International Journal of Horticultural Science and Technology
Vol. 7, No. 3; September 2020, pp 213-225
Print ISSN: 2322-1461 Online ISSN: 2588-3143
DOI: 10.22059/ijhst.2020.302076.365
Web Page: https:// ijhst.ut.ac.ir, Email: ijhst@ut.ac.ir

Effect of Low Temperature on Postharvest Behaviors of Oyster Mushroom *(Pleurotus spp.)*

Md. Saidee Rahman[1], Md. Kamrul Hassan[2], Fakhar Uddin Talukder[3*] and Md. Sohanur Rahman[3]

1. Scientific Officer, Rice Farming System Division, Bangladesh Rice Research Institute, Regional Station, Gopalgonj, Bangladesh.

2. Professor, Department of Horticulture, Bangladesh Agricultural University, Mymensingh – 2202, Bangladesh.

3. Scientific Officer, Pest Management Division, Bangladesh Jute Research Institute, Manik Mia Avenue, Dhaka-1207, Bangladesh.

(Received: 1 April 2020, Accepted: 16 June 2020)

Abstract
A large amount of oyster mushrooms is wasted every year due to post-harvest losses/decays. An experiment was conducted to observe the effect of low temperature to extend shelf life and nutritional quality of oyster mushroom. The experiment consisted of two treatments including: mushrooms stored at ambient (25 °C) temperature or stored at 3 °C temperature. The experiment was laid out in a Completely Randomized Design (CRD) with three replications. Parameters investigated were color, firmness, freshness, appearance, flavor, texture, moisture and dry matter contents, weight loss, protein content, disease incidence, disease severity and shelf life. Highest moisture contents (85.3%) and shelf life (11.92 days) were recorded in mushrooms exposed to low temperature, while the highest dry matter content (35.25%), weight loss (15.28%), protein content (24.64%) were detected in mushrooms exposed to ambient temperature and the lowest moisture content (64.75%), shelf life (3.33%) were observed in mushrooms exposed to ambient temperature. Lowest dry matter content (14.97%) and weight loss (4%) were recorded in low temperature-exposed mushrooms. At 3 °C, mushrooms had the best quality especially in relation to weight loss, disease incidence and severity, color, firmness, freshness, appearance, flavor, texture, and dry matter content compared to those exposed to ambient temperature. Storage at 3 °C ultimately resulted in prolonged shelf life.

Keywords: Low temperature, oyster mushroom, postharvest, Shelf life.

Introduction

Mushroom is fleshy, spore-bearing fruiting bodies of a fungus, typically produced above ground on the soil or on food sources. Mushrooms describe a variety of gilled fungi, with or without stems and also describe both the fleshy fruiting bodies of some Ascomycota and the woody or leathery fruiting bodies of some Basidiomycota, depending upon the context of the word. Moreover, it is soft delicate white fruiting bodies of the fleshy fungi. The microscopic fine thread-like

* Corresponding Authors, Email : fakharuddin155@gmail.com

bodies called mycelium is the real fungus which grows on the substratum or under the surface of soil. As it lacks in chlorophyll and hence require a substrate for its own absorptive nutrition. Enzymes producing fungi degrade complex organic matter and absorb the soluble substances (Chang and Miles, 2004).

Nowadays mushroom is cultivated all over the world. Mushrooms of the genus *Pleurotus* are commonly called 'Oyster mushrooms'. They are the second most popular mushrooms after button mushroom throughout the world (Atkins FC, 1966). Oyster mushrooms grow over a range of temperature of 15-30 °C and thus are suitable for cultivation under both temperate and tropical climatic conditions. In south Asian countries, oyster mushrooms are the most prospective mushrooms (Alam et al., 2007). The productions of four species of oyster mushroom including: *Pleurotus ostreatus*, *P. lorida*, *P. sajor-caju* and *Pleurotus sp.* occurs in every season (January to December) in south Asian countries. In the developed countries, mushrooms have become one of the most important of horticultural crops (Alam and Saboohi, 2016). There are about 5000 different species of mushrooms of which at least 1250 are reported to be edible (Gupta and Sarma, 2004). Grouped with vegetables, mushrooms provide many of the nutritional attribute that are commonly found in meat, beans or grains. Though neither meat nor vegetable, mushrooms are known as the "meat" of the vegetable world (Haas and James, 2009). Besides of its food value it is medicinally effective as antitumor, antibacterial, antiviral and hematological agents and in immune modulating treatments (Weiss, 1999) but also found to possess significant antioxidant capacity.

Nowadays mushrooms are becoming a popular food in daily meal because of their nutritious and medicinal values. Mushrooms are low in calories, fat-free, cholesterol-free, gluten-free, and very low in sodium, yet they provide important nutrients, including selenium, potassium (8%), riboflavin, niacin, vitamin D and some more. In general, the fruiting bodies of mushrooms contain about 56.8% carbohydrate, 25.0% protein, 5.7% fat and 12.5% ash on a dry weight basis (Ouzouni et al., 2009). Edible mushrooms are recommended by FAO as food, contributing to the protein nutrition for the people of the developing countries that largely depend on cereals. Importantly, edible mushrooms have gained popularity in modern medicine for their pharmaceutical properties (Kovfeen, 2004). Mori and colleagues (1986) observed that mushroom reduces serum cholesterol and high blood pressure. The tumor growth in mice was suppressed by 40-60% through oral administration of edible mushroom. The polysaccharides from oyster mushroom, *Agarics Bosporus*, are found to have anti-tumor activity. According to Chang (1992), the protein value of dried mushroom is in the range of 30-40% comprising all the essential amino acids. It is also rich in iron, copper, calcium, potassium, vitamin D and folic acid (Alam and Saboohi, 2001). Mushroom can be produced in large quantities in a short time, and it provides more protein per unit area than any other crops (Gupta, 1986).

