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DETERMINATION OF HOW TO MINIMIZE POSTHARVEST LOSSES IN OYSTER MUSHROOM (*PLEUROTUS OSTREATUS*)

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ABSTRACT

The study was carried out in the Ho Municipality of the Volta Region of Ghana to determine how to minimize postharvest losses in oyster mushrooms**.** One hundred and eighty (180) pieces of freshly harvested mushrooms of uniform size and shape were used. A 3x2x2 factorial experiment was used for the study. The treatments were replicated three times. The factors consisted of three different packaging periods (0 hour, 12 hours and 24 hours), two different packaging materials (perforated polythene bags and opened transparent plastic bowls) and two storage environments (refrigerator and room temperature). Each sample was weighed daily with electronic weighing balance, in grams, to determine weight loss. Data gathered were analyzed using GraphPad Prism (version 4.0). Post-hoc Tukey test was conducted on all computed weight losses for all time-dependent treatments to identify significant interactions and differences between treatments. The study showed that oyster mushroom samples that were kept at room temperature lost more of their weights than replicates that had been stored in a refrigerator at 2-3 ^{0}C with 8-10 % relative humidity. Oyster mushroom samples that had been packaged into perforated polythene bags and stored in a refrigerator at 2-3 ^{0}C had longer shelf-lives than oyster mushroom samples kept in room (average temperature 30 ^{0}C with 61 % relative humidity). Packaging into perforated polythene bags immediately after harvest and stored in a refrigerator at 2-3 ^{0}C with 8-10 % relative humidity had longer shelf life of 8 days. Samples packaged 12 hours after harvest into perforated polythene bags and kept at room temperature of 30 ^{0}C with 61 % relative humidity had 3 days shelf life while samples packaged 24 hours after harvest into perforated polythene bags and kept at room temperature had 2 days shelf life. It is recommended that harvesting of mushroom should be done in the morning, packaged immediately after harvesting and stored under cool conditions.

KEYWORDS: *Agaricus ostreatus*, postharvest losses, perforated polythene bags, room temperature, package materials, relative humidity.

INTRODUCTION

Oyster mushroom (*Pleurotus ostreatus*) is an edible mushroom of the kingdom *Mycetae* and belongs to the family *Agaricaceae*. It has a distinctive oyster like flavour when cooked. The oyster mushroom grows from 5-10cm tall and has irregular lobed orange, yellow or grey cap.[1] According to Sawyerr[2] in Ghana, mushrooms serve as a tasty meat-substitute and as a vegetable. However, it is not freely available particularly due to its perishable nature which limits the storage life to a couple of days. Physiological disorders are the main causes of postharvest losses of mushrooms. These disorders are mainly caused by slow handling of the products which enhance opening and darkening of the gills, wilting of the entire structure and brown discolouration of the cap and stem.[3]

Mushrooms have very short shelf life and therefore cannot be stored or transported for more than 24 hours at the ambient conditions and the shelf life is limited to a few days under normal refrigeration conditions which may contribute to postharvest losses and serve as a constraint on distribution and marketing of fresh mushrooms.[4,5] Freezing as conservation method preserves mushrooms for many consumers. The quick freezing method gives a whiter product, thus improving the appearance of the mushrooms. The mushrooms are transported through a tunnel where they are cooled with nitrogen vapour to -25^{o}C.[6]

Mushrooms being products with high respiration rate require packaging films with high oxygen and carbon dioxide permeability. Micro perforated and macro perforated films are suitable for use as packaging materials as they are extremely chemical resistant. These are required due to occurrence of anaerobic conditions and physiological damages as a result of high carbon dioxide concentrations. Because of their high oxygen, carbon dioxide and water vapour permeability, these films precludes the possibility of developing an adequate modified atmosphere for packaging high respiring products.

According to Villaescusa and Gil.[7] the main changes associated with oyster mushrooms deterioration during postharvest storage are change in colour, caused by enzymatic browning, and the occurrence of soft and spongy texture, due to cell growth and water migration. High texture losses and discolouration to yellow colour can occur after 7 days of storage at 4°C and 7°C. In Ghana, Oyster mushroom is delicacy and therefore serves as a tasty meat-substitute and as a vegetable.[2] However it is highly perishable in nature and how to store the produce for a considerable length of time to minimize postharvest losses has been a challenge to the mushroom industry players and as such there is little or no information on determining ways of minimizing postharvest losses in mushrooms using various storage methods. The aim of the study was to determine the effects of combinations of temperature, time of packaging, packaging materials and storage methods on percentage weight loss in oyster mushrooms. Again, the study seeks to find out the effects of the treatment on the shelf life of oyster mushrooms after harvest.

