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Effect of packaging and storage on physico-chemical characteristics of osmotically dehydrated oyster mushrooms

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Abstract
Mushrooms treated with 15% NaCl (dipping in brine solution of concentration of 15% for 1 hour) and dried in cabinet tray dryer at 50^0C were packaged in LDPE, PET jars and aluminium laminated pouches for extending their storage life. Mushrooms packaged in aluminium laminated pouches were found best followed by those packed in PET jars and LDPE. However, with the advancement in storage period, there was decline in the sensory score whereas microbial count increased but within acceptable limits. The overall acceptability score decreased from an initial score of 8.08 to 7.46 after storage period of 90 days in LDPE pouches and minimum decrease in overall acceptability was recorded in samples packed in laminated pouches where the decrease was from 8.08 to 7.86 at the end of storage.

Keywords: Oyster mushrooms, packaging materials, LDPE, PET jars, aluminium laminated pouches

Introduction
Mushrooms are basically fungi, which have a fleshy and spore-bearing fruiting body. They have been in use not only for consumption purposes but also for medicinal purposes since ages. Pleurotus is a versatile genus belonging to white-rot basidiomycete fungi and well known for their complexity of the enzymatic system and prominent lignocellulolytic property, member of this genus can colonize a wide range of natural lignocellulosic wastes (Naraian *et al.*, 2016) [9]. Apart from flavour and taste, the fruiting bodies of mushrooms are considered as sources of organic nutrients such as digestible proteins, carbohydrates, fibre and certain vitamins, as well as minerals and antioxidants (Wang *et al.*, 2014) [23]. Therefore, Pleurotus is one of the second most cultivated mushrooms and cultivated all over world.
Pre-drying treatments are noted for good sensory qualities such as colour and flavour with stable final product. Osmotic dehydration is one of the most imperative predrying treatments of food commodities which involve partial removal of water from food by means of a concentrated hypertonic osmotic agent (salt, sugar, honey, jaggery, corn starch syrup) that preserves and sometimes improves the initial food qualities such as colour, aroma, flavour and nutritional constituents (Sunjka and Raghavan, 2004) [21]. Packaging and storage conditions play an important role in enhancing the shelf life of processed products, by adding as a barrier for air borne contamination and loss or gain of moisture, thus ensuring the retention of all desirable quality attributes of the product during storage (Kumar *et al.*, 1993; Sagar and Maini, 1997) [6, 16].

Materials and Methods
Mushrooms were purchased from M/S Romesh Chander and Sons, Fresh Vegetable and Mushroom Shop, Parade, Jammu. They were washed with tap water and then kept on blotting paper to remove surface moisture. The research was conducted in the department of Food Science and Technology, SKUAST-J. Mushrooms were cut into slices of 1 cm wide by 1 cm long for the stipe, while 1.5 cm by 3 cm long for the cap and subjected to osmosis by dipping in brine solutions of 15% for 1 hour and dried in cabinet tray dryer at 50^0C were packaged in LDPE, PET jars and aluminium laminated pouches.

Moisture content
Ten grams of mushroom were dried in hot air oven at 70^oC in pre-weighed dishes till constant weight. The dish with dried sample was transferred to desiccators and cooled to room temperature. The dish was then weighed and moisture content in percent was calculated from loss in weight (AOAC, 2002) [2].

$$\text{Percent (\%) moisture} = \frac{\text{Loss in weight (g)}}{\text{Weight of sample (g)}} \times 100$$

$$\text{Microbial load (cfu/g)} = \frac{N \times 1 \times D}{V}$$

Where,
N = Numbers of colonies counted
V = Volume of inoculums
D = Dilution factor

Water activity
Water activity was estimated using Aqualab water activity meter (Model Series: 3TE).

