C for 16 days (d). Mushroom weight loss, firmness, colour, percent open caps, total phenolics, ascorbic acid and H2O2 contents, superoxide anion (O2) production rate and activities of polyphenol oxidase (PPO), superoxide dismutase (SOD), catalase (CAT), and ascorbate peroxidase (APX) were measured. The results indicate that treatment with 1 mM DETANO maintained a high level of firmness, delayed browning and cap opening, promoted the accumulation of phenolics, ascorbic acid and reduced the increases in both O2 production rate and H2O2 content. Furthermore, NO inhibited the activity of PPO, and increased the antioxidant enzymes activities of CAT, SOD and APX throughout storage period. Thus it was observed that application of NO in combination with modified atmosphere packaging (MAP) can extend the storage life of button mushroom up to 12 d (**Jiang, 2011**).

Koushki *et al*. in 2011 research on Effect of integrated application of CaCl2 dipping and MAP on physiological properties of Agricus bisporus mushrooms. Results show that MAP of 5% CO2: 10% O2 (P2G2) with CaCl2 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.

REFERENCES

ABAH, S. E., ABAH, G. 2010. Antimicrobial and Antioxidant Potentials of *Agaricus bisporus*. *Advances in Biological Research*, 4(5), 277-282.

ABOU-HEILAH, A.N., KASIONALISM, M.Y., KHALIEL, A.S. 1987. Chemical composition of the fruiting bodies of *Agaricus bisporus*. *Int. J. Expt. Bot.*, 47, 64-68.

AGRAHAR-MURUGKAR, D., & SUBBULAKSHMI, G. 2005. Nutritional value of edible wild mushrooms collected from the Khasi hills of Meghalaya. *Food Ch*emistry, 89, 599–603.

AGUIRRE, L., FRIAS, J. M., RYAN, C. B., & GROGAN, H. 2008. Assessing the effect of product variability on the management of the quality of mushrooms (*Agaricus bisporus*), *Postharvest Biology and Technology*, 49, 247-254.

AGUIRRE, L., FRIAS, J. M., BARRY-RYAN, C., GROGAN, H. 2009. Modelling browning and brown spotting of mushrooms (*Agaricus bisporus*) stored in controlled environmental conditions using image analysis. *Journal of Food Engineering*, 91, 280-286.

AIDA, F. M. N. A., SHUHAIMI, M., YAZID, M., and MAARUF, A. G. 2009. Mushroom as a potential source of prebiotics: a review. *Trends in Food Science and Technology*, 20,567-575.

AKINDAHUNSIA, A. A., OYETAYOB, F. L. 2006. Nutrient and antinutrient distribution of edible mushroom,*Pleurotus* tuber-regium (fries) singer. *LWT*, 39, 548–553.

ALAM, N., AMIN, R. KHAN, A., ARA, I., SHIM, M. J., Lee, M. W., Lee, T. S. 2008. Nutritional Analysis of Cultivated Mushrooms in Bangladesh - *Pleurotus ostreatus*, *Pleurotus* sajor-caju, *Pleurotus* florida and Calocybe indica. *Mycobiology*,36(4), 228-232 .

ALETOR, V.A. 1995. Compositional studies on edible tropical species of mushrooms. *Food Chemistry* , 54, 265-268.

ANDERSON. E.E., FELLERS, C. R. 1942. The food value of mushrooms (A Campestris). *Proc. Am. Soc. Hort. Sci*., 41,301.

ANTMANN, G., ARES, G., LEMA, P., LAREO, C. 2008. Influence of modified atmosphere packaging on sensory quality of shiitake mushrooms. *Postharvest biology and technology*, 49, 164-170.

ARES, G., PARENTELLI, C., GAMBARO, A., LAREO, C., LEMA, P. 2006. Sensory shelf life of shiitake mushrooms stored under passive modified atmosphere. *Postharvest Biology and Technology*, 41, 191-197.

ARES, G., LAREO, C., LEMA, P. 2007. Modified Atmosphere Packaging for Postharvest Storage of Mushrooms. Global Science Books.

BANO, Z., RAJARATHANAM, S., 1982. *Pleurotus* mushrooms as a nutritious food. In: Tropical mushrooms –Biological Nature and cultivation methods, (Chang ST, Quimio, TH, eds.) *The Chinese University press, Hongkong*,363-382.

BANO, Z., BHAGYA, S., SRINIVASAN, K.S., 1981. Essential amino acid composition and proximate analysis of Mushroom, *Pleurotus florida*. *Mushrooms News Lett. Trop*,1,6-10.

