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Studies on Short-term Storage of Paddy Straw Mushroom (Volvariella volvacea) in Zero Energy Cool Chamber during Summer Period of Coastal Area

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Abstract: *Paddy straw mushroom is highly perishable and need immediate storage in a favourable environment just after harvest for maintaining its freshness and marketability. Its importance is now-a-days gaining momentum among the consumers because of its nutritive and medicinal attributes, besides unique flavour and texture. However, majority of farmers is not interested to grow paddy straw mushroom due to its high perishability and lack of proper storage facilities which force them to sell the harvested material immediately at a lower price, resulting ultimately the reduced net profit to the growers. An attempt has therefore been made in this paper to study the feasibility of using a low cost and very low energy consuming storage device for short-term storage of paddy straw mushroom for about two days and to encourage the farmers to go for cultivating the same in a small scale mostly in their back yard for achieving nutritional and livelihood security. One such storage device used for the present study is zero energy cool chamber (ZECC), developed at Indian Agricultural Research Institute, New Delhi. Zero energy cool chamber for this study was modified by incorporating a gravity fed micro-dripper watering system for uniform and continuous wetting of sand bed. A zero energy cool chamber of 100 kg capacity constructed in coastal area of Odisha i.e. at Bhubaneswar, was used to study the storability of most prevailing paddy straw mushroom in various cooling chambers during April-May 2016. It was found that in the summer period, the paddy straw mushroom could be stored in ZECC for 30 hrs in the marketable form and for 36 hours in consumable form, 12 hrs in room condition and 72 hrs in domestic refrigerator when the prevailing ambient air temperatures and humidity were in the range of 30-42 ^{0}C and 40-68 % respectively.*

Key Words: *Paddy straw mushroom, Zero energy cool chamber, Micro-dripper, Evaporative cooling, Shelf-life.*

INTRODUCTION

Paddy straw mushroom with increasing recognition of its value in the human diet is now-a-days gaining commercial importance in the agricultural sector. Mushroom farming is becoming successful because of its very low inputs. In Odisha, mushroom cultivation is highly rewarding owing to the prevailing climatic conditions (Mohapatra, 2011). The technology profitably is feasible in areas where land is a limiting factor and agricultural residues are abundantly available. Paddy straw mushroom is a popular variety among people because of its distinct flavor, pleasant tastes, higher protein content and shorter cropping duration compared to other cultivated mushrooms (Ahlawat and Tewari, 2007). The materials for paddy straw mushroom are also available freely and therefore, this cultivation is ideal in rural area where paddy straw is abundantly available after each paddy harvest and it can provide additional income. The fast growing nature, easy cultivation technology and great acceptability at consumers' level further make this mushroom an important species among the cultivated edible mushrooms. The high temperature

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requirement for its cultivation also makes it a good choice for adoption in round the year growing of mushrooms. However, farmers are reluctant to cultivate mushrooms because of their high perishability and difficulties in controlling environmental factors such as temperature and relative humidity for short term storage resulting ultimately in reduced net profit to the growers.

Post harvest losses are very high in most of the horticultural commodities and it may be one of the highest in mushrooms. Mushrooms even after harvesting continue to grow, respire, mature and senesce resulting in weight loss, veil-opening, browning, wilting and finally leading to spoilage. Almost all the mushrooms have very short shelf-life but the paddy straw mushroom has the shortest (about 12 hours at the ambient) and milky has very good shelf-life (3-5 days) if microbial spoilage is taken care of (Mohapatra et al 2010). Utmost post harvest care of mushrooms is therefore needed not only for the fresh market but also for the processing of the same for value addition purposes.

The paddy straw mushroom generally gets deteriorated at a faster rate and need to be properly stored in order to extend its shelf life. It gets deteriorated even after 5-6 hours of harvesting due to harsh climatic conditions (Mohapatra *et al.* 2011). Proper storage means controlling both the temperature and relative humidity of the storage area. Reducing temperature and increasing humidity inside the stored chamber are required to maintain freshness and to enhance shelf-life. The recommended storage temperature and humidity for mushroom are about 10-15 ^{0}C and 50-60% respectively to attain their shelf-life of around 2-3 days (Ahlawat and Tewari, 2007). Establishment of a cold chain facility is though considered ideal for storage of horticultural produces, it would take a long way to establish such a system in our country, to the extent of benefitting even the small and marginal farmers, scattered in areas which are far off and not well connected to the major markets. Farmers and traders still practice their age-old storage methods leading to large-scale wastage during storage and transportation (Lata and Singh 2013). The problem is further made complex with prevailing energy crisis and energy cost for mechanical refrigeration system. Considering the present circumstances, development and popularization of any storage technology which is cheaper and does not depend on non renewable energy sources and high technologies, could largely benefit the small and marginal farmers in on-farm storage of their produce for a shorter period so that they could accumulate their harvested produce over a few days and take them to the market for getting a reasonable price.