Rehydration ratio
The rehydration ratio of dried mushroom flakes was determined by soaking samples with a defined weight (approx. 5 g) in boiling distilled water at 95ºC for 20 minutes. The samples were removed, filtered, dried and weighed. In order to minimize the leaching losses, water bath was used for maintaining the defined temperature (Ranganna, 1986) [13]. Rehydration ratio (RR) of the samples was computed as follows:

$$\text{Rehydration ratio} = \frac{M_r}{M_d}$$

Where, M_r = Mass of rehydrated sample, g;
M_d = Mass of dehydrated sample, g

Color
The color was evaluated by measuring L*, a*, b* parameters by means of Hunter lab colorimeter. The instrument was standardized against white tile before the measurements. Colour was expressed in CIE-Lab parameters as L* (whiteness / darkness), a* (redness / greenness), and b* (yellowness / blueness) (Byrnes and O Beirne, 2008) [3].

Browning index
The degree of non-enzymatic browning of the dried mushrooms was determined following the method of Mudahar and Bains (1982) [8]. The color was extracted from dried mushroom using 60% ethanol, and the absorbance of the filtrate was measured using a spectrophotometer at 440 nm.

Microbial count
Spread plate technique described by Palczar and Chan (1997) [12] was used. 1g of each sample was aseptically transferred to 9 ml of sterile water in a separate tube and mixed vigorously. 1 ml of the resulting mixture was transferred to 9 ml of sterile water in a separate tube. The process was continued till 6th dilution (10^{-6}). Nutrient agar (NA) was inoculated with a 0.1 ml of appropriately diluted sample (10^{-6}) by spread plating technique and incubated at 37ºC for 24 hours. Colonies were counted and multiplied by the dilution factor.

Sensory evaluation
Sensory evaluation depends upon the responses given by different sense organs. The samples were evaluated on the basis of overall acceptability by semi-trained panel of 9-10 judges by using 9 point hedonic scale assigning scores from 9 (like extremely) to 1 (dislike extremely). A score of 5.5 and above was considered acceptable (Amerine *et al.*, 1965) [1].

Results and Discussion
Moisture content and Water activity
Increase in moisture content of osmotically dehydrated oyster mushrooms was recorded during the storage period of 90 days (Table-1). The moisture content increased from 7.75 per cent at the beginning to 8.11 per cent on 90 days of storage in mushrooms packed in LDPE while it increased to 7.96 per cent in mushrooms packed in aluminium laminated pouches. On the basis of mean value, moisture content increased from an initial value of 7.75 per cent to 8.04 per cent after 90 days of storage. Moisture content of osmotically pretreated and cabinet dried oyster mushrooms increased with increase in storage duration irrespective of packaging materials and storage conditions. The increase in moisture content may be due to the migration of water vapor from the storage environment into the packaging material. Similar findings were reported by Ramya and Kumar (2017) [7] regarding the storage studies of osmo-microwave dehydrated oyster mushroom flakes and also by Swain *et al.* (2013) [22] who observed a slight increase in moisture content of osmotically dehydrated sweet pepper (*Capsicum annum*). Increase in water activity of osmotically dehydrated oyster mushrooms was observed during the storage period of 90 days (Table-2). The water activity increased from 0.32 at the beginning to 0.55 on 90 days of storage in mushrooms packed in LDPE while it increased to 0.51 in mushrooms packed in aluminium laminated pouches. On the basis of mean value, water activity increased from 0.32 at the beginning to 0.53 after 90 days of storage. Water activity was observed to increase with increase in storage duration. Similar results were observed in the study regarding the influence of packaging material along confined storage and duration on quality attributes of osmo-cum-microwave dehydrated *Pleurotus sajor-caju* mushroom flakes (Ramya *et al.*, 2016) [14] and Swain *et al.* (2013) [22] also observed a slight increase in water activity in osmotically dehydrated sweet pepper.