MATERIALS AND METHODS

Preparation of Oyster Mushroom for the Experiments

The oyster mushrooms were sorted by size and appearance. Damaged, fully veil opened and extremely large or small oyster mushrooms were discarded to minimize biological variability. One hundred and eighty (180) pieces of freshly harvested mushrooms of fully intact veil were used. The mushrooms were divided into three groups. Each group contained sixty (60) pieces of oyster mushrooms. The first group which contained sixty (60) pieces of oyster mushrooms were packaged into low density perforated polythene bags (four 1cm diameter holes) and opened transparent plastic bowls of equal size and shape and the packaging was done immediately after harvest for storage. The oyster mushrooms in this group were divided again into two sub-groups and each sub-group contained 30 pieces of oyster mushrooms. In the first sub-group, six (6) pieces of the perforated polythene bags (four 1cm diameter holes) were used. Five pieces of oyster mushrooms were packaged into the six perforated polythene bags. Three (3) of the packages were stored in a refrigerator at 2-3^{0}C for 8 days and the remaining three of the packages were stored at an average room temperature of 24^{0}C with 87% relative humidity for 3 days. In the second sub-group which also contained 30 oyster mushrooms, six opened transparent plastic bowls were used. Five pieces of oyster mushrooms were also packaged into the six opened transparent plastic bowls. Three of the packages were stored in a refrigerator at 2-3^{0}C for 9 days and the remaining three packages were stored at room temperature of 24^{0}C with 87% relative humidity for 5 days.

The second group which also contained sixty (60) pieces of oyster mushrooms were packaged into low density perforated polythene bags (four 1cm diameter holes) and opened transparent plastic bowls of equal size and shape and the packaging was done 12 hours after harvest for storage. The oyster mushrooms in this group were divided again into two sub-groups and each sub-group contained 30 pieces of oyster mushrooms. In the first sub-group, six (6) pieces of the perforated polythene bags (four 1cm diameter holes) were used. Five pieces of oyster mushrooms were packaged into the six perforated polythene bags. Three of the packages were stored in a refrigerator at 2-3^{0}C for 8 days and the remaining three of the packages were stored at an average room temperature of 30^{0}C with 61% relative humidity for 3 days. In the second sub-group which also contained 30 oyster mushrooms, six opened transparent plastic bowls were used. Five pieces of oyster mushrooms were also packaged into the six opened transparent plastic bowls. Three of the packages were stored in a refrigerator at 2-3^{0}C for 9 days and the remaining three packages were stored at an average room temperature of 30^{0}C with 61% relative humidity for 5 days.

Furthermore, the third group which also contained sixty (60) pieces of oyster mushrooms were packaged into low density perforated polythene bags (four 1cm diameter holes) and opened transparent plastic bowls of equal size and shape and the packaging was done 24 hours after harvest for storage. The oyster mushrooms in this group were divided again into two sub-groups and each sub-group contained 30 pieces of oyster mushrooms. In the first sub-group, six (6) pieces of the perforated polythene bags (four 1cm diameter holes) were used. Five pieces of the oyster mushrooms were packaged into the six perforated polythene bags. Three of the packages were stored in a refrigerator at 2-3^{0}C for 7 days and the remaining three of the packages were stored at an average room temperature of 25^{0}C with 85% relative humidity for 2 days . In the second sub-group which also contained 30 oyster mushrooms, six opened transparent plastic bowls were used. Five pieces of oyster mushrooms were also packaged into the six opened transparent plastic bowls. Three of the packages were stored in a refrigerator at 2-3^{0}C for 8 days and the remaining three packages were stored at an average room temperature of 25^{0}C with 85% relative humidity for 4 days.

Experimental Design

A 3x2x2 factorial experiment established in a Randomized Complete Block Design (RCBD) and treatments were replicated three times. The factors consisted of three different packaging periods (0 hour, 12 hours and 24 hours), two different packaging materials (perforated polythene bags and open transparent plastic bowls) and two storage environments (refrigerator and room temperature).