Hence, the essence of storage is of great importance because not all the harvested paddy straw mushroom in general will be used immediately after their harvest. Measures for safe storage before it exceeds its shelf life are also highly necessary. Most of the farmers are not able to afford the cost of purchasing high-tech storage equipment for their harvested crops. Evaporative cooling has been found to be an effective and economical means of reducing temperatures and increasing humidity in an enclosure where the humidity is comparatively low (Jain 2007; Jha 2008; Jadhav *et al.,* 2010). Minimizing deteriorative reactions in horticultural produces enhances their shelf lives, implying that the produce will be available for longer periods; this would reduce fluctuation in market supply and prices. Evaporative cooler works on the principle of cooling resulting from evaporation of water from the surface of the structure. The cooling achieved by this device also results in high relative humidity of the air in the cooling chamber from which the evaporation takes place relative to ambient air (ASHRAE 2003). The atmosphere in the chamber thus becomes more conducive for storage of produces. Therefore, it is required to develop and popularize a low cost, less energy consuming and environment friendly cool chamber which would not only be affordable for resource poor farmers but also safe storage for a short period, resulting into a prospect of getting remunerative price of the produce. The evaporative cooling systems have prospect for use for short term storage of horticultural produces after harvesting (Libertya *et al.,* 2013). It reduces the storage temperature and also increases the relative humidity within the optimum level of the storage thereby helps in keeping them fresh.

In order to overcome the problem of on-farm storage, low cost environment friendly Pusa Zero Energy Cool Chambers have been developed (Roy and Pal 1991). The Zero Energy Cool Chamber was initially developed by Dr. S.K. Roy during 1980's at the Indian Agricultural Research Institute, Pusa, New Delhi and has been field tested and redesigned over the past few years to improve its function. Though this technology of on-farm storage of fruits and vegetables for shorter periods had been developed long back, the efforts to popularize this technology are now gaining momentum because of today's increasing post harvest losses, rising environmental concern and growing cost of power. This is almost similar to earthen pots widely used to cool water. Transfer of heat due to evaporation of water from the surface of the cooling vessel ultimately leads to cooling the atmosphere within the vessel. The water contained in the sand between the two brick walls evaporates towards the outer surface of the outer wall, where the dry outside air is circulating. By virtue of the laws of thermodynamics, the evaporation process automatically causes a drop in temperature of several degrees, cooling the inner container and the horticultural produces inside (Mordi and Olorunda 2003). Hence, looking towards health, employment and income of small and marginal farmers through cultivation of remunerative horticultural produces in a small scale round the year in their unutilized back yard and for their short term storage to maintain freshness and nutritive values resulting into a good market value, an attempt has been made to study the feasibility of short-term storage of paddy straw mushroom in a low cost zero energy cool chamber for selling the product in the marketable form for maintaining its economic viability and livelihood security. The importance of this low cost cooling technology lies on the fact that it does not require any electricity or power to operate and all the materials required to construct the cool chamber are available easily at cheaper cost. Even an unskilled person can install it at any site as it does not involve any specialized skill. Most of the raw materials used in cool chamber are also reusable. Zero energy cool chamber can retain the freshness of the fruits and vegetables for a short period (Olosunde 2006). Small farmers can easily construct these chambers nearer to their houses or fields in order to store their harvested produce. In this way, the farmers can store their produce for few days and send the bulk of the commodity to the whole sale market so that they will not be forced to make any distress sale in the local market. The involvement of middle men in making this distress sale increases the price of horticultural produces by 60-100 per cent in retail outlets compared to the growing areas (Anon, 2013). The cool chamber can reduce the temperature by few degrees and maintain a high relative humidity compared to ambience, thereby helping in enhancing the freshness of the produce (Rayguru *et al.,* 2010; Islam and Morimoto 2012). Keeping this in view, the present study is undertaken to evaluate the efficacy of IARI design Zero Energy Cool Chamber with a modification of using gravity fed micro dripper for uniform and continuous wetting of sand bed for effective evaporative cooling in enhancing the shelf-life of paddy straw mushroom under coastal conditions.

