

Storage Studies on Osmo-microwave Dehydrated Oyster Mushroom Flakes; Impact of Storage Condition, Interval and Packaging Material

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ABSTRACT

Experiments was conducted to study the influence of packaging material along confined storage condition and duration on quality attributes of osmo-cum-microwave dehydrated *Pleurotus sajor-caju* mushroom flakes during storage. Mushrooms pre-treated with salt-sugar were dried by microwave drying technique to a moisture content of around 6 % (w.b.) was stored under different storage conditions. Various quality attributes that contributes for overall consumer acceptability were studied along storage period. The mushroom flakes were found to be highly acceptable up to two months of storage that was packed in high density poly ethylene material with greater overall acceptability.

Key words: Oyster mushrooms; osmosis; microwave drying; quality attributes; storage conditions

INTRODUCTION

Mushrooms are familiar as important food items from antiquity. Consumption of mushrooms has augmented progressively because of the momentous role in human health and nutrition. Mushrooms are good source of protein, vitamin and minerals and have broad range of uses as food and medicine¹⁰. Oyster mushrooms show a wide range of temperature tolerance (15-30°) and are suitable for cultivation under both temperate and tropical climatic conditions. Oyster mushrooms are cultivated and harvested throughout the year³. Oyster mushroom have 25-30% protein besides,

2.5% fat, 17-44% sugar, 7-38% mycocellulose and 8-12% mineral (potassium, phosphorus, calcium and sodium)¹⁶. Bountiful species of oyster mushrooms are of highly medicinal importance. *Pleurotus* spp., commonly known as “oyster mushrooms” are the second most well-liked mushroom after white button mushroom in the world¹. *Pleurotus sajor-caju* inhibits hypertensive effects through its active ingredients, which affect the rennin-angiotension system⁷. The medicinal properties of various types of *pleurotus* mushrooms are because of their nutritional or chemical composition.

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Further, nutritional composition is inflated by several factors including differences among strains, composition of growth substrate, method of cultivation, stage of harvesting, specific portion of fruiting bodies, used analysis, time interval between harvest and measurement method⁶. Nonetheless, mushrooms are awfully perishable because of their high initial moisture content and delicate nature so cannot be stored for more than 24 h at ambient temperature (25-30°C). Hence, in order to augment produce shelf-life and to delight consumer's consumption requirements, post-harvest processing becomes indispensable.

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 pre-drying 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 constituents¹⁷. Osmotic dehydration can tag along by microwave drying. Microwave drier dries the food material faster than any conventional drier by using short high-frequency energy waves similar to TV radar and radio waves. As compared to the conventional drying, microwave drying offers advantages of shorter drying times, improved energy transfer into the matrix, increased productivity and greater energy savings¹⁸. Furthermore, the food processing industries are the predominant consumer of microwave energy, where it is engaged for cooking, thawing, tempering, drying, freeze-drying, and sterilization, baking, heating or re-heating⁸. A handful studies have been reported for the drying kinetics of oyster mushrooms. But, studies on quality attributes during storage of dried oyster mushrooms are scanty. The present study was aimed to investigate the influence of osmo-cum-microwave dehydration on the quality of stored oyster mushroom flakes in different packaging material for different time interval at refrigerant and ambient storage conditions.

MATERIALS AND METHODS

Response Surface Method was used to determine the optimum operating conditions that yield maximum water loss, weight reduction and minimum solute gain in order to increase process efficiency of osmotic dehydration of oyster mushrooms. The optimal conditions for maximum water loss and weight reduction and minimum solute gain correspond to immersion time 44.21 min, sucrose concentration of 52.57 %, solution temperature 42.3 °C and STFR 4.99:1 was 41 (g/100 g of initial mass), weight reduction of 38.6 (g/100 g of initial mass) and solute gain 2.15 (g/100 g of initial mass) respectively. The superior quality mushroom flakes obtained through optimization of osmo-cum-microwave dehydration of mushrooms was used for the storage studies. These flakes were stored in 100 gauge (25 µm) packaging materials; low density poly ethylene (LDPE) having water vapour transmission rate (WVTR) of 6-23 g m⁻²/day and high density poly ethylene (HDPE) having water vapour transmission rate (WVTR) of 4 – 10 g m⁻² day⁻¹, and kept under refrigerated and ambient storage conditions for three months. The quality attributes of stored flakes like colour, texture, rehydration ratio, moisture content, water activity, ascorbic acid and overall acceptability were evaluated at regular interval of fifteen days along storage period of three months to achieve the desired final product specifications for commercial processing. Experimentation was carried out at quality analysis and Food Engineering Laboratory, Department of Processing and Food Engineering, Punjab agricultural University, Ludhiana.

