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Effect of respiratory gases (O_2; CO_2) on shelf-life of fresh oyster mushrooms packaged with different sealable polymeric materials

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Abstract

The present study was conducted to evaluate the effects of respiratory gases on shelf life of fresh Oyster mushrooms. The complete randomize design was followed for the experiment. After sorting of collected cultivated mushrooms were packed in different polymeric packaging materials-polystyrene trays over wrapped with polyvinyl chloride (PVC) microfilm and polypropylene (PP) at refrigerated and ambient temperature condition for 12 days. Gas composition as CO_2, O_2, N_2, concentration at 3 days intervals of the total 12 days duration also including sensorial quality were evaluated. CO_2 contents were found to be increased but O_2 contents was found to be reduced for both packaging materials within 3 days storage at ambient temperature. In refrigerator, oxygen content in both of trays increased sharply within 3 days of storage. Off flavor appeared strongly and started to spoil from third days after Oyster mushrooms packed in ambient temperature, which on the contrary was not detected in mushroom packed and stored until 12 days in refrigerator. Shortest storage period for a single day at ambient condition and extended period of 12 days self life was determined when mushrooms were stored in refrigerator in respect of sensorial quality in sealed polypropylene bag or in polystyrene trays.

Keywords: Respiratory gases; Shelf-life; Oyster mushrooms; Package; Polyvinyl chloride; Polypropylene

Introduction

Mushrooms are a rich source of good quality protein, having most of the essential amino acids, minerals and vitamins having low calories. Though around 20 genera of mushrooms are being cultivated for commerce throughout the world but in Bangladesh only oyster mushroom (Pleurotus spp.) has been grown popularly due to the particular taste and texture which makes it very successful with consumers. 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) and get spoiled due to browning, wilting, liquefaction, loss of texture, aroma, flavour, etc, making it unsealable . It was suggested that spoilage might be caused by the action of bacteria on the mushroom tissue and browning of mushrooms was due to a combination of autoenzymatic and microbial action on the tissue. Storage of mushroom in prepacks and the effects of carbon dioxide and oxygen on qualities of mushrooms had been reviewed by Halachmy and Mannheim (1992). The main oxidative reactions are enzymatic browning. They involve two oxidoreductases enzymes: polyphenoloxidase (PPO) and peroxydase (POD). PPO catalyzes two reactions; the first, a hydroxylation of monophenols to diphenols, which is relatively slow and results in colourless products. The second, the oxidation of diphenols to quinines, is rapid and gives coloured products (Queiroz, Lopes, Fialho and Valente-Mesquita, 2008). The substrates involved in these reactions are located in the vacuoles while enzymes are in the cytoplasm; the reactions can take place only if they are mixed and in the presence of oxygen. So, all phenomena (cutting, shock, loss of firmness) lead to the starting of browning reactions which induce losses or changes of flavor, odor and nutritional value (Toivonen and Brummell, 2008). Sound postharvest practices have since been developed to extend the shelf life of fresh mushrooms. Artes (1998) reviewed the methods to prevent oxidation by chemical, controlled atmosphere and coating treatments. Different types of new

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preservation technologies like sun drying, canning, pickling, mechanical and chemical drying (freeze drying, fluidized bed drying, batch type cabinet drying and osmotic drying) and irradiation treatment of mushrooms have been developed to improve the shelf life and consumption of mushrooms. These methods include proper use of refrigeration and modified atmosphere packaging (MAP) (Amodio *et. al.,* 2003; Choi and Kim 2003). The MAP technique which has been reported as an effective tool for extending the shelf-life of mushrooms (Ares *et al.,* 2006) along with keeping them fresh. Modified atmospheres, richer in CO_2 and poorer in O_2 than air, are assumed to be able to reduce respiration rate, decay and physiological deteriorations of vegetables, which results in shelf-life extension (Antmann *et al.,* 2008). Although many advantages are attributed to low concentration of O_2, less than 2% could cause anaerobic respiration as well as potential growth of anaerobic pathogens (Kim *et al.,* 2006) and the excessive accumulation of CO_2 (>12 kPa) inside the mushroom package can also result in their severe browning (Villaescusa and Gil, 2003). So, in order to encourage the mushroom growers to supply wholesome, safe, nutritious, delicious fresh mushroom and developed quality food to consumers throughout the year appropriate packaging materials are required. Research on this shelf-life on the mushroom under local environment is almost nil in Bangladesh. The present study is aimed at providing useful preliminary information to reduce losses and find out the condition in respect of emission of respiratory gases due to metabolic activities produced by the mushrooms inside the packages.