BARROS, L., Ventuizini, B. A., Baptista, P., Estevinho, L. M., & Ferreira, I. 2008. Chemical composition and biological properties of Portuguese wild mushrooms: A comprehensive study. *Journal of Agricultural and Food Chemistry*, 56, 3856-3862.

BARROS, L., BAPTISTA, P., ESTEVINHO, L. M., & FERREIRA, I. C. F. R. 2007a. Effect of fruiting body maturity stage on chemical composition and antimicrobial activity of Lactarius sp. mushrooms. Journal of Agricultural and Food Chemistry, 55: 8766-8771.

BARROS, L., CALHELHA, R. C., VAZ, J. A., FERREIRA, I., BAPTISTA, P., & ESTEVINHO, L. M. 2007b. Antimicrobial activity and bioactive compounds of Portuguese wild edible mushrooms methanolic extracts. *European Food Research and Technology*, 225, 151-156.

BAYSAL, E., PEKER, H., YALINKLIC, M. K., TEMIZ, A. 2003. Cultivation of oyster mushroom on waste paper with some added supplementary materials. *Bioresour Technol*, 89, 95-9.

BORCHERS, A. T., KRISHNAMURTHY, A., KEEN, C. L., MEYERS, F. J., GERSHWIN, M. E. 2008. The Immunobiology of Mushrooms. *Society for Experimental Biology and Medicine*, Mini review.

BONATTI, M., KARNOPP, P., SOARES, H. M., & FURLAN, S. A. 2004. Evaluation of *Pleurotus ostreatus* and *Pleurotus* sajor-caju nutritional characteristics when cultivated in different lignocellulosic wastes. Food Chemistry, 88: 425–428