Table 1: Effect of packaging and storage on the moisture content (%) of osmotically dehydrated (15% NaCl) and cabinet dried oyster mushrooms

Packaging material	Moisture content (%)				
	Storage period (days)				
	0	30	60	90	Mean
LDPE	7.75	7.86	7.97	8.11	7.92
PET Jars	7.75	7.84	7.92	8.05	7.89
Aluminium laminated pouches	7.75	7.82	7.88	7.96	7.85
Mean	7.75	7.84	7.92	8.04	

$CD_{(0.05)}$	±S.E.(m)
Packaging material	0.05 0.02
Storage	0.06 0.02
Packaging material × Storage	N.S. 0.04

Table 2: Effect of packaging and storage on the water activity (a_w) of osmotically dehydrated (15% NaCl) and cabinet dried oyster mushrooms

Packaging material	Water activity				
	Storage period (days)				
	0	30	60	90	Mean
LDPE	0.32	0.40	0.47	0.55	0.43
PET Jars	0.32	0.38	0.45	0.53	0.42
Aluminium laminated pouches	0.32	0.37	0.44	0.51	0.41
Mean	0.32	0.38	0.45	0.53	

$CD_{(0.05)}$	±S.E.(m)
Packaging material	N.S. 0.01
Storage	0.05 0.02
Packaging material × Storage	N.S. 0.03

Rehydration ratio

Decrease in rehydration ratio of osmotically dehydrated oyster mushrooms was observed during the storage period of 90 days (Table-3). The rehydration ratio decreased from 2.41 at the beginning to 2.16 on 90 days of storage in mushrooms packed in aluminium laminated pouches while it decreased to 2.06 in mushrooms packed in LDPE. On the basis of mean value, rehydration ratio decreased from an initial value of 2.41 to 2.11 after 90 days of storage. Rehydration ratio of osmotically dehydrated mushrooms reduced with increase in storage duration in all packaging materials i.e. LDPE, PET jars and aluminium laminated pouches. The rehydration ratio was more in mushrooms packed in aluminium laminated pouches whereas it was less in mushrooms packed in LDPE after 90 days of storage. These results are in agreement with the findings of Ramya and Kumar (2017) [15] in osmotically dehydrated oyster mushroom flakes.

Table 3: Effect of packaging and storage on the rehydration ratio of osmotically dehydrated (15% NaCl) and cabinet dried oyster mushrooms

Packaging material	Rehydration ratio				
	Storage period (days)				
	0	30	60	90	Mean
LDPE	2.41	2.29	2.18	2.06	2.23
PET Jars	2.41	2.34	2.22	2.12	2.27
Aluminium laminated pouches	2.41	2.36	2.25	2.16	2.29
Mean	2.41	2.33	2.21	2.11	

$CD_{(0.05)}$	±S.E.(m)
Packaging material	N.S. 0.02
Storage	0.06 0.02
Packaging material × Storage	N.S. 0.03

Color and Browning index

Decrease in L* value and increase in a* and b* values of osmotically dehydrated oyster mushrooms was observed during the storage period of 90 days (Table-4). The L* value decreased from 55.46 at the beginning to 40.10 on 90 days of storage in mushrooms packed in aluminium laminated pouches while it decreased to 38.07 in mushrooms packed in LDPE. The a* and b* values increased from 4.18 and 18.62 at the beginning to 8.74 and 24.58 in mushrooms packed in LDPE while a* and b* values increased to 7.43 and 23.43 in mushrooms packed in aluminium laminated pouches after 90 days of storage. The storage period of 90 days affected color values of osmotically dehydrated oyster mushrooms packed in LDPE, PET jars and aluminium laminated pouches kept under ambient conditions. Colour change (yellow/brown) may be due to faster absorption of moisture which resulted in dark colour of stored mushroom sample during storage (Ramya and Kumar, 2017) [15]. Increase in browning index of osmotically dehydrated oyster mushrooms was observed during the storage period of 90 days (Figure-1). The browning index increased from 0.23 at the beginning to 0.68 on 90 days of storage in mushrooms packed in LDPE while it increased to 0.58 in mushrooms packed in aluminium laminated pouches. On the basis of mean value, browning index increased from 0.23 on 0 day to 0.64 after 90 days of storage. There was slight increase in browning index during storage period of 90 days. Browning index was less in osmotically dehydrated oyster mushrooms packed in aluminium laminated pouches while it was more in LDPE packages. Similar results were reported by Sagar and Khurdiya (1999) [17] in dehydrated mango slices and also the findings of Sharma *et al.* (2000) [18] regarding the influence of packaging on quality and shelf-life of osmo-air dried apricot.