Description of the Equipment Used For the Experiments

Refrigerator

A Samsung refrigerator frost free type with model RT26ADTS1/XTL manufactured in 2010 and made in India was used for the experiments.

Digital Electronic Weighing Scale

A Scout Pro balance with model SPU402 manufactured in 2009 and made in China was used to measure the weight loss of the individual samples during the experimental periods.

Parameters Measured

Weight Loss of Oyster Mushroom

The oyster mushrooms in the storage environment were observed and weighed daily with digital electronic weighing scale and the amounts of weight loss each day due to dehydration were recorded and it was observed that the mushroom structure shriveled or withered due to loss in weight of experimental unit. Weight loss was calculated thus:

$$\%\text{Weight loss} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100\%$$

Shelf life of oyster mushrooms

The shelf life was determined by the length of time (number of days) the mushrooms remained usable and fit for consumption or saleable from the day and time of harvesting and packaging into storage where fresh water loss, colour change and texture were observed.

Data Analysis

Data gathered were analyzed using GraphPad Prism (version 4.0). Post-hoc Tukey test was conducted on all computed weight losses for all time-dependent treatments to identify any true or significant interactions and possible significant differences between treatments.

RESULTS AND DISCUSSIONS

Table 1 showed that by the second day of post-treatment, oyster mushroom samples that had been packaged into perforated polythene bags immediately after harvest and kept at an average room temperature of 24^{0}C with 87% relative humidity had lost approximately 4% of their initial weight and had reached their shelf-life before the fifth day.

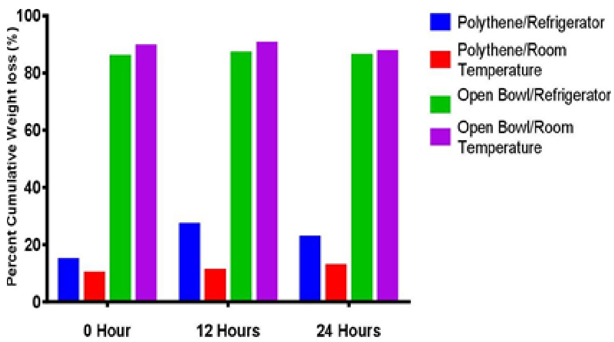
Table 1: Percentage weight losses of mushrooms treated with combinations of temperatures and packaging materials and at varied packaging hours after harvestand stored (*Weight loss is presented as Mean ± Standard Deviation*; *Bowl = Transparent Plastic Bowl; Polythene = Perforated Polythene Bag; * = Mushroom samples had gone past shelf life and had been disposed).*

Treatment Time	Storage Methods	Packaging Materials	Storage Duration (days)		
			2	5	8
	Room Temperature	Polythene	4.05 ± 2.19	*0.00 ± 0.00	*0.00 ± 0.00
Immediately After Harvest	Temp/RH.; 24^{0}C/87%	Bowl	39.04 ± 6.01	89.15 ± 4.42	*0.00 ± 0.00
	Refrigerator	Polythene	1.77 ± 1.29	7.67 ± 0.47	14.51 ± 4.71
	Temp/RH.; 2-3^{0}C/8-10%	Bowl	12.79 ± 1.70	56.31 ± 3.78	80.07 ± 1.00
12 Hours After Harvest	Room Temperature	Polythene	5.10 ± 1.09	*0.00 ± 0.00	*0.00 ± 0.00
	Temp/RH.; 30^{0}C/61%	Bowl	23.78 ± 8.16	90.19 ± 4.65	*0.00 ± 0.00
	Refrigerator	Polythene	0.83 ± 0.54	13.02 ± 9.09	26.79 ± 19.01
	Temp/RH.; 2-3^{0}C/8-10%	Bowl	14.28 ± 1.50	57.04 ± 1.37	81.57 ± 0.26
	Room Temperature	Polythene	12.40 ± 6.70	*0.00 ± 0.00	*0.00 ± 0.00
24 Hours After Harvest	Temp/RH.; 25^{0}C/85	Bowl	31.46 ± 14.23	*0.00 ± 0.00	*0.00 ± 0.00
	Refrigerator	Polythene	4.74 ± 0.77	14.16 ± 0.96	*0.00 ± 0.00
	Temp/RH.; 2-3^{0}C/8-10%	Bowl	13.25 ± 6.60	52.07 ± 7.09	85.83 ± 0.36

