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A Review on novel technique of Modified atmospheric packaging for mushroom preservation

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Introduction

According to the recent FAO report, 50% of agricultural products are wasted because of the absence of packaging due to bad weather, physical, chemical and microbiological deteriorations. Progress in the packaging of foodstuffs will prove crucial over the next few years mainly because of new consumer patterns, demand creation and world population growth which are estimated to reach 15 billion by 2025.

Mushroom production and consumption is increasing very fast throughout the world mainly due to its nutritive and medicinal attributes. However, high deterioration rate and short shelf life of mushrooms causes difficulties for their distribution and marketing. After harvesting mushrooms continue to grow, respire, mature leading to senescence resulting in veil opening, browning, wilting, weight loss and finally spoilage. Quick deterioration is mainly caused due to their high metabolic activity, respiration rate and dehydration. Shelf life of fresh mushroom is limited to 1-3 days at ambient temperature and to 4-7 days at 4ºC. Extending the shelf-life of highly perishable mushroom is still a scientific and economical challenge. The several benefits that make the modified atmospheric storage of mushroom very popular are,

- Availability of fresh mushroom throughout the year
- Microbial safe and fresh produce
- Convenient package for marketing

The current concept of food preservation is not only for extending the shelf life but also for sustaining the quality of mushroom. Modified Atmospheric Packaging is most economical and effective method of extending the shelf life of mushroom. Modified atmosphere packaging alters the normal composition of air to provide an optimum atmosphere for reduced respiration rate and there by preserving its quality and increasing its shelf life. Therefore the use of modified atmospheric packaging is an alternative technology to extend the shelf life of mushroom during postharvest storage and for commercialization. A better understanding of the effects of modified atmospheric storage could lead to more targeted strategies for reducing postharvest quality loss in button mushroom as well as in other types of mushrooms. Hence, this project aims to develop suitable modified air composition system to extend the shelf life of mushroom by Modified Atmospheric Packaging.
Mushrooms are very popular proteinaceous food in the world. Mushrooms are rich in minerals; vitamins, water content and also they are low in calories, salt, fat

and devoid of sugar, starch and cholesterol which make them ideal and nutritional supplement. Mushrooms are highly perishable and start deteriorating perishable and tend to lose quality soon after harvest. Shelf life of mushroom is less than 3 days under usual shipping and marketing conditions. Therefore there is an increasing trend for enhancing the shelf life of mushroom. Modified atmospheric packaging is an excellent tool to extend the shelf life of the button mushroom. There is an upsurge of interest in this packaging system as research is beginning to reveal many possibilities associated with enhancing shelf life of mushroom.

Modified atmospheric packaging has a great economic value and it has been accepted that they contribute in improving the shelf life of mushroom. During the last 10 years much of the research on Modified Atmospheric Packaging are focused on fruits and vegetable preservation. Investigators now include various gas concentrations and different packaging films in wide variety of mushroom. This project aims in the developing the standard conditions of MAP, for enhancing shelf life of mushroom comprising of a nutritional and biological preservation. A Modified Atmospheric Packaging for button mushroom which will ensure its preservation for longer periods will be developed, which will also focus on retaining the nutritional factors of the packed mushrooms.

Studies on varying gas concentrations with storage temperature for lowering the respiration rate will be done to provide scientific evidence to claim MAP for mushroom preservation. The developed MAP will have the attribute of fresh mushroom of maturity index, color and weight. The development of successful MAP will be contingent on both proof of freshness and maintain the quality of mushroom as fresh. Also, the nutritional value of the preserved mushroom will be evaluated.

Current status of the MAP in mushroom preservation

In the buyer's market, mushroom is chosen on the basis of their appearance and nourishing value. Since mushrooms are fast respiring and highly perishable, prolonging post harvest storage period while preserving their quality shelf life would benefit the mushroom industry and consumer. Due to storage complexities involved with produce, that is varying respiration rates which are product and temperature dependent, different optimal storage temperatures for each commodity, water absorption and so on, many considerations are involved in choosing an acceptable packaging technology. There has been enormous increase in the demand for fresh fruit and vegetable products especially that mushroom has required the industry to develop new and improved methods for maintaining quality and extending the shelf life.

Modified atmospheric packaging has emerged as an excellent tool for packaging and extends the shelf life of the mushroom. MAP provides an affordable packaging system that partly avoids enzymatic browning, fermentation and other biochemical processes by maintaining a suitable gas atmosphere. Several factors, including optimum CO_2 and O_2 partial pressures, permeability, package material, thickness, or product weight, must be considered in order to design a suitable modified atmospheric package for mushrooms. Thus, different strategies are available to preserve mushroom quality after harvest.