Table 4: Effect of packaging and storage on the color of osmotically dehydrated (15% NaCl) and cabinet dried oyster mushrooms

Packaging Material	Color					
		Storage period (days)				
		0	30	60	90	Mean
LDPE	L*	55.46	48.27	43.24	38.07	46.26
	a*	4.18	5.27	6.60	8.74	6.19
	b*	18.62	20.47	22.41	24.58	21.52
PET Jars	L*	55.46	48.32	44.65	39.10	46.88
	a*	4.18	5.04	6.27	8.33	5.95
	b*	18.62	20.21	21.98	23.75	21.14
Aluminium laminated pouches	L*	55.46	50.09	46.06	40.10	47.92
	a*	4.18	4.73	6.06	7.43	5.60

	b*	18.62	19.88	21.65	23.43	20.89
Mean	L*	55.46	48.89	44.65	39.09	
	a*	4.18	5.01	6.31	8.17	
	b*	18.62	20.18	22.01	23.92	

$CD_{(0.05)}$			±S.E.(m)			
	L*	a*	b*	L*	a*	b*
Packaging material	0.07	0.06	0.07	0.03	0.02	0.02
Storage	0.09	0.07	0.08	0.03	0.02	0.03
Packaging material × Storage	0.15	0.13	0.13	0.05	0.04	0.04

L* (Whiteness/darkness)
a* (redness/greenness)
b* (yellowness/blueness)

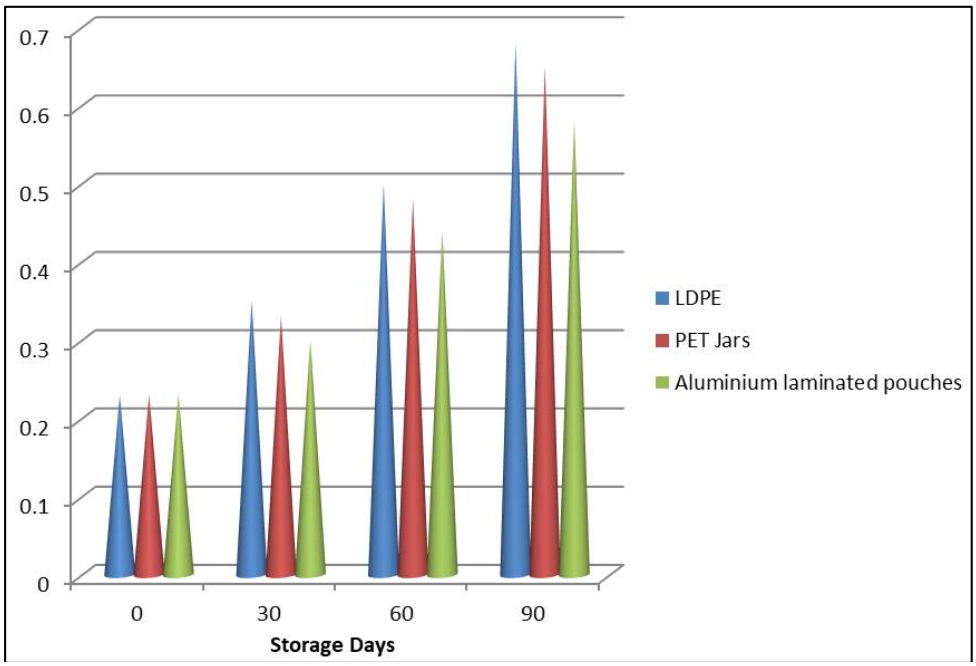

Fig 1: Effect of packaging and storage on the browning index of osmotically dehydrated (15% NaCl) and cabinet dried oyster mushrooms