BORCHERS, A. T., KEEN, C. L., GERSHWIN, M. E. 2004. Mushrooms, tumors, and immunity: an update. *Exp Biol Med (Maywood),* 229,393-406.
CAGLARIRMAK, N. 2007. The nutrients of exotic mushrooms (Lentinula edodes and *Pleurotus* species) and an estimated approach to the volatile compounds. *Food Chemistry*, 105: 1188-1194.
CHANG, S.T. 1982. Prospects for mushroom protein in developing countries. In: Tropical Mushroom Biological Nature and Cultivation Methods (Chang ST, Quimio TH. eds.), *Chinese University Press, Hong Kong*,463-473.
CHEN, J. N., WANG, Y. T., & WU, J. S. B. 2009. A glycoprotein extracted from golden oyster mushroom *Pleurotus* citrinopileatus exhibiting growth inhibitory effect against U937 leukemia cells. *Journal of Agricultural and Food Chemistry*, 57, 6706-6711.
CHEUNG, P. C. K. 2008. Mushrooms as Functional Foods. *John Wiley & Sons, Inc*, 3, 23-24.
CHEN, SH., OH, S. R., PHUNG, SH., HUR, G., YE, J. J., KWOK, S. L., SHRODE, G. E., BELURY, M., ADAMS, L. S., and WILLIAMS, D. 2006. Anti-Aromatase Activity of Phytochemicals in White Button Mushrooms (*Agaricus bisporus*). Cancer Res, 66: 24
CHOI, Y., LEE, S.M., CHUN, J., LEE, H.B., LEE, J. 2006. Influence of heat treatment on the antioxidant activities and polyphenolic compounds of shiitake (Lentinus edodes) mushroom. *Food Chemistry*, 99, 381-387.
CHEUNG, L. M., and CHEUNG, P. C. K. 2005. Mushroom extracts with antioxidant activity against lipid peroxidation. *Food Chemistry*, 89,403–409.
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 biology and technology*, 48, 283-294.
DEMIBRAS, A. 2001. Concentrations of 21 metals in 18 species of mushrooms growing in the east Black Sea region. *Food Chemistry*, 75,453-457.
DORE, C., AZEVEDO, T. C. G., DE SOUZA, M. C. R., REGO, L. A., DE DANTAS, J. C. M., SiLVA, F. R. F., et al. 2007. Antiinflammatory, antioxidant and cytotoxic actions of betaglucan-rich extract from Geastrum saecatum mushroom. *International Immunopharmacology*, 7, 1160-1169.
DUBOST, N. J., Ou, B., EELMAN, R. B. 2007. Quantification of polyphenols and ergothioneine in cultivated mushrooms and correlation to total antioxidant capacity. *Food Chemistry*, 105, 727-735.
EUM, H. L., KIM, H. B., CHOI, S. B., & LEE, S. K. 2009. Regulation of ethylene biosynthesis by nitric oxide in tomato (Solanum lycopersicum L.) fruit harvested at different ripening stages. *European Food Research and Technology*, 228, 331-338.
EISSA, H. A. A. 2007. Effect of chitosan coating on shelf life and quality of fresh-cut mushroom, *Journal of Food Quality*, 30(5), 623-645.
ESCALONA, V. H., VERLINDEN, B. E., GEYSEN, S., & NICOLAI, B. M. 2006. Changes in respiration of fresh-cut butter head lettuce under controlled atmospheres using low and super atmospheric oxygen conditions with different carbon dioxide levels. *Postharvest Biology and Technology*, 39(1), 48-55.
FACCIN, L. C., BENATI, F., RINCAO, V. P., MANTOVANI, M. S., SOARES, S. A., GONZAGA, M. L., et al. 2007. Antiviral activity of aqueous and ethanol extracts and of an isolated polysaccharide from Agaricus brasiliensis against poliovirus type 1. *Letters in Applied Microbiology*, 45, 24-28.
GARCIA -LAFUENTE, A., MORO, C., VILLARES, A., GUILLAMN, E., ROSTAGNO, M. A., D'ARRIGO, M., et al. 2010. Mushrooms as a source of anti-inflammatory agents. *Antiinflammatory and Anti-allergy Agents in Medicinal Chemistry*, 9, 125-141.
GUILLAMON, E., GARCIA-LAFUENTE, A., LOZANO, M., D´ARRIGO, M., ROSTANGO, M. A., VILLARES, A., MARTINEZ, J. A. 2010.Edible mushrooms: Role in the prevention of cardiovascular diseases. *Fitoterapia*, 81, 715-723.
HAN, P., CHEN, C. Q., ZHANG, C. L., SONG, K. K., ZHOU, H. T., CHEN, Q. X. 2008. Inhibitory effects of 4-chlorosalicylic acid on mushroom tyrosinase and its antimicrobial activities, *Food Chemistry*, 107, 797-803.
HAYES, W.A., HADDAD, N. 1976. The food value of the cultivated mushrooms and its importance in industry. *Mushroom J*, 40, 104-110.
JIANG, T., ZHENG, X., Li, J., JING, G., CAI, L., YING. T. 2011. Integrated application of nitric oxide and modified atmosphere packaging to improve quality retention of button mushroom (*Agaricus bisporus*), *Food Chemistry*, 126, 1693-1699.
HEARST, R., NELSON, D., McCOLLUM, G., MILLAR, B. C., MAEDA, Y., GOLDSMITH, C. E. 2009. An examination of antibacterial and antifungal properties of constituents of Shiitake (Lentinula edodes) and Oyster (*Pleurotus ostreatus*) mushrooms. *Complementary Therapies in Clinical Practice*, 15, 5-7.
HOSSAIN, S., HASHIMOTO, M., CHOUDHURY, E. K., ALAM, N., HUSSAIN, N., HASAN, M., et al. 2003. Dietary mushroom (*Pleurotus ostreatus*) ameliorates atherogenic lipid in hypercholesterolaemic rats. *Clinical and Experimental Pharmacology and Physiology*, 30, 470-475.
JEONG, S. CH., JEONG, Y. T., YANGB, B. K., ISLAMB, R., KOYYALAMUDIA, S. R., PANGA, G., CHOA, K. Y., SONG, C. H. 2010. White button mushroom (*Agaricus bisporus*) lowers blood glucose and cholesterol levels in diabetic and hypercholesterolemic rats. *Nutrition Research*, 30, 49-56.