The objectives of the present study are therefore to study the quality and shelf-life of paddy straw mushroom stored in zero energy cool chamber, to compare its storability in domestic refrigerator and in room condition and to study the economics of using a small capacity (100 kg) zero energy cool chamber.

MATERIALS AND METHODS

An experiment was conducted during the year 2016 to evaluate the efficacy of zero energy cool chamber on the storability of paddy straw mushroom. This paddy straw mushroom was grown in 15 m^2 (160 sq. feet) area in the Mushroom Research Centre of Orissa University of Agriculture and Technology (OUAT) from March-April 2016. The zero energy cool chamber (fig. 1) has been constructed in the premises of College of Agricultural Engineering and Technology, OUAT, Bhubaneswar, which is coming under warm and humid climatic region and in the coastal belt of Odisha. The quality of the stored paddy straw mushroom with respect to physiological weight loss and rotten percentage has been studied in zero energy cool chamber, room condition and domestic refrigerator during peak

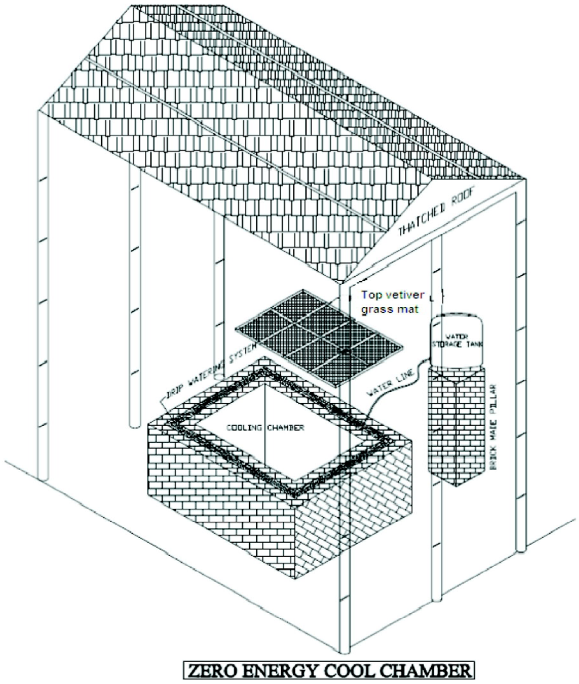

Figure 1: Constructional details of experimental zero energy cool chamber

summer i.e. from 20-28th April 2016 when there was high temperature (35-42 ^{0}C) with low relative humidity (50-65%) outside.

Zero energy cool chamber is an on-farm rural oriented storage structure which operates on the principle of evaporative cooling and has been constructed using locally available raw materials such as bricks, sand, bamboo, rice straw, vetiver grass, jute cloth etc. The chamber has been constructed above the ground and comprises of a double-walled structure made up of bricks. The cavity of the double wall is filled with riverbed sand. The upper part of the chamber was covered with vetiver grass mat on a bamboo frame. Floor of the chamber was made with the help of bricks and of size 165 cm x 115 cm. the space between the double wall is 7.5 cm, filled with fine sand. After construction of the chamber, the following procedures were adopted for its use.

The walls of the chamber were made wet and the sand in between the double wall was saturated with water by the gravity fed micro-dripper from a 35 litre capacity plastic bucket placed 50 cm from the top of the chamber. Fresh paddy straw mushroom to be stored were weighed and taken in perforated polythene bag placed inside the chamber. The chamber was closed completely with the wetted vetiver grass mat. The walls of the chamber as well as the sand filled in the gap of the double wall structure were watered twice daily (morning and afternoon) to maintain high relative humidity and low temperature inside the chamber. The temperature and relative humidity inside the chamber were monitored periodically using a hand held portable RH / Temperature meter (least count 1% for Rh and 0.5 ^{0}C for temperature). Simultaneously the two samples of same amount of paddy straw mushroom were stored in room condition and domestic refrigerator to study the comparative effectiveness in storage among them.