Evaluation of quality attributes

The quality attributes analyzed during storage period were colour, texture, rehydration ratio, moisture content, water activity, ascorbic acid and overall acceptability.

Colour measurement

The colour reader CR-10 (Konica Minolta Sensing Inc. USA) was used for the measurement of colour of the oyster mushroom flakes. Colour parameters (L, a and b) of the flakes were recorded at D 65/10°,

under proper lighting at regular intervals. The Δa , Δb , ΔL and colour change (ΔE) was also

calculated for each experiment using following expression.

$$\text{Color change } \Delta E = \sqrt{(L_0 - L)^2 + (a_0 - a)^2 + (b_0 - b)^2},$$

Where, L is degree of lightness to darkness, L_0 is initial value of L, a is degree of redness to greenness, a_0 is initial value of a, b is degree of yellowness to blueness and b_0 is initial value of b. Furthermore, other colour parameters such as chroma and hue were also calculated. Chroma (C) indicates colour saturation which is proportional to its intensity:

$$\begin{aligned} \text{Chroma (C)} \\ = \sqrt{a^2 + b^2} \end{aligned}$$

For the hue value (h), an angle of 0 or 360° indicates red hue, while angles of 270, 180 and 90° indicate blue, green and yellow hue, respectively. The hue angle value corresponded to whether the object was red, orange, yellow green, blue or violet¹³.

$$\begin{aligned} \text{Hue angle (H)} = \\ \arctan\left(\frac{b}{a}\right) \end{aligned}$$

Colour kinetics for dehydrated mushroom during storage

The variation in colour parameters for dehydrated mushroom sample during storage was represented by a mathematical equation of the following form:

$$\frac{\partial C}{\partial t} = kC^n$$

Where, C is the colour parameter measured, T = storage period (in days), K = rate constant which depends upon temperature and water activity, N = power factor also called the order of reaction, $\frac{\partial C}{\partial t}$ = rate of change of C with time. A negative sign was used if deterioration was the loss of C and a positive sign if it was for production of an undesirable change in stored sample. In zero order reaction rate was independent of the colour parameter. For a degradation reaction:

$$-\frac{\partial C}{\partial t} = k$$

This by integration results in,

$$C = C_i - kt$$

Where, C_i is the quality parameter at time zero days.

The mathematical expression for a first order degradation reaction is as follow:

$$-\frac{\partial C}{\partial t} = kC$$

Which by integration this equation

$$\text{becomes, } C = C_i e^{-kt}$$

Texture analysis

Texture of the dried mushroom flakes was determined with the help of Texture Analyzer (Model TA-XT2i, Stable Microsystems Ltd. UK). The samples were compressed by spherical probe. The pre-test speed was set at 1.5 mm s⁻¹, post test speed was set at 10 mm s⁻¹ whereas; test speed of 2 mm s⁻¹ was set during compression. The height of peak during compression cycle was defined as hardness (g-f).

Rehydration characteristics

The rehydration tests were conducted to evaluate the reconstitution qualities of dehydrated samples. The rehydration ratio of dried mushroom flakes was determined by soaking the samples with a defined weight (approx. 5 g) in boiling distilled water at 95°C for 20 min. The samples were removed, dried off with filter paper and weighed. In order to minimize the leaching losses, water bath was used for maintaining the defined temperature¹⁵. 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 = Test mass of dehydrated sample, g.