JIANG, T., LUO, Sh., 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 Chemistry*, 122, 761-767.
KALAC, P., SBOVODA, L. 2000. A review of trace element concentrations in edible mushrooms. *Food Chemistry*, 69, 273-281.
KIM, K. M., KO, J. A., LEE, J. S., PARK, H. J., & HANNA, M. A. 2006. Effect of modified atmosphere packaging on the shelf-life of coated, whole and sliced mushrooms. *Food Science and Technology*, 39(4), 365-372.
Koushki, M. R., Khoshgozaran Abras, S., Mohammadi, M., Hadian, Z., Bagheri Pourfallah, N., Sharayei, P., Mortazavian, A. M. 2011. Physicochemical properties of mushrooms as affected by modified atmosphere packaging and CaCl2 dipping. *African Journal of Agricultural Research*, 6(24), 5414-5421.
KOOPMAN, R., LANEY, K. 2010. Mushrooms, Industry and trade. *United States International Trade Commission, Publication ITS-07*.
KOYYALAMUDI, S. R., JEONG, S. CH., SONG, CH. H., CO, K. Y., PANG, G. 2009. Vitamin D2 Formation and Bioavailability from *Agaricus bisporus* Button Mushrooms Treated with Ultraviolet Irradiation. J. Agric. *Food Chemistry*, 57 (8), 3351-3355.
KOZARSKI, M., KLAUS, A., NIKSIC, M., JAKOVLJEVIC, M., HELSPER, J. P. F. G., Van Griensven, L. J. L. D. 2011. Antioxidative and immunomodulating activities of polysaccharide extracts of the medicinal mushrooms *Agaricus bisporus*, Agaricus brasiliensis, Ganoderma lucidum and Phellinus linteus. *Food Chemistry*, 129, 1667-1675.
LEE, E. K., NOH, B. S., KIM, G. H. 2007. Minimization of Off-Flavor Occurrence During the Storage of Modified Atmosphere Packaged *Pleurotus ostreatus*. *Food Sci Nutr*,12,222-228.
LINDEQUIST, U., NIEDERMEYER, T. H. J., JULICH, W. D. 2005. Pharmacological potential of mushrooms. *Evidence-based Complementary and Alternative Medicine*, 2, 285-299.
LU, SH., LUO, Y., TURNER, E., FENG, H. 2007. Efficacy of sodium chlorite as an inhibitor of enzymatic browning in apple slices.*Food Chemistry*, 104, 824-829.
MAHAJAN, P. V., RODRIGUES, F. A. S., MOTEL, A., LEONHARD, A. 2008a. Development of a moisture absorber for packaging of fresh mushrooms (Agaricus bisporous). *Postharvest Biology and Technology*, 48, 408-414.
MAHAJAN, P. V., OLIVIERA, F. A. R., MACEDO, I.2008b. Effect of temperature and humidity on the transpiration rate of the whole mushrooms. *Journal of Food Engineering*, 84, 281-288.
MANZI, P., AGUZZI, A., & PIZZOFERRATO, L. 2001. Nutritional value of mushrooms widely consumed in Italy. *Food Chemistry*, 73, 321-325.
MATTILA, P., KONKO, K., EUROLA, M., PIHLAWA, J.M., ASTOLA, J., VAHTERISTO, L.V, KUMPULAINEN, J., VALTONEN, M., PIIRONEN, V. 2001. Contents of vitamins, mineral elements, and some phenolic compounds in cultivated mushrooms. Journal of Agriculture and Food Chemistry, 49, 2343-2348.
MEHTA, B. K., JAIN, S. K., SHARMA, G. P., DOSHI, A., JAIN, H. K. 2011. Cultivation of button mushroom and its processing: an techno-economic feasibility. *International Journal of Advanced Biotechnology and Research*, 2(1), 201-207.
MORADALI, M. F., MOSTAFAVI, H., GHODS, S., and HEDJAROUDE, G. A. 2007. Immunomodulating and anticancer agents in the realm of macromycetes fungi (macrofungi). *International Journal of Immunopharmacology*, 7, 701-724.
MOTA, W.F.da, FINGER, F.L., CECON, P.R., SILVA, D.J.H.da, CORREA, P.C., FIRME, L.P. and NEVES, L.L.DE M. 2006. Shelf-life of four cultivars of okra covered with PVC film at room temperature. *Horticultura Brasileira*, 24, 255–258.
NERYA, o., BEN-ARIE, R., LUZZATO, T., MUSA, R., KHATIV, S., VAYA, J. 2006. Prevention of *Agaricus bisporus* postharvest browning with tyrosinase inhibitors. *Postharvest Biology and Technology*, 39,272-277.
OLIVIERA, F., SOUSA-GALLAGHER, M.J., MAHAJAN, P.V., TEIZERIA, J. A. 2012. Development of shelf-life kinetic model for modified atmosphere packaging of fresh sliced mushrooms. 111(2), 466-473.
PALACIOS, I., LOZANO, M., MORO, C., D'ARRIGO, M., ROSTAGNO, M. A., MARTINEZ, J. A., GARCIA-LAFUENTE, A., GUILLAMN, A., VILLARES, A. 2011. Antioxidant properties of phenolic compounds occurring in edible mushrooms. *Food Chemistry*, 128, 674-678.
PARENTELLI C, ARES G, CORONA M, LAREO C, GAMBARO A, SOUBES M, LEMA P. 2007. Sensory and microbiological quality of shiitake mushrooms in modified atmosphere packages. *Journal of the Science of Food and Agriculture* ,87(9), 1645–1652.
PENG, L., JIANG, Y. 2006. Exogenous salicylic acid inhibits browning of fresh-cut Chinese water chestnut. *Food Chemistry*, 94, 535-540.
PRISTIJINO, P., WILLS, R. B. H., & GOLDING, J. B. 2006. Inhibition of browning on the surface of apple slices by short term exposure to nitric oxide (NO) gas. *Postharvest Biology and Technology*, 42, 256-259.
QIU, L., CHEN, Q. H., ZHUANG, J. X., ZHONG, X., ZHOU, J. J., GUO, Y. J., et al. 2009. Inhibitory effects of a-cyano-4-hydroxycinnamic acid on the activity of mushroom tyrosinase. *Food Chemistry*, 112,609-613.