Microbial count

Increase in microbial count of osmotically dehydrated oyster mushrooms was observed during the storage period of 90 days (Table-5). The microbial count increased from 1.15×10^2 cfu/g at the beginning to 4.56×10^2 cfu/g on 90 days of storage in mushrooms packed in LDPE while it increased to 4.50×10^2 cfu/g in mushrooms packed in aluminium laminated pouches. On the basis of mean value, microbial count increased from 1.15×10^2 cfu/g on 0 day to 4.53×10^2 cfu/g after 90 days of storage. An increase in microbial count of osmotically dehydrated oyster mushrooms was observed as there was increase in moisture content of mushrooms during storage period of 90 days. Similar findings were reported by Kumar *et al.* (2017) in osmo-air dried button mushrooms and Narayana *et al.* (2003) in osmo-dehydrated banana slices during storage. The total microbial count though increased with storage, but was lesser than the count of ISI specification (IS: 7463-2004) (Singh *et al.*, 2011) [20].

Table 5: Effect of packaging and storage on the microbial count (cfu/g) of osmotically dehydrated (15% NaCl) and cabinet dried oyster mushrooms

Packaging Material	**Microbial count ($\times10^2$ cfu/g)**				
	Storage period (days)				
	0	**30**	**60**	**90**	**Mean**
LDPE	1.15	2.23	3.40	4.56	2.83
PET Jars	1.15	2.20	3.37	4.53	2.81
Aluminium laminated pouches	1.15	2.17	3.34	4.50	2.79
Mean	1.15	2.20	3.37	4.53	

$CD_{(0.05)}$	±S.E.(m)	
Packaging material	0.03	0.01
Storage	0.04	0.01
Packaging material × Storage	0.07	0.02

Sensory evaluation

Decrease in overall acceptability rating of osmotically dehydrated oyster mushrooms was observed during the storage period of 90 days (Table-6). The overall acceptability rating decreased from 8.08 at the beginning to 7.86 on 90 days of storage in mushrooms packed in aluminium laminated pouches while it decreased to 7.46 in mushrooms packed in LDPE. On the basis of mean value, overall acceptability score decreased from an initial value of 8.08 to 7.66 after 90 days of storage. The highest product acceptability in terms of appearance, flavor, texture, taste and overall acceptability scores were observed in osmotically dehydrated mushrooms

packed in aluminium laminated pouches as compared to mushrooms packed in PET jars and LDPE. A decrease in all sensory quality parameters was observed with the increase in storage duration of 90 days. These results are in agreement with the findings of Donglu *et al.* (2017) [4] in mushrooms (*Flammulina velutipes*) and Kumar *et al.* (2017) [7] in osmo-air dried white button mushrooms. Similar findings have also been reported by Sharma *et al.* (2006) [19] and Gupta (2007) [5] in osmodehydrated apricot and in dried ber fruits.

Table 6: Effect of packaging and storage on the overall acceptability of osmotically dehydrated (15% NaCl) and cabinet dried oyster mushrooms

Packaging material	Overall acceptability				
	Storage period (days)				
	0	30	60	90	Mean
LDPE	8.08	7.96	7.76	7.46	7.81
PET Jars	8.08	8.01	7.86	7.66	7.90
Aluminium laminated pouches	8.08	8.06	7.96	7.86	7.99
Mean	8.08	8.01	7.86	7.66	

$CD_{(0.05)}$	±S.E.(m)
Packaging material 0.04	0.02
Storage 0.05	0.01
Packaging material × Storage 0.08	0.03

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