Oyster mushroom samples that had been packaged into opened transparent plastic bowls and kept at an average room temperature of 24^{0}C with 87% relative humidity, however, lost more weight (approximately 39%) compared to oyster mushroom samples that had been packaged into perforated polythene bags. By the fifth day however, these mushrooms had lost more than half of their initial weight (89%) and reached their shelf life before the eighth day of post-treatment. Furthermore, oyster mushrooms samples treated with perforated polythene bags and stored in a refrigerator at 2-3^{0}C with 8-10% relative humidity had lost approximately 2% of their initial weights by the second day after treatment and continued to remain usable until the eighth day after treatment by which time they had lost approximately 15% of their initial weights.

Oyster mushroom packaged into opened transparent plastic bowls and stored in a refrigerator at 2-3^{0}C had lost more weight (approximately 13%) than those kept in perforated polythene bags by the second day after treatment and continued to lose weight even up to the eighth day after treatment. A similar trend of weight loss was recorded for treatments that were replicated twelve hours and twenty-four hours after harvest (Table 1). For example, oyster mushrooms that had been packaged into perforated polythene bags 24 hours after harvest and kept at room temperature of 25^{0}C with 85% relative humidity by the second day of post-treatment lost initial weight approximately 12% while oyster mushrooms packaged into opened transparent plastic bowls and kept at the same temperature lost initial weight approximately 31%.

The trends in weight loss at an average room temperature of 30^{0}C with 61% relative humidity (Table 1) may most possibly be accounted for by rapid water loss in mushrooms when exposed to a combination of other factors such as atmospheric pressure, temperature of ambient air and high relative humidity of the storage environment. It could also be attributed to high metabolic activities of the mushrooms, packaging materials and temperature of the storage environment. According to Kumah and Olympio[8] water loss in perishables leads to weight loss and other consequent attributes such as wilting, loss of appearance and texture. Severe wilting can be induced by storage for even less than 24 hours under hot dry conditions. This trend translated into cumulative weight loss by the end of the experiment as shown in Figure 1 below.



Time of treatment after harvesting (Hours)

Figure 1: Effects of four combinations of temperatures and packaging materials treatments on cumulative weight loss in mushrooms immediately after harvest, 12 hours and 24 hours after harvest.

The weight loss that was observed for mushrooms kept in perforated polythene bags was also indicative of a very plausible restriction or retardation of the rate of water loss and therefore, showed a possible strong association and or causation between packaging materials and weight loss (Table 2). A similar study by Maalekuu[9] demonstrated that high relative humidity is essential to prevent desiccation and loss of glossiness. Type of Packaging materials and storage methods used for the storage of the oyster mushrooms could also have influenced moisture loss. According to Jayathunge and Illeperuma[10], packaging oyster mushrooms in 0.015mm linear-low density polythene packages with 3g of MgO after washing with 0.5% CaCl and 0.5% citric acid can extend the shelf life of oyster mushroom from 6-12days. Zanderighi[11] also reported that mushrooms have high respiration rates and require packaging film with oxygen and carbon dioxide permeability. Micro and macro perforated films are suitable for use as packaging materials. These are required due to occurrence of anaerobic conditions and physiological damage as a result of high carbon dioxide concentrations. Also polythene is extremely chemical resistant, making it suitable as packaging materials. During storage, film packaging retards weight loss, deterioration, texture changes and discolouration.

Generally, oyster mushroom samples that were kept at room temperatures lost more of their weights than replicates that had been stored in a refrigerator. For example, oyster mushroom samples that had been packaged into perforated polythene bags and kept at room temperature of 24^{0}C with 87% relative humidity had lost approximately twice the amount of weight of oyster mushroom samples that had been stored in a refrigerator at 2-3^{0}C (approximately 2%). Ares *et al.*[12] had reported that water loss from growing mushroom is comparable to that from a free water surface since 90% of mushroom weight at harvest is water and therefore freshly harvested mushrooms transpire at the same rate as the fruiting sporophore. Dehydration causes economic losses to mushroom producers, marketers and consumers and also influences their deterioration rate. Mushrooms lost large quantity of water soon after harvest and this contributed to dehydration of mushrooms structure. Epidermal layer of mushrooms does not prevent a quick superficial dehydration that causes important quality loss. Therefore, dehydration causes weight loss of mushrooms and affects their shelf life.