Shelf life is mostly influenced by five events: light, gas, heat, and humidity transmissions and mechanical stresses. Mushroom contains high proportion of moisture 85 to 95% (Phathak and Yadav, 1998). Like all flashy fruits and vegetables, mushrooms are highly perishable because of their high moisture content and delicate nature, and cannot be stored for more than 24 hours at ambient temperature (Kaushal and Sharma, 1995). Fast spoilage of mushroom during post-harvest is one of the main problems in developing country due to their poor infrastructural facilities. Introduction of low temperature would further refine the modified atmosphere storage for extending the shelf life of mushroom for quite a longer period. Once the fruiting body of mushroom matures, the degradation process starts and it

becomes inconsumable after a while. The present study was carried out to investigate the effects of low temperatures on physico-chemical properties and shelf life of oyster mushroom.

Materials and methods

To study the effect of low temperature on physic-chemical changes and extension of shelf life and maintenance of nutritional quality of oyster mushrooms, the present experiments were carried out at the laboratories of the Department of Horticulture, Soil Science and Plant Pathology of Bangladesh Agricultural University, Mymensingh during the period from 10 February to 15 April, 2016.

Atmospheric conditions of storage room

The temperature and relative humidity of the storage room were recorded daily during the study period with a digital thermo hygrometer (THERMO, TFA, and Germany). In this study 25 $^{\circ}$C was considered as ambient temperature. The minimum and maximum relative humidity was 46 and 80%, respectively.

Experimental materials: Oyster mushroom (Pleurotus spp.)

The *Pleurotus* mushroom is generally referred as 'Oyster mushrooms'. It is a basidiomycete and belongs to the Genus *Pleurotus*. The fruit bodies of this mushroom are distinctly shell, fan or spatula shaped with different shades of white, cream, grey, yellow, pink or light brown depending on the species. The oyster mushroom is one of the most suitable fungal organisms for producing protein rich foods from various agro wastes without composting. Oyster Mushrooms were collected from Mushroom Development Institute at Savar, Dhaka.

Experimental factor and treatments

This experiment was single factor having two temperatures as indicated in the following

T_1=Mushroom stored at ambient (25 $^{\circ}$C) temperature

T_2=Mushroom stored at 3 $^{\circ}$C temperature

Experimental design

The experiment was laid out in the completely randomized design with three replications. 5 mushrooms were placed per each replication. A total of 30 of more or less similar shape and size and free of visible disease symptoms fruiting body of oyster mushroom were used as experimental materials. The postharvest treatments were assigned randomly to the selected fruiting body of oyster mushroom.

Methods of application of postharvest treatments

All of fruiting bodies of mushroom were kept on brown paper and divided into two equal parts containing 15 number of fruiting bodies. The postharvest treatments were randomly assigned to the selected fruiting bodies. At first, five fruiting bodies in each plot were taken. Here, three fruiting bodies were kept for different parameters studies and another two were used for destruction samples at 3rd and 6th days after storage respectively for analysis. Then the selected fruiting bodies were subjected to the following treatments as per the experimental design.

Observation

During the entire period of storage, the fruiting bodies used in the experiment were observed every day. Data were recorded from different postharvest treatments at an interval of 1 day during storage.

Measurements

(A). Physical parameters

1. Color

Days required to reach different stages of color during storage were determined objectively using numerical rating scale of 1-4, where 1 = Pure White, 2 = Slightly Brown, 3 = Brown, 4 = Black. Mushroom color has been usually measured using the L value of the Hunter scale (Jolivet et al.,

1998; Brennan et al., 2000; Cliffe-Byrnes and O'Beirne, 2007).

2. Firmness

Storing mushrooms at low temperature maintains firmness (Burton and Noble, 1993). Days required to reach different stages of firmness during storage and ripening were determined using numerical rating scale of 1-4, where 1 = Firm, 2 = Slightly Soft, 3 = Soft, 4 = Very Soft and totally unfit for consumption.

3. Freshness

Storing mushrooms at low temperature maintains freshness (Umiecka, 1986). Days required to reach different stages of freshness during storage and ripening were determined using numerical rating scale of ,1-4, where 1 = Excellent, 2 = Good, 3 = Fair, 4 = Poor.

4. Appearance

Days required to reach different stages of appearance during storage and ripening were determined using numerical rating scale of 1-4, where 1 =Excellent, 2 = Good, 3 = Fair, 4 = Poor.

5. Texture

Heat treatment like drying affects texture of various products like oyster mushroom (Kotwaliwale et al., 2007). Days required to reach different stages of shrinkage during storage and ripening were determined using numerical rating scale of 1-4, where 1 =Firm, 2 =Slightly Soft, 3 = Soft, 4 = Very Soft.

6. Flavor

Days required to reach different stages of flavor during storage were determined using numerical rating scale of 1-4 where, 1 =Excellent, 2 =Slightly Odor (Acceptable), 3 = Odor, 4 = Rotten.

7. Estimation of total weight loss

Storing mushrooms at low temperature reduces weight loss (Woznaik and Gapinski, 1996 c). Initially the fruiting bodies of each replication were weighed using an electrical balance and kept for storage. Percentage of total weight loss was calculated at 3rd and 6th days of storage using the following formula:

$$\text{Weight loss } (\%) = \frac{\text{IW} - \text{FW}}{\text{IW}} \times 100$$

where,

IW= Initial weights (g) of fruiting bodies and

FW= Final fruit weight (g) of fruiting bodies

8. Estimation of moisture content

The initial moisture content of mushroom was calculated by the AOAC method No. 934.06 (AOAC, 2000). Ten grams of fruit pulp was weighed in a porcelain crucible (which was previously cleaned, dried and weighed) from each treatment and replications. The crucible was placed in electric oven at 800 °C for 72 hours until the weight became constant. It was then cooled in desiccators and weighed again.