Materials and methods

Mushrooms cultivation and collection

Common cultivated Oyster mushrooms (*Pleurotus ostreatus*) were grown at the cropping room of Institute of Food Science and Technology (IFST), Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka, on traditional sawdust-based substrate, using standard IFST practice. Mushrooms were harvested early in the morning on the day of the experiment. All visible debris and dirt were removed but did not washed for cleaning up the samples. Mushrooms were selected based on size, free from major blemishes (bruising, gouges), disease and maturity . Only first flushes of mushrooms were used to reduce variation due to cropping and environment. Collected mushrooms were in between 4 to 9cm in diameter.

Experimental setup

Complete Randomize Design (CRD) was applied to conduct the current experiments. After collecting and sorting of fresh oyster mushroom was packaged by using in two different packaging materials as Poly-propylene (pp) and Polystyrene-tray wrapped with PVC film. Mushroom sample was kept in two different condition (ambient and in refrigerator). Packaging materials properties and environmental condition has been given in table 1. Samples were stored in earlier mentioned environmental condition for 12 days. Respiratory gaseous composition as concentration of oxygen, carbon dioxide, and nitrogen was measured at three days interval (at 0, 3, 6, 9, and 12 days) during total 12 days of experiment. Quality was determined by sensory evaluation parameters.

Sensory evaluation

The shelf life of the mushrooms were determined using two different types of packaging materials by evaluating the sensorial quality (Xiao *et al.,* 2011) (appearance, flavor, color and texture,) considering 1-9 points hedonic scale. Participants were recruited among the students, officer, staff and visitors to the IFST for the sensory panel. The panel consisted of 7 members. Hedonic values are based on a nine-point scale (1 = "dislike extremely," 5 = "neither dislike nor like," 9 = "like extremely"). Flavor description values are based on a nine-point scale (1 = "extremely tart," 5 = "neither tart nor sweet," 9 = "extremely sweet"). Color values are based on a nine-point scale (1 = "extremely light," 5 = "neither light nor dark," 9 = "extremely dark"). Texture values are based on a nine-point scale (1 = "extremely frail," 5 = neither frail nor liquefaction," 9 = "extremely liquefaction"). In general, sensorial properties were faster in limiting the shelf life than microbiological criteria (Sheikh *et al.,* 2010). The packaged mushrooms were stored under an ambient condition and the shelf- life was compared with the unpackaged mushrooms.

Measurement of gaseous composition

The experiment was arranged for 12 days with 3 days interval of the total duration. Respiratory gases, O_2, CO_2 including N_2 were measured using the gas analyzer MAP-4050 (Yanjie Li1 *et al.,* 2013) (Plate 13) at 3 days intervals of the total duration.

Results and discussion

Status of respiratory gases at different condition

The O_2 and CO_2 gases concentration were inversely changed (Fig 1. and Fig 2.) with days of measurement in both condition as refrigerator and ambient but N_2 concentration remained more or less constant.

Table I. The features of packaging materials used and environmental conditions of experiment

Packaging Materials	Size		Thick - ness (mm)	Excluding Sealing area or Net area	Weight of Samples (gm)	Storage Condition		
	Length (cm)	Width (cm)				Temp. (ºC)		Humi dity %
						Refri - gerated	Ambie nt	
Poly - propylene (pp)	22.5	17	0.35	323cm ^{2}	40	6±1	23 ± 1	67~78
Polystyren e-tray warped with PVC film	19.5	14.5	0.02 5	413cm ^{3}	40			

Comparison of respiratory gases and its effects on self life

As can be seen in Fig 3, the contents of respiratory gases including Nitrogen obtained by gas analyzer showed that at 'zero' day (actually immediate after packaging), the contents of carbondioxide was nil in both of PP and tray. It could be happened due to not get the chance to accumulate the gas just after packaging. On the third day, oxygen had increased rapidly but carbon dioxide increased steadily in both kinds of packages. Ajlouni (1991) found similar results at 0, concentrations between measured and predicted values for 50, 80 and 100g packages for the first five days, implied that there was no respiratory rise in the mushrooms. Packages containing 120g mushrooms had lower 0, concentrations than predicted at the end of 2 days storage, suggesting that respiration increased after 2 days. Mushrooms stored in air had a respiratory rise after 3 days storage at 18°C and at 12°C as reported by Nichols and Hammond (1975). In this present study increasing tendency was observed to continue up to 6-days in case of oxygen, whereas, slightly decreasing tendency was observed in case of carbondioxide in tray only. At ninth day and on wards, oxygen contents reached up to 20.90 % and remained unchanged in both types of packaging materials and also found that the contents of carbondioxide and nitrogen were 0.00% and 79.10% respectively. This finding is very nearer to the normal composition of the air (78% N_2, 21% O_2, and 0.003% CO_2). From this observation, we can assume that there was equilibrium between atmospheric air and in air present in both kinds of packets. The results also showed that the equilibrium had occurred in between six to nine days. It was also observed that till 12 days, mushrooms in both packages were good in condition organoleptically, whereas, mushrooms packed in tray was comparatively better in respect of appearance and texture. It had been pointed out by Gormley and MacCanna (1967) that the shelf-life of mushrooms could be prolonged by wrapping with polyvinyl chloride (PVC) films.