The short postharvest life could also be due to heat build-up and condensation of moisture within the perforated polythene bags. It was observed that at a certain stage of the storage, the mushrooms smelled rancid; an indicator that determines the end of shelf life. It was also observed that there were accumulation of moisture in the polythene bags due to heat build-up even though they were perforated. This therefore, contributed to softening of the mushroom structure as asserted by Brennan and Gormely[13] that spoiled mushroom is identified when smell of ammonia or smell rancid, soft to touch and had slime spots on its structure. Oyster mushrooms packaged into opened transparent plastic bowls experienced high amount of weight loss (Table 1) due to their larger surface area. Fresh mushrooms are metabolically active for long periods after harvest. Therefore, the large surface area of the packaging materials might have contributed to the high weight loss of the mushrooms since the greater the surface area the higher the rate of respiration of the produce in storage.

Table 2: Post-hoc Turkey's multiple comparisons of treatments within treatment times.

Tukey's multiple comparisons test	95% CI	Significant	Summary
0 Hours			
PR vs. PT	-11.18 to 20.73	No	Ns
PR vs. BR	-86.96 to -55.04	Yes	****
PR vs. BT	-90.59 to -58.68	Yes	****
PT vs. BR	-91.73 to -59.82	Yes	****
PT vs. BT	-95.37 to -63.46	Yes	****
BR vs. BT	-19.59 to 12.32	No	Ns
12 Hours			
PR vs. PT	0.1441 to 32.06	Yes	*
PR vs. BR	-75.82 to -43.91	Yes	****
PR vs. BT	-79.35 to -47.44	Yes	****
PT vs. BR	-91.92 to -60.01	Yes	****
PT vs. BT	-95.45 to -63.54	Yes	****
BR vs. BT	-19.49 to 12.43	No	Ns
24 Hours			
PR vs. PT	-6.019 to 25.89	No	Ns
PR vs. BR	-79.46 to -47.54	Yes	****
PR vs. BT	-80.90 to -48.99	Yes	****
PT vs. BR	-89.39 to -57.48	Yes	****
PT vs. BT	-90.84 to -58.93	Yes	****
BR vs. BT	-17.40 to 14.51	No	Ns

*CI = Confidence Interval, * = Level of Significance, PR = Perforated Polythene Bag and Refrigerator Treatment, PT = Perforated Polythene bag and Room Temperature Treatment, BR = Opened Transparent Plastic Bowl and Refrigerator Treatment, BT = Opened Transparent Plastic Bowl and Room Temperature Treatment, 0 hour = Treatments immediately after Harvest, 12 hours = Treatments done 12 hours after harvest, 24 hours = Treatments done 24 hours after harvest, ns = not significant.*

All post-hoc comparisons revealed that when temperature was kept constant and packaging materials were varied among treatments that were conducted at the same time, there was significant weight loss while on the other hand when packaging materials were kept constant and temperature was varied among treatments there was no significant resultant weight loss among oyster mushroom samples (Table 2).

The only other striking observation from analysis of the post-hoc tests was that samples that were packaged into perforated polythene bags immediately after harvest and stored in a refrigerator at 2-3^{0}C with 8-10% relative humidity lost significantly different weights from those that were treated similarly 12 hours after harvest (Table 3). Since the degree of significance was weak for the comparison of weight loss for the same treatment at 0 hour and 12 hours and that such a trend was not observed for treatments that were even conducted at 24 hours after harvest, it is very likely that any observed difference in weight loss might have been due to an error in the application of the treatment.

Table 3: Post-hoc Turkey's multiple comparisons of treatments between treatment times.