Percentage of moisture content was calculated by using the following formula:

$$\text{Moisture content } (\%) = \frac{\text{IW-FW}}{\text{IW}} \times 100$$

where,

IW= Initial fruit weights (g) of mushroom fruiting bodies and

FW= Final fruit weight (g) of mushroom fruiting bodies

9. Estimation of dry matter content

Percentage of dry matter content of the pulp was calculated from the data obtained during moisture estimation using the following formula:

Dry matter (%) = (100 - % moisture content)

(B). Chemical parameters

1. Total protein percentage

Chemical analysis was performed in the laboratory of the Department of Soil Science, Bangladesh Agricultural University, Mymensingh. The total protein was estimated using the modified micro-Kjeldahl method (AOAC, 1980). The principle of protein estimation is based on

estimating the nitrogen content of the material and then multiplying the nitrogen value by 6.25. This is referred to as crude protein content, since the non-protein nitrogen (NPN) present in the material was taken into consideration in the present investigation.

Kejldahl method depends on the fact that organic nitrogen, when digested with concentrated sulphuric acid is converted into ammonium sulphate. Ammonia liberated by making the solution alkaline is distilled into a known volume of standard boric acid, which is then back titrated. Reagents required include: (1) Kjel Tab. Catalyst mixture (potassium sulphate + selenium), (2) Concentrated sulphuric acid (H_2SO_4) solution, (3) 2% Boric acid (H_3B0_4) solution, (4) Hydrochloric acid (0.1N HC1) solution, (5) 40% sodium hydroxide solution (NaOH), (6) Mixed indicator (Methyl red and Methylene blue) and (7) Hydrogen peroxide (11202). 100 mg of dried ground fruiting body sample was taken in weighing paper and measured accurately. It was poured into a 75 mL clean Kjeldahl flask, to which 3 mL conc. H_2SO_4, 1 gel tab., 2 mL H_20_2 and 2-3 glass balls were added. The sample mixture was heated at 370 °C for 1 hr over a preheated heater. When the sample color became color less (white) then the digestion of the sample was completed. The digested sample was cooled at room temperature (25 °C) and diluted to 75 mL solution. 10 ml of the digested diluted sample solution was taken in a distillation apparatus with 10 mL 40% NaOH. The distillate (about 60 mL) was collected in a conical flask containing 10 mL 2% boric acid solution and 2 drops of mixed indicator (methyl red and methyl blue). The total distillate was collected and titrated with standardized HC1 solution (0.1N HC1). The amount of nitrogen was calculated according to the following equation:

$$\text{Nitrogen } \% = \frac{\text{Ts-Tb} \times \text{strength of HCL acid} \times 0.014 \times 7.5}{\text{weight of sample}} \times 100$$

where,

Ts= Titre value of the sample in mL

Tb = Titre value of the blank in mL

Strength of the HC1 acid = 0.1N

The % nitrogen of the sample was multiplied by 6.25 to obtain the total crude protein present in the sample. Methods described by Ranganna (1994) were taken into consideration for the protein content determination.

(C). Microbial characters

1. Assessment of disease incidence

The fruiting bodies were critically examined for the appearance of rot. The incidence of rot was recorded every day. The first count was made at the first day of the storage. The rots on fruiting body were identified by the visual comparison with those of the symptoms (cottony growth, soft rot and decay) already published. The incidence of fruiting body rot was calculated by using following formula:

$$\text{Diseases incidence} = \frac{\text{Number of Infected Fruiting Bodies}}{\text{Total Number of Fruiting Bodies Under Study}} \times 100$$

(D). Estimation of shelf life

Shelf life of mushroom fruiting bodies as influenced by different postharvest storage treatments was calculated by counting the days till retaining optimum marketing and eating qualities.

Statistical analysis

The collected data on various parameters were statistically analyzed using MSTAT statistical package. The mean of different parameters was compared by DMRT (Duncans' Multiple Range Test) as described by Gomez and Gomez, 1984. The significance of difference between the pairs of means was compared by least significant difference (LSD) test at the 1% and 5% levels of probability.

Results

The data obtained from different characteristics of physical, chemical, microbial properties and shelf life of oyster

mushroom were recorded during storage period at ambient and low temperatures.

(A). Physical changes

1. Color

Color is one of the important characters for determination of quality of edible mushroom. During postharvest life the color is changed from pure white to black. Significant variation was found in respect of color of mushroom fruiting bodies at 2 to 7 days after storage (DAS). Higher color score (3.59) was observed at ambient temperature at 7 DAS and lower color score (1.92) was observed at low temperature (7 DAS) (Table 1).

2. Firmness

Firmness is one of the important criteria for determination of quality of edible mushroom. During postharvest the firmness changes from hard to soft state. Significant variation was found in respect of firmness of mushroom fruiting bodies during 2 to 7 DAS. The higher firmness score (3.25) was observed at ambient temperature and lowest firmness score (1.83) was observed at low temperature (T_2) (Table 2).

3. Freshness

Variation among the treatment means in respect of freshness of mushroom was significant at 2 to 7 days after storage due to exposure to ambient and low temperatures. The minimum freshness score (1.83) was observed in fruits kept in low temperature (T_2) at 7^{th} DAS. The maximum freshness score (3.75) was observed in mushroom fruiting bodies kept in ambient temperature (T_1) at 7^{th} DAS (Table 3).