RESULTS AND DISCUSSION

The loss in weight of the stored paddy straw mushroom i.e. physiological loss in weight (PLW) is an indication of moisture loss from the produce which renders the paddy straw mushroom unmarketable as they lose the lusture and freshness. The moisture loss from horticultural produce is not a mere loss of weight rather it is a loss of appearance, taste and even nutrients from the produce which ultimately results in economic loss of the produce. So, any storage method for the perishables should aim at minimizing the moisture loss and respiration from the produce so as to enhance their keeping quality and marketability. This would be possible by reducing the storage temperature and increasing the relative humidity of air surrounding the produce in the storage atmosphere. The data regarding percentage physiological loss in weight, rotten percentage, comparative prevailing temperatures, relative humidity in ZECC, room condition (RC), domestic refrigerator (REF) and ambient condition (AC) of paddy straw mushroom under study were recorded during peak summer period and are presented in the tables 1-4. The shelf life of paddy straw mushroom in various cooling chambers was presented in Fig. 2. The physiological weight loss in the range of 10-15 percent and rotten percentage to be in the range of 20-30 are allowable for maintaining the freshness and marketability of horticultural produces (Olosunde 2006 and Jha 2008).

Table 1
Physiological loss in weight, PLW (%) of paddy straw mushroom during storage period with the use of 100 litres water/day

	24hrs			*30hrs*			*36hrs*			*48hrs*		
Paddy straw	*ZECC*	*RC*	*RFR*	*ZECC*	*RC*	*RFR*	*ZECC*	*RC*	*RFR*	*ZECC*	*RC*	*RFR*
mushroom	5.103	12.08	3.27	6.94	18.14	4.43	9.55	30.28	5.97	14.05	-	11.5

Table 2
Percentage of rotten/unmarketable paddy straw mushroom during storage period

	24hrs			*30hrs*			*36hrs*			*48hrs*		
Paddy straw mushroom	*ZECC*	*RC*	*RFR*	*ZECC*	*RC*	*RFR*	*ZECC*	*RC*	*RFR*	*ZECC*	*RC*	*RFR*
	-	22.78	-	-	29.07	-	15.37	40.5	-	20.22	spoiled	9.12

Table 3
Comparison of temperature (^{0}C), relative humidity (%), solar radiation (W/m^2) during the experimental period (27th-29th April 2016)

SL NO	*TIME*	*ZECC*		*RC*		*RFR*		*AC*		
		Temp(°C)	*RH(%)*	*Temp(°C)*	*RH(%)*	*Temp(°C)*	*RH(%)*	*Temp(°C)*	*RH(%)*	*SR(W/m^2)*
1	8.00am	24-26	80-83	27-31	68-72	16-19	48-51	32-34	52-56	600-620
2	10.00am	25-28	76-79	30-34	62-65	17-20	50-53	36-39	48-50	680-720
3	12noon	28-30	72-76	33-37	60-63	18-21	49-52	40-42	40-44	780-810
4	2.00pm	30-32	70-73	35-39	50-53	16-18	44-48	40-43	38-40	580-610
5	4.00pm	23-26	75-79	32-35	58-61	19-20	47-50	32-34	54-57	380-420
6	6.00pm	21-24	79-83	30-33	64-68	19-21	48-52	30-32	65-68	180-210

Table 4
Experimental temperatures and humidity for storage of paddy straw mushroom in ZECC, Room condition and Refrigerator during summer period

Type of mushroom	*Recommended temperature and humidity and shelf-life (hour)*			*Experimental Temp., humidity and shelf-life (hrs) in ZECC*			*Experimental Temp., humidity and shelf-life (hrs) in Room Condition*			*Experimental Temp., humidity and shelf-life (hrs) in Refrigerator*		
	Temp (^{0}C)	*Rh (%)*	*Shelf-life (hrs)*	*Temp (^{0}C)*	*Rh (%)*	*Shelf-life (hrs)*	*Temp (^{0}C)*	*Rh (%)*	*Shelf-life (hrs)*	*Temp (^{0}C)*	*Rh (%)*	*Shelf-life (hrs)*
Paddy straw	10-15	50-60	76	22-30	70-83	36	27-39	50-72	12	16-21	44-53	72