Same as refrigerated condition there was an accumulation of carbondioxide in both types of packages. At third day, oxygen was lower in both tray and PP ranging from 8.99% to 4.65% and 6.03% to 0.65%, respectively. On the other hand, carbondioxide increased abruptly in both types of packages especially in PP, resulting 0.00% to 8.90% in tray and 0.00% to 13.30% in PP. Actually after 3-days, maximum mushrooms decayed and turned into liquefaction (Plate 14). Further it was kept with an intention to compare internal gases produced under ambient condition with refrigerated mushrooms till the experiment to be completed. At sixth day, an opposite trend, against which had been observed at third day were found in both kind of packets. At ninth day and onward, oxygen gradually reached to the level of atmospheric air, but carbondioxide raise up slightly. This finding is similar to that recorded by Roy *et. al.,* (1994). They reported that conventionally mushrooms stored in 50g packages had higher surface moisture after 9 days storage and the mushrooms in that package had a higher respiration rate, which resulted in more water being formed. Isenberg (1979) and Geeson *et. al.,* (1985) found that in a sealed package, containing a fresh product, a modified atmosphere (MA) is created by respiratory gas exchange, namely oxygen (O_2) uptake and carbondioxide (CO_2) evolution. When the rates of gas

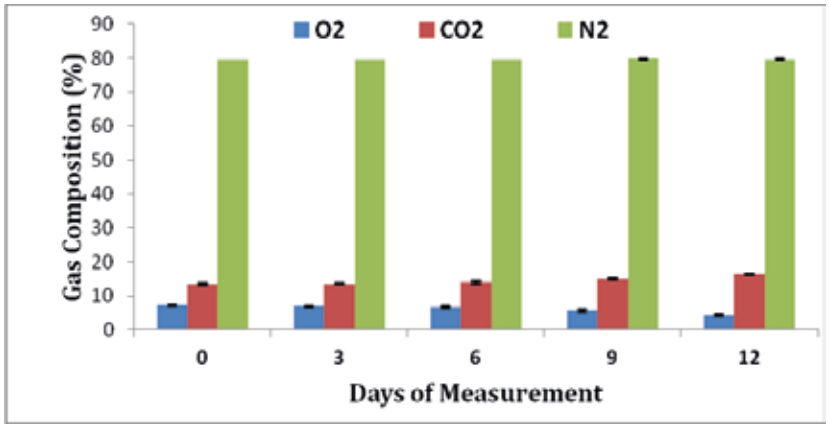

Fig. 1. Status of emitted respiratory gases from packed mushroom at refrigerator condition. Error bars represents the standard deviations (SDs)

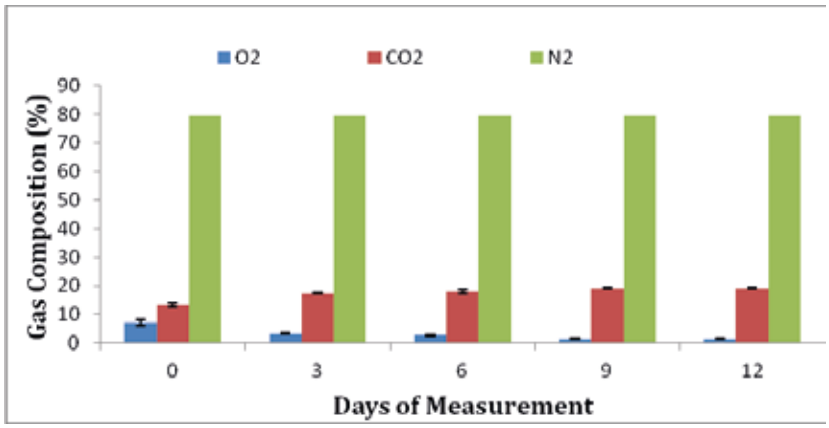

Fig. 2. Status of emitted respiratory gases from packed mushroom at ambient condition. Error bars represents the standard deviations (SDs)