Table 1. Effect of temperature during storage on colour of oyster mushroom

Treatment	Colour at different days after storage (DAS)						
	D_1	D_2	D_3	D_4	D_5	D_6	D_7
T_1	1.00	1.75	1.92	2.42	2.84	3.25	3.59
T_2	1.00	1.00	1.08	1.42	1.58	1.75	1.92
$LSD_{0.05}$		0.067	0.131	0.157	0.217	0.278	0.295
LSD0.01		0.092	0.181	0.217	0.299	0.383	0.406
Level of sign.	ND	3.375**	4.158**	5.970**	9.413**	13.65**	16.683**

** = Significant at 1% level of probability, ND= Statistical analysis not done

T_1 = Ambient temperature, T_2 = Low temperature (3^0C)

1 =Pure white, 2 =Slightly brown, 3 = Brown, 4 = black

Table 2. Effect of temperature during storage on firmness of oyster mushroom

Treatment	Firmness at different days after storage (DAS)						
	D_1	D_2	D_3	D_4	D_5	D_6	D_7
T_1	1.00	1.75	1.92	2.25	2.50	2.84	3.25
T_2	1.00	1.00	1.42	1.50	1.75	1.75	1.83
$LSD_{0.05}$		0.128	0.164	0.186	0.194	0.232	0.186
$LSD_{0.01}$		0.177	0.226	0.256	0.267	0.320	0.256
Level of significant	ND	3.375**	1.485**	3.353**	3.375**	7.063**	12.01**

** = Significant at 1% level of probability, ND= Statistical analysis not done

1 =Firm, 2 =slightly soft, 3 =Soft, 4 = Very Soft and totally unfit for consumption.

T_1 = Ambient temperature, T_2 = Low temperature (3^0C)

Table 3. Effect of temperature during storage on freshness of oyster mushroom

Treatment	Freshness at different days after storage (DAS)						
	D_1	D_2	D_3	D_4	D_5	D_6	D_7
T_1	1.00	1.75	2.00	2.67	3.08	3.50	3.75
T_2	1.00	1.00	1.08	1.42	1.58	1.75	1.83
$LSD_{0.05}$		0.131	0.155	0.201	0.224	0.294	0.278
$LSD_{0.01}$		0.181	0.213	0.277	0.309	0.404	0.383
Level of significant	ND	3.37**	5.051**	9.375**	13.500**	18.428**	22.061**

** = Significant at 1% level of probability ND= Statistical not done 1 = Excellent,

2 = Good, 3 = Fair, 4 = Poor, T_1 = Ambient temperature, T_2 = Low temperature (3^0C)

4. Appearance

The highest appearance score (3.67) was observed at ambient temperature (T_1) at 7 DAS and the lowest score (1.75) was observed at low temperature (T_2) at 7 the same time (Table 4).

5. Flavour

Temperature had significant effects on flavour of oyster mushroom during 2 to 7 DAS. The highest flavour score (3.42) was recorded at ambient temperature (T_1) at 7 DAS and the lowest score (1.83) was observed at low temperature (T_2) at 7 DAS (Table 5).

6. Texture

Texture is one of the important criteria for determination of edible mushroom quality. The texture changes from firm to very soft during post-harvest. In this present investigation a significant effect of temperature was found on texture score of mushroom during storage. As can be seen in the Table 4, it was detected that the texture changes occurred at faster rate (3.50 DAS) in ambient temperature whereas the rates were slower in those mushroom held in low temperature (Table 6).

Table 4. Effect of temperature during storage on appearance of oyster mushroom

Treatment	Appearance at different days after storage (DAS)						
	D_1	D_2	D_3	D_4	D_5	D_6	D_7
T_1	1.00	1.58	2.00	2.67	3.00	3.34	3.67
T_2	1.00	1.00	1.00	1.17	1.42	1.58	1.75
$LSD_{0.05}$		0.095	0.137	0.155	0.164	0.188	0.221
$LSD_{0.01}$		0.131	0.189	0.213	0.226	0.259	0.304
Level of significant	ND	2.04**	3.24**	3.60**	4.28**	5.43**	6.61**

** = Significant at 1% level of probability ND= Statistical analysis is not done 1 = Excellent, 2 = Good, 3 = Fair, 4 = Poor T_1 = Ambient temperature, T_2 = Low temperature (3^0C).

Table 5. Effect of temperature during storage on flavour of oyster mushroom

Treatment	Flavour at different days after storage (DAS)						
	D_1	D_2	D_3	D_4	D_5	D_6	D_7
T_1	1.00	1.67	2.09	2.42	2.75	3.25	3.42
T_2	1.00	1.00	1.00	1.17	1.50	1.75	1.83
$LSD_{0.05}$		0.095	0.155	0.166	0.188	0.186	0.246
$LSD_{0.01}$		0.131	0.213	0.229	0.259	0.256	0.339
Level of significant	ND	2.673**	7.06**	9.33**	9.375**	13.50**	15.07**

** = Significant at 1% level of probability, ND= Statistical not done

T_1 =Ambient temperature, T_2 = Low temperature (3^0C). 1 = Excellent, 2 = Good, 3 = Fair, 4 = Poor