From the experiments, it was found that there were decrease in temperatures in the range of 6 ^{0}C to 9 ^{0}C and increase in RH by 11 to 22 per cent inside the ZECC compared to room conditions at various times of a day. Similarly, decrease in temperature in the range of 9 ^{0}C to 12 ^{0}C and increase in RH by 15 to 32 per cent inside the ZECC compared to outside ambient condition were recorded at various times of a day during the experimental observations. The highest differences were mostly observed at 2.00 pm. The physiological loss in weight (PLW) recorded for paddy straw mushroom inside the Zero Energy Cool Chamber (ZECC) was only 9.55 per cent as against 30.28 per cent in room condition after

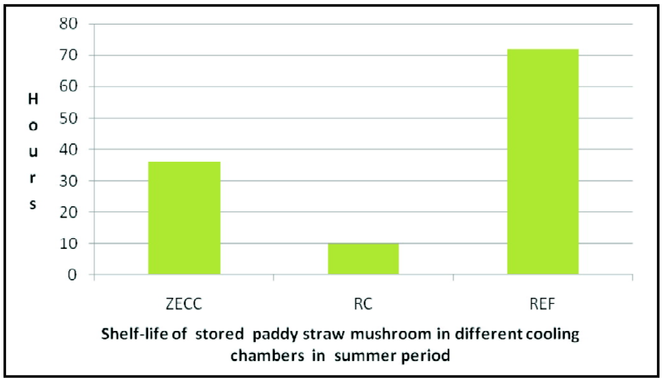

Figure 2: Shelf-life of paddy straw mushroom in ZECC and Room Condition and Refrigerator during summer period

36 hours of storage. After 48 hours, the same was found to be 14.05 % in ZECC, 11.5 % in REF and spoiled in RC. The rotten percentages were recorded to be only 15.37 % as against 40.5 per cent in room condition after 36 hours of storage. After 48 hours, the same was found to be 20.22 % in ZECC, 9.12 % in REF and spoiled in RC. Considering the PLW (9.55 per cent) and rotten/ unmarketable greens (15.37 per cent) together, paddy straw mushroom could be well stored in the ZECC for 36 hours after harvesting in consumable form. However, the same could be stored in good marketable form after 30 hours of storage as against 8-10 hours in room condition. In the summer period, it was found that paddy straw mushroom could be stored for 30 hours in ZECC in the marketable/saleable form and 36 hours in consumable form, 12 hrs in room condition and 72 hrs in domestic refrigerator. The temperatures in the range of 22-30 ^{0}C, 27-39 ^{0}C, 16-21 ^{0}C and 30-42 ^{0}C were maintained respectively in ZECC, RC, REF and AC during conducting experiment. Similarly, humidities in the range of 70-83 %, 50-72 %, 44-53 % and 38-68 % were maintained respectively in ZECC, RC, REF and AC (Tables 3-4).

CONCLUSION

Mushrooms have very short shelflife – these cannot be stored or transported for more than 24 hours at the ambient conditions prevailing in most parts of year and the country. Browning, veil-opening, weight-loss and microbial spoilage are the most common postharvest changes in the mushrooms which often result into enormous economic losses. Proper and appropriate postharvest practices of storage and processing are needed to sustain the growing mushroom farming and industry in the country. One of the major constraints faced by marginal and small farmers engaged in cultivation of paddy straw mushroom is the perishability of the produce which forces them to sell the produce to whatever prices offered in the nearby market point. Taking the produce to a distant market is not feasible owing to the small quantity of sundry paddy straw mushroom being harvested every day. On the other hand, the consumers are also paying a high price for a poor quality produce as there is no cold chain market facilities established in rural and sub urban areas. Considering the above constraints, the farmers interested for growing mushroom on a smaller area should have some alternate technologies for storing their produce at least for a shorter period of 2 days for the benefits of growers, vendors and consumers by the availability of fresh and nutritious paddy straw mushroom. Nowadays, evaporative cooled storage system is increasingly being used for on-farm storage of fruits and vegetables as it not only lowers the air temperature surrounding the stored produce, it also increases the moisture content of the air. This helps preventing the moisture loss of the produce, therefore extends the shelf life of paddy straw mushroom. Zero Energy Cool Chamber which works exclusively on the principle of evaporative cooling could be used effectively for short term storage of paddy straw mushroom with almost on energy consumption and low investment suitable for small and marginal farmers for on-farm storage of their produce. It not only reduces the storage temperature but also increases the relative humidity of the storage space which is essential for maintaining the freshness of the commodity like paddy straw mushroom.

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