Research, design and development of modified atmospheric packaged mushroom into the food processing sector are one of the most dynamically growing fields. Mushrooms constitute at least 14,000 species, of which approximately 2,000 are edible (Chang 1999a).

Mushrooms are among functional foods consumed for the longest time, and they still dominate the market of fruits and vegetables. Consumers with malnutrition such as protein deficiency and minerals, lack the benefits of mushroom. Due to thin layer in cap and spongy tissue, mushroom now spoiled easily and gets the reduced market price. Hence, the storage of the mushroom should be improved, and to satisfy the market and biochemical needs of the individual. With this motivation, we are proposing to develop modified atmospheric storage of mushroom. Among the mushroom variety, button mushroom has the highest calorie content. In addition, mushroom is better balance of essential amino acids. We have planned to add few biopreservatives to the mushroom so as to enhance the prevention of pathogenic microorganisms and increase the quality of the fresh produce. In the end, we will have developed a novel modified atmospheric packaging system will benefit to extend the shelf life of mushroom.

The enormous increase of population has necessitated more and more food production and preservation through alternate resources such as mushroom.

Mushrooms can be described as 'Macrofungus with a distinctive fruiting body, large enough to be seen with the naked eye and to be picked by hand'. These visible structures are generically referred to as "fruiting bodies". (Chang and Miles, 1992) From a taxonomic point of view, mainly *Basidiomycetes* but also some species of *Ascomycetes* belong to mushrooms (Lindequist *et al*., 2005).

Considering the increased interest of consumers in health and well being, the demand and markets for edible mushrooms might increase if they are promoted as functional foods. A functional food can be considered as a food that has value beyond its nutritional value because it promotes specific aspects of human health. In this context, many health benefits have been ascribed to mushrooms and compounds isolated from them, including bioactive polysaccharides (3-glucans, such as lentinan), antioxidants, dietary fiber, ergosterol, vitamin B_1, B_2 and C, folates, niacin and minerals (Mattila *et al*., 2001; Lindequist *et al*., 2005).

Numerous studies have reported mushrooms having medicinal attributes including anti-tumor (Ikekawa *et al*., 1969; Suzuki *et al*., 1994; Mizuno 1999; Cheung 2003; Lindquist *et al*., 2005; Choi *et al*., 2006); antimicrobial activity, liver function improving and enhancement of macrophage function and host resistance to many bacterial, viral, fungal and parasitic infections (Lin-dequist *et al*., 2005); activation of a non-specific immune stimulation (Yoshino *et al*., 2001; Lindequist *et al*., 2005); and reduction of blood cholesterol and blood glucose levels (Fukushima *et al*., 2001; Lindequist *et al*., 2005).

Button mushroom (*Agaricus bisporous*) is one of the most popular mushrooms, traditionally cultivated in the world. It is most extensively edible mushroom comprising 32% of the world production (Chang, 1999). However, due to high respiration rate, water loss, senescence and microbial attack shelf-life of fresh mushrooms (*Agaricus bisporus*) is limited to 1- 3 days at ambient temperature (Burton and Twyning, 1989). Short life of mushroom is an impediment to the distribution and marketing of fresh product. Therefore special care to retain freshness and quality of mushroom has created a need for a technology that allows distribution of fresh produce around the year and to increasing the shelf - life of mushroom, is an enormous economic benefit for the food industry.

Need of map on preservation

Modified atmosphere packaging (MAP) has been reported to be most economical and effective method of extending the shelf life of mushroom (Tano *et al.*, 1999). A modified atmosphere can altering the normal composition of air (78% nitrogen, 21% oxygen, 0.03% carbon dioxide and traces of noble gases) to provide an optimum atmosphere for increasing the storage length and quality of food/produce (Moleyar and Narasimham 1994). MAP in terms of reduced O_2 and elevated Co_2 can extend the post harvest life of fruits and vegetables by reducing their respiration rate as well as production of ethylene, minimizing metabolic activity, delaying enzymatic browning, retaining visual appearance (Kader, 1986).

Use of modified atmosphere packaging (MAP) to extend shelf-life of mushroom was demonstrated by Nichols and Hammond (1974), Burton *et al.* (1987), Burton and Twyning (1989), and more recently by Roy *et al*. (1995a). Roy *et al*. (1995a) reported the optimum in-package O_2 concentration to be 6% for maximum increase in shelf-life of mushrooms stored in modified atmospheric package without creating anaerobic conditions. Modified atmospheric packaging delays the development and senescence of the product and can also affect the type and growth rates of microorganisms

Much of the studies on the modified atmosphere packaging of mushrooms focused on methods for creating and maintaining optimal atmosphere and on the suitability of the various films currently found on the market (Burton *et al*., 1987; 1993; Exama *et al*, 1993; Roy *et al*., 1995a).