Table 6. Effect of temperature during storage on texture of oyster mushroom

Treatment	Texture at different days after storage (DAS)						
	D_1	D_2	D_3	D_4	D_5	D_6	D_7
T_1	1.00	1.83	2.00	2.42	2.67	3.00	3.50
T_2	1.00	1.00	1.17	1.33	1.67	2.00	2.17
$LSD_{0.05}$		0.155	0.216	0.171	0.099	0.355	0.310
$LSD_{0.01}$		0.213	0.297	0.235	0.136	0.489	0.427
Level of significant	ND	4.158**	4.16**	7.096**	6.030**	6.000**	10.693**

** = Significant at 1% level of probability, T_1 = Ambient temperature, T_2 = Low temperature (3^0C), 1 =Firm, 2 =Slightly Soft, 3 = Soft, 4 = Very Soft, ND=statistical analysis is not done

7. Moisture content

Significant variations were found in moisture content at 3 and 6 DAS due to different temperature. Moisture content of the mushroom was the highest (85.03%) in those held in low temperature (T_2) at 3 DAS. On the other hand, the lowest moisture content (64.75%) was found at ambient temperature (T_1) at 6 DAS (Table 7).

8. Dry matter content

Dry matter content varied significantly due to the effect of different temperatures at 3 and 6 DAS. It was observed that the percentage of dry matter content increased as a result of longer storage duration. The highest dry matter content (35.25%) was found in mushroom stored at ambient temperature (T_1) and the lowest dry matter content (14.97%) was found at low temperature (T_2) at 3 DAS (Table 8).

9. Weight loss

Highly significant effects, on percentage of weight loss of mushroom were observed due to the exposure to different temperatures 3 and 6 DAS. Significantly, the maximum (15.28%) weight loss was found at ambient temperature (T_1) at 6 DAS and the minimum (4.00%) weight loss was recorded at low temperature (T_2) 3 DAS (Fig. 1).

Table 7. Effect of temperature on moisture content (%) and dry matter content of oyster mushroom at 3 and 6 days after storage

Treatment	Moisture content (%) at 3 and 6 days after storage	
	D_3	D_6
T_1	76.79	64.75
T_2	85.03	75.21
$LSD_{0.05}$	0.325	0.317
$LSD_{0.01}$	0.448	0.437
Level of significant	407.880**	656.470**

** = Significant at 1% level of probability, T_1 = Ambient temperature, T_2 = Low temperature (3^0C)

Table 8. Effect of temperature on dry matter content of oyster mushroom at 3 and 6 days after storage

Treatment	(%) Dry matter content at different days after storage	
	D_3	D_6
T_1	23.21	35.25
T_2	14.97	24.79
$LSD_{0.05}$	0.923	0.620
$LSD_{0.01}$	1.272	0.854
Level of significant	407.880**	656.470**

** = Significant at 1% level of probability, T_1 = Ambient temperature, T_2 = Low temperature (3^0C)

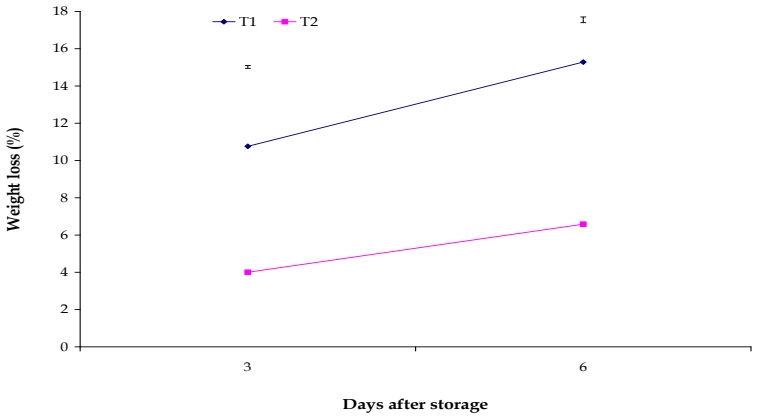

Fig. 1. Effect of temperature on total weight loss of mushroom (T_1 = Ambient temperature, T_2 = 3 °C temperature)

(B). Chemical characters of mushroom during storage

1. Total protein content

The total protein content of mushroom fruiting bodies was significantly influenced by different temperatures at 3 and 6 DAS. It was observed that the percentage of protein content decreased as a result of longer storage duration (Table 9).

(C). Microbial properties

1. Disease incidence

Percentage of disease incidence varied significantly due to the effect of different temperature at 3 to 6 days after storage. Generally, the level of disease incidence was gradually increased as a result of longer storage duration. The disease incidence rate is slower in low temperature (3 °C) compared to ambient temperature (Fig. 2).

(D). Shelf life

Shelf life of mushroom was significantly affected by different temperatures. Results revealed that the longest shelf life (11.92 days) belonged to mushrooms held in low temperature (T_2) and the shortest shelf life (5.83 days) obtained from mushroom held in ambient temperature (T_1) (Fig. 3).

Table 9. Effect of temperature on protein content of mushroom at 3 and 6 days after storage

Treatment	Protein content (%)	
	D_3	D_6
T_1	24.64	15.10
T_2	22.70	15.13
$LSD_{0.05}$	0.316	0.617
$LSD_{0.01}$	0.435	0.851
Level of significant	22.640**	0.005NS

** = Significant at 1% level of probability, NS = Not significant

T_1 = Ambient temperature, T_2 = Low temperature (3^0C)