Tukey's multiple comparisons test	95% CI	Significant	Summary
PR			
0 Hours vs. 12 Hours	-21.27 to -3.306	Yes	**
0 Hours vs. 24 Hours	-16.80 to 1.161	No	Ns
12 Hours vs. 24 Hours	-4.514 to 13.45	No	Ns
PT			
0 Hours vs. 12 Hours	-9.944 to 8.017	No	Ns
0 Hours vs. 24 Hours	-11.64 to 6.321	No	Ns
12 Hours vs. 24 Hours	-10.68 to 7.284	No	Ns
BR			
0 Hours vs. 12 Hours	-10.13 to 7.831	No	Ns
0 Hours vs. 24 Hours	-9.301 to 8.661	No	Ns
12 Hours vs. 24 Hours	-8.151 to 9.811	No	Ns
BT			
0 Hours vs. 12 Hours	-10.02 to 7.937	No	Ns
0 Hours vs. 24 Hours	-7.111 to 10.85	No	Ns
12 Hours vs. 24 Hours	-6.067 to 11.89	No	Ns

*CI = Confidence Interval, * = Level of Significance, PR = Perforated Polythene Bag and Refrigerator Treatment, PT = Perforated Polythene bag and Room Temperature Treatment, BR = Opened Transparent Plastic Bowl and Refrigerator Treatment, BT = Opened Transparent Plastic Bowl and Room Temperature Treatment, 0 hour = Treatments immediately after Harvest, 12 hours = Treatments done 12 hours after harvest, 24 hours = Treatments done 24 hours after harvest, ns = not significant.*

Appendix 1: Colour wheel chart to guide to determine mushroom discolouration after harvest.

Weight loss is a function of shelf life. The results of the treatments on weight loss translate directly to how long oyster mushroom samples remained viable for consumption. Shelf-lives of oyster mushroom samples were shorter (for 2 days), although not significantly, when they were treated 24 hours after harvest than when they were treated immediately after harvest and 12 hours after harvest. This could be attributed to high respiration rate of mushrooms when exposed to the atmosphere as asserted by Ares *et al.*[12] According to Maalekuu,[9] water loss equates to loss of saleable weight, and thus constitutes a direct loss in marketing.

Colour change in mushrooms is an indicator of quality loss and that had affected the shelf life. With the aid of a colour wheel and chart, (Appendix 1), it was observed that irrespective of the kind of packaging materials used, time of packaging of the mushrooms and storage methods, during the storage period, the grey colour of oyster mushrooms had changed. Villaescusa and Gil,[7] reported that one of the main changes associated with oyster mushroom deterioration during postharvest storage is change in colour and the occurrence of soft and spongy texture, due to cell growth and water migration. High texture losses and discolouration to yellow colour can occur after 7 days of storage at 4°C and 7°C. It was also observed that irrespective of the kind of packaging materials used, time of packaging, and storage methods carried out, the texture of the oyster mushrooms felt soft when touched. Also, slimy spots developed on the mushrooms that were packaged into perforated polythene bags and opened transparent plastic bowls and kept at an average room temperature of 30^0C with 61% relative humidity and began to smell rancid of ammonia on the third day and fifth day respectively. Ares *et al*.[12] reported that one of the main changes associated with oyster mushrooms deterioration is changes in their texture. Postharvest senescence in a variety of horticultural commodities is accompanied by changes in cell membrane characteristics, which leads to loss of barrier function and loss of turgor.

CONCLUSIONS

The study conclude that oyster mushrooms packaged into perforated polythene bags immediately after harvest and stored in a refrigerator at $2\text{-}3^0$C with 8-10% relative humidity retarded weight loss significantly and extended the shelf life to 8-9days. Oyster mushroom samples packaged into opened transparent plastic bowls immediately after harvest and stored in a refrigerator at $2\text{-}3^0$C with 8-10% relative humidity had firm texture till the ninth day. After 8 days of storage, the grey colour changed to orange colour for mushrooms packaged into perforated polythene bags while samples in opened transparent plastic bowls changed the grey colour to orange colour after 9 days when stored in a refrigerator at $2\text{-}3^0$C with 8-10% relative humidity. However, samples that were subjected to the same treatment but stored at room temperature showed orange colour with dark spots (5 days). Oyster mushroom samples that had been packaged into perforated polythene bags and stored in a refrigerator also had longer shelf-lives than oyster mushroom samples kept at room temperatures.

RECOMMENDATIONS

On the basis of the findings the following recommendations were made:

1. Oyster mushroom should be packaged immediately into perforated polythene bags after harvest and stored in a refrigerator to reduce weight loss.
2. Oyster mushroom should not be allowed to stay up to 24 hours before packaging for storage.
3. Mushrooms should not be stored at room temperatures.

Disclosure of conflict of interest

Authors have declared that, no conflict of interests exist.

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