Modification of the atmosphere as an adjunct to low temperature can be quite effective in extending their shelf-life. Since it is often difficult to ensure constant temperature during transportation and storage, temperature variations will affect the produce respiration rates. But the permeability of the package may not change to the same extent as respiration rate; hence, the atmosphere inside the package will be altered (Exama *et al*., 1993).

Biological reactions tend to increase by a factor of 2 to 3 for each increase in temperature by 10°C (Exama *et al*., 1993). Modifying the atmosphere surrounding the produce may decrease the respiration rate and extend the shelf-life of the produce (Burton, 1979). Low temperature storage in combination with modified atmospheric packaging (MAP) is reported to extend the postharvest life of vegetables (Paull., 1999) by lowering the temperature of mushrooms storage leads to low respiration and transpiration, delaying senescence, preventing wilting and shriveling and thus extending shelf life (Burton and Twyning, 1989).

Mushroom catabolism is not dependent on O_2 partial pressure from 0.1 to 20 kPa or CO_2 partial from 0 - 20 kPa. Therefore, they suggested that Controlled Atmospheric Storage or Modified Atmospheric Packaging would reduce neither respiration nor metabolite consumption in mushroom. However it has been demonstrated that CO_2 at partial pressure for 5-20 kPa, prevented cap opening, probably due to repression of aerobic metabolism (Burton *et al*., 1987), inhibition of endogenous growth regulators or the effect of CO_2 as regulator for mycelia growth and mushroom morphogenesis (Roy *et al*., 1995).

High CO_2 and low O_2 concentrations prevented cap opening and optimum atmosphere for achieving maximum shelf life was 0.1% O_2 and 5% CO_2. On the contrary 0% CO_2 retarded pileus expansion and stipe growth while 5% CO_2 promoted pileus expansion and stipe growth after 7 days at 10^0C. Besides, CO_2 at 5% stimulated stipe elongation but suppressed cap growth. However CO_2 concentration higher than 5% might induce both internal and external yellowing of the cap. Mushrooms, being a product with high respiration rate require packaging films with high O_2 and CO_2 permeability. Permeabilities of the commonly used polymeric films are not sufficiently high as required and anaerobic conditions might occur, as well as physiological damage due to high CO_2 concentration. In order to overcome this problem, micro perforated and macro perforated films has been developed (Farber *et al*., 2003). Because of their high O_2, CO_2 and water vapor permeability, these films preclude the possibility of developing an adequate modified atmosphere for packaging of high respiring products. The permeability of these films depends on the type of film, its thickness and the number, size and shape of the perforation (Zanderighi, 2001).

Post harvest physiology of *Agaricus bisporous* has been directly related to development of spores (Braaksma *et al*., 1994). Although modified atmosphere packaging of *Agaricus bisporous* has been studied for more than 30 years, there is little published consensus on the optimum atmosphere storage of this type of mushrooms.

At present three types of mushrooms are being cultivated in India are the white mushroom (*Agaricus bisporus*), the paddy-straw mushroom (*Volvariella volvvacea*) and the oyster mushroom (*Pleurotus sajor-caju*). *Agaricus bisporus* (button mushroom) contributes about 80 - 85 per cent of the total annual production of mushroom. Mushrooms are capable of producing the highest quality of protein per unit area and time from the agro-wastes. Production of mushrooms, especially of the white button mushrooms, in India has gone up during recent years creating marketing problems.

The market for processed foods has yet to develop in the country and basically fresh fruits and vegetables are preferred. The marginal increase in demand is for fresh mushrooms instead of dried/preserved mushrooms. Fresh mushrooms have very short shelf-life and therefore cannot be transported to long distances without refrigerated transport facility.

In India, mushrooms are packed in perforated poly bags each containing around 250-500 g of mushrooms. They can be stored in polythene bags at $4\text{-}5^0$ C for a short period of 3-4 days. The mushrooms are usually packed in unlabelled simple polythene or polypropylene for retail sale. In developed countries, modified atmosphere packaging (MAP) and controlled atmosphere packaging (CAP) are in vogue.

White button mushrooms are not usually dried by common procedures used in case of oyster, paddy and shitake mushrooms. Canning is the most popular method of preserving the white button mushrooms and sizeable quantity of canned produce are exported to international markets. Besides that, freeze drying, IQF and pickling are also practiced by some units. Recently, Mushroom India Pv Ltd at Nashik (Dindori) are packing whole mushrooms, slices, pieces & stems in international quality cans which make the product inert. Directorate of Mushroom, Indian Council of Agricultural Research proposed the refinement in modified atmospheric packaging suiting mushroom for their increased shelf life.