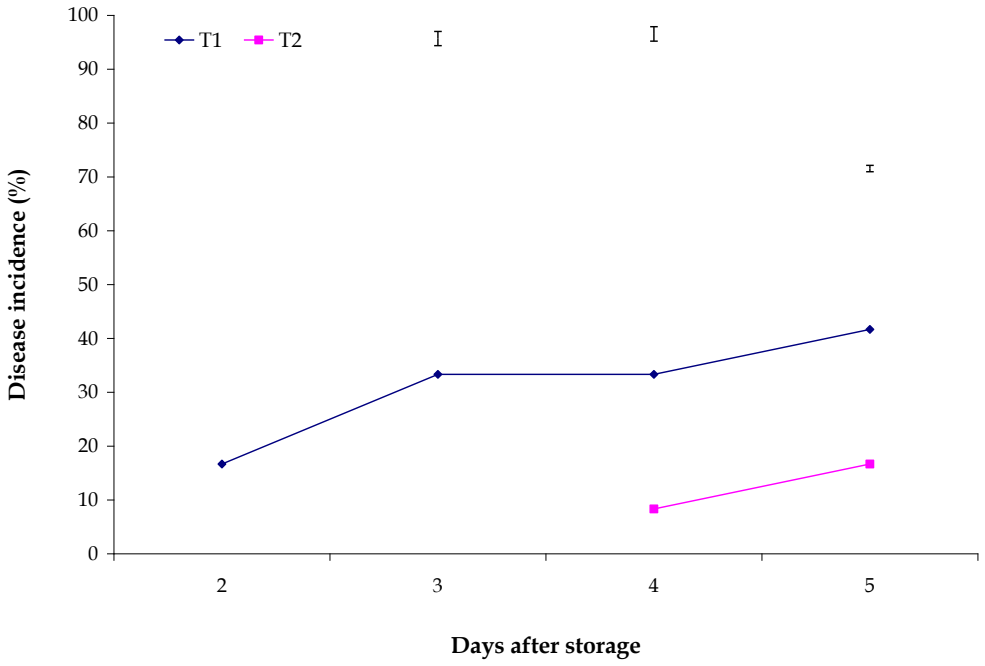

Fig. 2. Effect of temperature on disease incidence in oyster mushroom (T_1 = Ambient temperature, T_2 = 3 °C temperature)

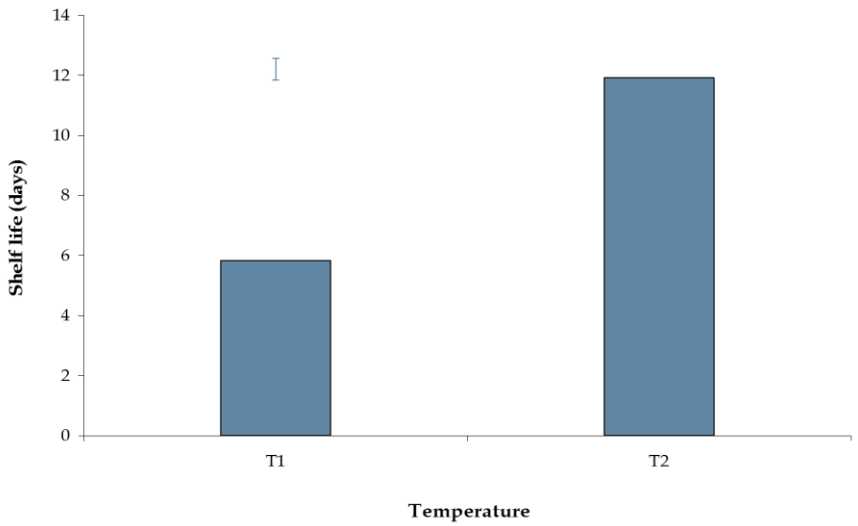

Fig. 3. Effect of temperature on shelf life (days) of oyster mushroom (T_1 = Ambient temperature, T_2 = 3 °C temperature)

Discussion

Color is one of the most important criteria of edible mushroom. The color scores increased as the duration of storage progressed at ambient temperature (T_1) than the color of those exposed to low temperature (3 °C) (T_2). The increase in color score during storage might be due to series of physico-chemical changes such as rapid respiration rate, microbial attack of the fruiting bodies, enzymatic oxidation and degradation. It has been known that high temperature accelerates and low temperature decelerate respiration. For this reason, mushroom kept under low temperature had less color change but those in ambient temperature had rapid change in color. Mohapatra et al. (2008) reported that a steady increase in the color pattern was evident as storage time progressed. The color of mushrooms are predominantly white when they are initially purchased, but as the storage days progressed the discoloration on their cap intensified due to enzymatic reactions.

Hyphae of white strains are virtually colorless and translucent but they contain enzymes which react with the substrates in the cell content to form pigmented compounds under certain conditions, which result in browning of mushrooms during postharvest (Burton, 1986).

The firmness of mushrooms changed due to change in their chemical properties. It was observed that the firmness changes occurred at faster rate in ambient temperature (T_1) at 7 DAS (became very soft), whereas the rate was slower in case of those fruiting bodies kept in low temperature (T_2), which were slightly soft mushroom. According to Alikhani-Koupaei et al. (2014), firmness best describes as changes in metabolic activity and water content in the mushroom. Most satisfactory result was obtained under low temperature due to slower rate of change in chemical and microbial activities. This result is similar to those reported by Alikhani-Koupaei et al. (2014).

Freshness changes occurred at faster rate in ambient temperature (T_1) within 7 days, whereas the rate was slower in case of those fruiting bodies kept in low (3 °C) temperature (T_2). The present result was somehow similar to the findings of Choi and Kim, (2003) who reported that film packaging prevented the deterioration of mushroom freshness and texture during storage. The degradation of freshness over time would probably due to the increase in

transpiration, dehydration, respiration and disease attack.