RAI, R. D., ARUMUGANATHAN, T. 2008. POST HARVEST TECHNOLOGY OF MUSHROOMS. National Research Centre for Mushroom, Technical Bulletin.

RUDAWSKA, M., LESKI, T. 2005. Macro and micro elemental contents in fruiting bodies of wild mushrooms from the Netecka forest in west central Poland. *Food Chemistry* , 92, 499-502.

SABOURY, A. A. 2009. Enzyme Inhibition and Activation: A General Theory. *J. Iran. Chem. Soc*, 6(2), 219-229.

Taghizadeh, M., Goven, A., Ward, P., O'Donnell, C. P. 2010. Use of hyperspectral imaging for evaluation of the shelf-life of fresh white button mushrooms (*Agaricus bisporus*) stored in different packaging films. *Innovative Food Science and Emerging Technologies*, 11, 423-431.

SANDHYA,. 2010. Modified atmosphere packaging of fresh produce: Current status and future needs. *Food Science and Technology*, 43, 381-392.

SIMON, A., GONZALEZ-FANDOS, E. 2011. Influence of modified atmosphere packaging and storage temperature on the sensory and microbiological quality of fresh peeled white asparagus. *Food Control*, 22, 369-374.

THOMPSON, A. K. 2010. Controlled Atmosphere Storage of Fruits and Vegetables. *CAB International, Second edition*: 107,169.

Verma, R.N., Singh, G.B., Bilgrami, K.S. 1987. Fleshy fungal flora of N. E. H. India-I. *Manipur and Meghalaya. Indian Mush. Sci*, 2, 414- 421.

WANI, B. A., BODHA, R. H., and WANI, R. H. 2010. Nutritional and medicinal importance of mushrooms. *Journal of Medicinal Plants Research*, 4(24),2598-2604.

WEI, S., VAN GRIENSVEN, L. J. L. D. 2008. Pro- and Antioxidative Properties of Medicinal Mushroom Extracts. *International Journal of Medicinal Mushrooms*, 10(4), 315-324.

WILLS, R. B. H., SOEGIARTO, L., & BOWYER, M. C. 2007. Use of a solid mixture containing diethylenetriamine/nitric oxide (DETANO) to liberate nitric oxide gas in the presence of horticultural produce to extend postharvest life. *Nitric oxide*, 17, 44-49.

WILLS, R. B. H., PRISTIJONO, P., & GOLDING, J. B. 2008. Browning on the surface of cut lettuce slices inhibited by short term exposure to nitric oxide (NO). *Food Chemistry*, 107, 1387-1392.

WASSER, S. P. 2002. Medicinal mushrooms as a source of antitumor and immunomodulating polysaccharides. *Applied Microbiology and Biotechnology,* 60, 258-274.

XU, X., YAN, H., CHEN. J., ZHANG, X. 2011. Bioactive proteins from mushrooms. *Biotechnology Advances*.

Yi, W., Wu, X., Cao, R., Song, H., Ma, L. 2009. Biological evaluations of novel vitamin C esters as mushroom tyrosinase inhibitors and antioxidants, *Food Chemistry*, 117, 381-386.

YOSHINO, K., KONDOU, Y., ISHIYAMA, K., IKEKAWA, T., MATSUZAWA, T., & SANO, M. 2008. Preventive effects of 80% ethanol extracts of the edible mushroom Hypsizigus marmoreus on mouse type IV allergy. *Journal of Health Science*, 54, 76-80.

ZHU, S., SUN, L., LIU, M., & ZHOU, J. 2008. Effect of nitric oxide on reactive oxygen species and antioxidant enzymes in kiwifruit during storage. *Journal of the Science of Food and Agriculture*, 88, 2324-2331

ZHU, S. and ZHOU, J. 2007. Effect of nitric oxide on ethylene production in strawberry fruit during storage. *Food Chemistry*, 100, 1517-1522.

ZHANG, J., CHEN, Q., SONG, K., & XIE, J. 2006. Inhibitory effects of salicylic acid family compounds on the diphenolase activity of mushroom tyrosinase, *Food Chemistry*, 95, 579-584.