International status of modified atmospheric packaging of mushrooms

Today, 45% of mushrooms produced are consumed in the fresh form. The other 55% are processed, with 5% in dehydrated form and 50% in canned form. This is because their shelf life in the fresh form is very short and hence mushrooms are traded in the world market mostly in the processed form.

A recent scientific status on mushroom storage from packaging technology summarized the scientific support and science for the mushroom preservation using modified atmospheric packaging for retention of various quality concerns including color, weight and microbial safety. The review emphasizes that the future success of MAP of mushroom will require strong support from food and nutrition scientists and that studies documenting these effects in commercial method are limited.

10th Controlled and Modified Atmosphere Research Conference, held at Antalya, Turkey on 4-7 April 2009, focused on the enhancing storage life for fruits and vegetables especially with the aim of identifying suitable MAP system for mushroom.

The research published in Journal of food engineering, the good MAP 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 the shelf life of mushrooms.

Effects of modified atmospheric packaging with antimicrobial coating in reducing the respiration rate and microbial spoilage that could promote the shelf life of mushroom. Combinations of MAP with antimicrobials could be useful and more effective in retention of quality and inhibition of pathogen adhesion.

Commercially available modified atmosphere packaging for small and large quantities of products

Product	Description	Use
Pallet Package system	Pallet box wrapped in heavy gauge polyethylene	Apples, Pears and other Perishables
Tectrol system (Trans FRESH Co.)	Pellet box bulk unit - wrapped with a barrier plastic film; gases are injected and the bag sealed.	Strawberries for short term transport
Tom –Ah-Toes	Long narrow box overwrapped with gas permeable film, contains a sachet containing calcium chloride and activated lime to absorb CO_2	Avocados ,tomatoes, mangoes
MAPAX (AGA, Sweden)	This system incorporates the optimal atmosphere by testing, to choose the exact gas mixture and the best film for each product considering respiration rate, temperature, packaging film for each product considering respiration rate, temperature, packaging film, pack volume, fill weight and light.	Fresh cut produce, lettuce, mushrooms, pre-peeled potatoes
P-Plus films (Courtauld Packaging)	Spark perforated films which result in non uniform perforations throughout the film to facilitate gas exchange	Brussels sprouts, lettuce, broccoli, fresh mushrooms and bean sprouts
Laminated boxes (Georgia Pacific, Weyerhaeuser and Tamfresh Ltd.)	Cartons with films laminated within the cardboard or coated on the inside of the cardboard liner. Reduces moisture loss and potential air flow	Strawberries, broccoli and other perishables

Recommended gas mixture for Modified Atmospheric Packaging of fruits and vegetable (Day, 1993, Exama *et al*., 1993; Moleyar and Narasimhan 1994, Powrie and Skura1991, and Smith & Ramaswamy, 1996).

Produce	O_2 (%)	CO_2 (%)	N_2 (%)	Approximate storage life
Fruits				
Apple	1-2	1-3	95-98	2-11 m
Apricot	2-3	2-3	94 – 96	-
Avocado	2-5	3-10	85-95	8-10 d
Banana	2-5	2-5	90-96	15d
Grape	2-5	1-3	92 – 97	-
Kiwifruit	1-2	3-5	93-96	6m
Lemon	5-10	0-10	80-95	-
Mango	3-7	5-8	85-92	-
Orange	5-10	0-5	85-95	-
Papaya	2-5	5-8	85 - 95	-
Peach	1-2	3-5	93 - 96	-
Pine apple	2-5	5-10	85 - 93	-
Strawberry	5-10	15 - 20	70 - 80	-
Vegetables				
Artichoke	2-3	2-3	94-96	29d
Beans	2-3	5-10	87-93	21d
Broccoli	1-2	5-10	88 -94	7-10d
Brussels sprouts	1-2	5-7	91-94	2-3m
Cabbage	2-3	3-6	81 - 95	2-3m
Carrot	5	3-4	91 – 95	4-5m
Cauliflower	2-5	2 -5	90-96	2-3m
Chilli peppers	3	5	92	-
Corn sweet	2-3	10-20	76 -88	-
Cucumber	3-5	0	95-97	14-21d
Lettuce	1-3	0	97-99	3-4wks
Mushrooms	3-21	5-15	65-92	3-4d
Spinach	all	10-20	-	2-3wks
Tomatoes	3-5	0	95-97	-
Onion	1-2	0	98-99	8m

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