The appearance is depended on many factors (such as moisture content, vitamin and mineral content, chemical properties and microbial properties). Mushroom stored at 3 °C, the appearance is preserved in good condition up to 7 days. Under low temperature the respiration rate is slower and high temperature causes higher rate of respiration. Decreases in transpiration can result in maintenance of appearance in mushrooms held under cold treatment. Gormley et al. (1967) reported that wrinkling and brown patches on surfaces of uncovered mushrooms are due to excessive loss of moisture.

Flavour is depended on many factors (such as microbial growth, chemical properties and vitamin). After harvesting, mushroom had a specific excellent flavour. During storage the flavor was changed. Low temperature is one of the major causes for long time of flavor preservation. Mushroom held in ambient temperature preserved their flavour for only 2 days. Beit-Halachmy et al. (1992) found out that unpleasant odors can be detected in mushrooms packaged with non-perforated film, although they disappeared after a short period. These unpleasant odors were also found under 1.5–2% O_2 levels.

Texture is one of the important characters for determination of mushroom quality. The texture changes from firm to very soft during post-harvest. After harvesting, the texture changes due to rapid respiration, high temperature and rapid microbial growth. Mushroom stored at 3 °C had lower rate of respiration and transpiration. Lopez-Briones et al. (1992) reported that texture losses decrease when the carbon dioxide concentration increase, which is in line with the results obtained in the present study.

Generally, the moisture content decreases as a result of prolong storage duration. Narayana et al. (1993) reported that polyethylene wrapping reduces the rate of respiration by creating modified atmosphere around the vegetable and reduces moisture loss compare to than normal condition. As for dry matter content it was observed that the percentage of dry matter content increased with prolong storage duration. The dry content increased due to losses of moisture content.

For maintaining the quality of mushroom the weight loss changes is an important indicator. So, due to high rate of respiration and temperature the weight loss of mushroom enhanced. Keditsu et al. (2003) also reported that the higher weight loss occurs in unwrapped fruits than the packed ones. Because of higher temperature and respiration rate inside the polypropylene bag rapid weight loss is the consequence.

Protein content of mushrooms decreased gradually during storage. Lopez et al. (1993) reported that protein reduced throughout the storage period from 20.28% to 18.54% at modified atmospheric condition.

The disease incidence increased by longer duration of storage of oyster mushrooms. The rate of disease incidence was higher in ambient temperature. The rate of disease incidence was lower in the mushroom kept under low temperature**.** Due to slower rate of respiration under low temperature, low attack of different pathogen detected in mushroom fruiting bodies. However, the main causes of disease incidence are high temperature and presence of pathogen. Mushrooms exposed to low temperature had lower disease incidence as compared to those exposed to ambient temperature. Wet bubble or Mycogone, dry bubble or Verticillium, cobweb or Dactylium are the fungal diseases and blotch/bacterial blotch or brown blotch, ginger blotch and mummy diseases are the bacterial diseases of mushroom (Fletcher and Gaze, 2008).

The extension of shelf life of mushroom has been one of the most important concerns in postharvest industry of mushroom. Effects of low temperature was

also significant in extending shelf life of mushroom. The longest shelf life was obtained in mushroom stored at 3 °C, which was possibly due to the reduced rate of physico-chemical changes, reduced weight loss and minimal disease severity. Burton and Twyning, (1989) reported that mushroom has a short shelf-life of 1–3 days at ambient temperature and 8–10 days under refrigeration conditions. They are highly perishable due to their thin and porous epidermal structure resulting in high respiration rates, which induce its deterioration immediately after harvest. Villaescusa et al. (2003) reported that fresh mushrooms are a known perishable commodity, with a short shelf life of 1-3 days when compared to most vegetables at ambient temperature, due to high respiration rate and low ethylene production. They have no cuticle to protect them from physical or microbial changes or water loss.

Conclusion

A very few research works have been done on prolonging the shelf life of mushroom. But there are few reports related to the oyster mushroom. Therefore, this research was conducted to investigate the effect of low temperature on color, firmness, freshness, texture, appearance, flavour, total weight loss, moisture content, dry matter content, total protein percentage, disease incidence, disease severity and shelf life of oyster mushroom. Mushroom stored at 3 °C temperature kept their quality better with longer shelf life than those exposed to ambient temperature. Therefore, the results of this experiment will be useful for long term storage, quality control, transportation and marketing, and will also be beneficial for both the growers and consumers. The nutritional qualities and taste test required to be carried out to explicitly recommend this technology.

Acknowledgement

Authors are grateful to the ministry of science and technology, Bangladesh for providing financial support to conduct this research work.

Conflict of Interest

Authors have no conflict of interest to report.

References

1. Alam N, Khan A, Hossain M.S, Amin S.M.R, Khan L.A. 2007. Nutritional analysis of dietary mushroom *Pleurotus florida* Eger and *Pleurotus sajor-caju* (Fr.) Singer. Bangladesh Journal of Mushroom (**1)** 1-7.
2. Alam SM, Saboohi R. 2001. Importance of mushroom. WWW.mush-world.com.htm
3. Alam SM, Saboohi R. 2016. Importance of mushroom. [Online] Available at: www.mush-worldcom.htm.
4. Alikhani-Koupaei M, Mazlumzadeh M, Sharifani M, Adibian M. 2014. Enhancing stability of essential oils by microencapsulation for preservation of button mushroom during postharvest. Journal of Food Science Nutrient, 2(5), 526–533. https:// doi.org/10.1002/fsn3.129
5. AOAC (Association of Official Analytical Chemists). 1980. Official methods of analysis (13th Edn), Washington D.C., USA.
6. AOAC, 2000. Fruits and fruit products. In: Official Methods of AOAC (Ed. W. Horwitz), Gaithersburg, MD, USA.
7. Atkins F.C. 1966: Mushroom growing today, Macmillan. New York
8. Beit-Halachmy I, Mannheim C.H. 1992. Modified atmosphere packaging beneficial for fresh mushrooms. Lebensm.- Wiss. Technol. 25 426-432.
9. Brennan M, Le Port G, Gormley R. 2000. Post-harvest treatment with citric acid or hydrogen peroxide to extend the shelf life of fresh sliced mushrooms. Leben Wiseen Tech 33:285–9.
10. Burton K.S, Twyning R.V. 1989. Extending mushroom storage life by combining modified atmosphere packaging and cooling. Acta. Horticulture 258 565-571.
11. Burton K.S, Noble R. 1993. The influence of flush number, bruising and storage temperature on mushroom quality. Postharvest Biology and Technology. 3(1), 39-47.
12. Burton K.S. 1986. Quality investigations into mushroom browning. Mushroom Journal. 158: 68-70.