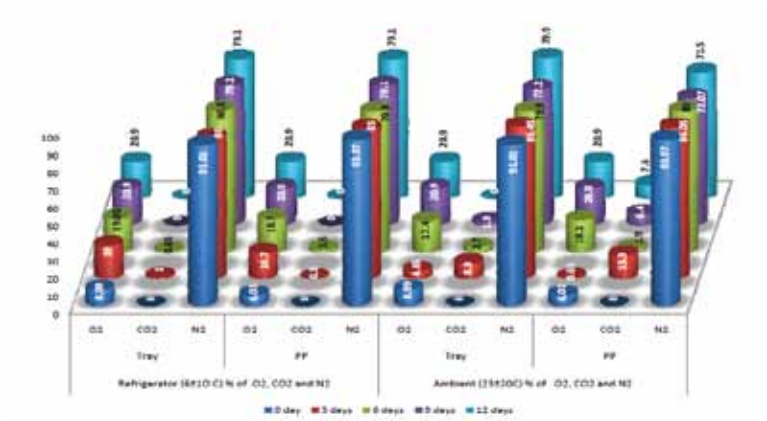

Fig. 3. Comparative contents of respiratory gases including nitrogen obtained by gas analyzer (MAP-4050)

permeation through the packaging material equal respiratory gas exchange, equilibrium concentrations of O_2 and CO_2 are consequently established. The equilibrium depends on: temperature, respiration rate of specific product, product weight, O_2 and CO_2 permeability of the packaging material, free volume in the package and film area. The microbial load of the product may also affect O_2 uptake and CO_2 evolution. An optimal atmosphere should extend shelf-life by minimizing respiration rate, reducing microbial spoilage, browning and other deleterious physiological changes. Oxygen concentrations below the respiration extinction point (onset of anaerobiosis) will cause an increase in the rate of CO_2 evolution, while CO_2 levels above a tolerance limit may lead to physiological disorders. Sveine *et al.*, (1967) reported that high CO_2 concentrations (above 10%), low O_2 levels (below 3 %), or a combination of both, prevented the opening of the mushroom caps at low storage temperatures. Nichols and Hammond (1975) found that aging, as well as visual deterioration of mushrooms in an overwrapped pre-pack was retarded, presumably as a result of modified O_2 and CO_2 and high RH. They also reported that since all the film overwraps prevented water loss to a similar extent and volatiles other than ethylene were not detected in the head space of the pre-packs, it seems likely that CO_2 and O_2 levels were responsible for the developmental changes that were observed. Films which permit an accumulation of CO_2 to about 10 to 12 and depletion of O_2 to about 2 % at 18°C have proved best in their experiments. This more or less corroborates with the findings as have been observed in PP at ambient temperature. The observation which was recorded at sixth days and onward indicated that the respiration rate decreased gradually and towards the end about to stop. Ajlouni (1991) also reported a decreased respiration rate of mushrooms after four days storage in air at 12°C. Murr and Morris (1975) found significant reductions in respiration rates of mushrooms at 10°C which occurred only over a very narrow range of O_2 concentrations, i.e. 0, 2, and 5%. According to Kader *et. al.,* (1989), Mannapperuma and Singh (1990) and Ballantyne (1986) for most commodities the respiration rate at low temperatures is only slightly reduced in some gas mixtures as compared to the rate in air. However, increasing of carbondioxide and decreasing of oxygen in different polymeric packages were also reviewed by Yong-Seon-Ahn (2000). It was reported that carbondioxide content in trays were increased from 0.5% to 5.5% ~ 8.6% within 1 day storage. In the present study oxygen contents in trays were found to decrease sharply from 20% to 0.8% ~ 8.2% within 1 day storage. In another review by Halachmy and Mannheim (1992) recorded that modified atmosphere packaging (MAP) was not found to be necessary for mushrooms and could have a damaging effect causing anaerobic respiration as well as potential growth of anaerobic pathogens. Packaging mushrooms was essential for reducing transpiration and maintaining quality and therefore the correct water vapour transmission rate (WVTR) of the film is of great importance. The most important parameters for extending sheaf-life of fresh mushrooms were low temperature and proper internal relative humidity.

Sensory evaluation

Sensory evaluations were performed as earlier mentioned method. Scores were above the median value (4.5), which indicated moderate acceptability of the experimental mushrooms (Where…freez or ambient??). Overall acceptability scores for packaged halves ranged from 4.0 to 4.9, indicating suboptimum acceptability as those mushroom samples could be stored only for 16-18 hours or less than a day after packaging.

Conclusion

It can recommend that freshly harvested Oyster mushrooms can be kept at low temperature (5 ± 1^{O} C), if those are packaged in either polythene (0.75 mm), polypropylene (0.35mm) or polystyrene tray overwrapped with microfilm. The environment friendly, recyclable or bio-degradable (GRAS) packaging materials having an eye appeal should be encouraged.

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