13. Chang S, Miles P.G. 2004. Mushrooms, cultivation, nutritional value, medicinal effect, and environmental impact, crc press, America.

14. Chang S.T. 1992. Cultivation of Volvariella Mushrooms in Southeast Asia, In: Trop. Mushrooms; Biological Nature and Cultivation Methods. The Chinese Univ. Press, Hong Kong. pp. 135-156.

15. Choi M.H, Kim G.H. 2003. Quality changes in Pleurotus ostereatus during modified atmosphere storage as affected by temperatures and packaging material. Acta Horticulture 628(1) 357-362.

16. Cliffe-Byrnes V, O'Beirne D. 2007. Effects of gas atmosphere and temperature on the respiration rates of whole and sliced mushrooms (Agaricus bisporus): implications for film permeability in modified atmosphere packages. Journal of food science72:197– 204.

17. Fletcher J.T, Gaze R.H. 2008. Mushroom Pest and Disease Control, A Colour Handbook. Manson Publishing, Boston, (2008).

18. Gomez K.A, Gomez A.A. 1984: Statistical Procedures for Agricultural Research. John Wiley and Sons Inc., New York.

19. Gormley T.R, MacCanna C. (1967), Prepackaging and shelf life of mushrooms. Irish Journal of Agricaltural Research 6(2) 255-265

20. Gupta. 1986. Mushroom cultivation on short time than any other vegetable.

21. Gupta M, Sarma R. 2004: Nutrient composition of oyster mushroom grown on different substrates. Journal of food science and technology 41(5) 584-586.

22. Haas E.M, James P. 2009: Nutritional importance of edible mushroom. Journal of Indian Mushroom Science (**7**) 22-24.

23. Jolivet S, Arpin N, Wicher H.J, Pellon G. 1998. Agaricus bisporus browning: a review. Mycol Res 102:1459–83.

24. Kaushal B.B, Sharma K.D. 1995: Post-Harvest Technology of Mushroom. In: Advances in Horticulture (Mushroom-volume 13). Eds. Chadha KL and Sharma SR, Ma]hotra Publishing House. New Delhi. pp. 553-566.

25. Keditsu R, Sema A, Maiti C.S. 2003. Effect of modified packaging and low temperature on post-harvest life of 'Khasi' Mandarin. Journal of Food Science and Technology, 40(6) 646-651.

26. Kotwaliwale N, Bakane P, Verma A. 2007. Changes in textural and optical properties of oyster mushroom during hot air drying. Journal of Food Engineering 78(4), 1207-1211.

27. Kovfeen C. 2004. Economic Times. www.techno-preneur.net.

28. Lopez- Briones G, Varoguaux P, Chambroy Y, Bouquant J, Bureau G, Paseat B. 1992. Storage of common mushroom under controlled atmosphere. International journal of food science & technology. 27:493-503.

29. Lopez-Briones G, Varoquaux P, Bureau G, Pascat B. 1993. Modified atmosphere packaging of common mushroom. International Journal Food Science and Technology 28 57–68.

30. Mohapatra D, Frias JM, Oliveira FAR, Bira ZM, Kerry J. 2008: Development and validation of a model to predict enzymatic activity during storage of cultivated mushrooms (*Agaricus bisporus spp*.). Journal of Food Engineering, 86 39-48.

31. Mori K, James R, Trokker H. 1986: Medicinal value of oyster mushroom. Journal of Food Science 16(2) 33-34.

32. Narayana S.K, Pal H.S. 1993: Use of high molecular weight-high density polyethylene film in transit of mango. Acta Horticulturae 291 489-492.

33. Ouzouni V, Louris E, Zakker R. 2009. Nutrional composition of oyster mushroom.

34. Pathak V.N, Yadav N, Gaur M. 1998. Mushroom production and processing technology. Agrobios. (India), Jodhpur, New Delhi 343, pp.13-45.

35. Ranganna S. 1994. Handbook of Analysis and Quality Control of Fruit and Vegetable Products. Tata-McGraw Hill Press, New Delhi, India.

36. Umiecka L. 1986. Effect of material quality, treatment, package methods and storage conditions on export quality of several mushroom races. Biul. Warz. 29, 271-292.

37. Villaescusa R, Gill M.I. 2003. Quality Improvement of Pleurotus mushrooms by modified atmosphere packaging and moisture absorbers. Journal of postharvest and Biotechnology 28 (1) 169-179.

38. Weiss 1999: Medicinal value of edible mushroom. Journal of postharvest and Biotechnology 2 (1) 16-17.

39. Woznaik W, Gapinski M. 1996 c. The influence of fresh mushroom Somycel 516 storing temperature on weight changes. Prob. Hig. 53, 152-156