Moisture analysis

The moisture content of dried flakes was determined gravimetrically according to AOAC⁵. The calculated amount of samples in pre-weighed moisture dishes were placed in hot-air oven at constant temperature of 105°C for 2 h. The loss in weight was noted and moisture (%) computed using with following formula:-

$$\text{Moisture (\%)} = \frac{\text{loss in weight (g)} \times 100}{\text{weight of sample (g)}}$$

Water activity (a_w)

Water activity is the amount of water that is available to the microorganisms for their growth. Water activity (a_w) is the ratio of water vapour pressure of food to the water vapour of pure water under the same conditions. It is expressed as:

$$\text{Water activity (} a_w) = \frac{p}{p_0}$$

Where, p = water vapour pressure of the food; p_0 = water vapour pressure of pure water.

Water activity of the samples was measured using digital water activity meter. The samples were placed in a standard measuring cup provided with the water activity meter, and were sealed against a sensor block. Reading was recorded which will displayed on the screen after few minutes.

Ascorbic acid

The ascorbic acid content in fresh and dried mushroom slices was determined by 2,6-dichlorophenol-indophenol visual titration method¹⁵. The ascorbic acid content s was calculated by the following formula;

$$\text{Ascorbic acid, } \frac{\text{mg}}{100\text{g}} = \frac{\text{Titre} \times \text{Dye factor} \times \text{Volume extract} \times 100}{\text{Aliquot of extract} \times \text{Wweight of sample taken}}$$

Organoleptic evaluation

A panel of fifteen members was drawn from the non-teaching staff and M. Tech. scholars from the Department of Processing and Food Engineering, PAU, Ludhiana. They were asked to assess the overall quality of dried flakes of oyster mushrooms taking into

account the following attributes: appearance, colour, texture, flavour and overall acceptability on a 9-point hedonic scale (9-like extremely, 5-neither like nor dislike and 1-dislike extremely) The values of overall acceptability have been given in the present study.

Statistical analysis

The data was statistically analyzed to estimate the significance between packaging material, storage duration and storage conditions on the quality of dried flakes. The analysis was done using CPCS1 software. Means were computed and least square difference (LSD) calculated at 5% of significance.

RESULTS AND DISCUSSION

The intent of storage studies was to produce shelf stable mushroom flakes with superior quality product. The different quality attributes of dehydrated oyster mushrooms during storage period are discussed and graphical representations are presented below. Means were computed and least square difference (LSD) was calculated at 5% of significance using CPCS1 software.

Colour

Colour of mushrooms is important parameters as colour is indicative of the commercial appraisal of the product for end user². The storage duration affected colour kinetics of dehydrated mushroom flakes packed in LDPE and HDPE, kept under different storage conditions (ambient and refrigeration). The values of L, a, b and colour change (ΔE) has been presented in Fig. 1. A steady and considerable drop off of L values was observed in all samples during the storage. Comparable trend were also noticed for white button mushrooms¹¹ and for oyster mushrooms¹⁴ in an earlier investigation. The change in L value of dehydrated samples was taken as a measurement of brightness, which in present study reduced from 46.6 to 40.96 during storage. The highest L value of 46.11 was observed for HDPE-R after 15 days of storage, whereas the lowest L value of 40.96 was noticed for LDPE-A after 90 days of storage. The 'a' value increased with increase

in storage duration with highest 'a' value of 7.06 observed for LDPE-A after 90 days of storage and lowest of 5.9 for HDPE-R after 15 days of storage. An increase in 'b' value was observed during storage period under different packaging material and storage conditions.

The highest 'b' value was observed as 21 for LDPE-A after 90 days of storage and lowest as 15.85 for HDPE-R after 15 days of storage. The value 'b' indicated the yellowness of stored sample. Colour change (yellow/brown) must be due to faster absorption of moisture which resulted in dark colour of stored sample during storage. The colour change (ΔE) and Chroma (C) of dehydrated mushroom increased along the storage period. The rate of increase of colour change was highest for 90 days after storage. The highest ' ΔE ' value was observed as 21.5 for LDPE-A after 90 days and lowest as 14.34 for HDPE-R after 15 days of storage. The chroma values varied between 16.86-22.15. The highest chroma value was observed as

22.15 for LDPE-A for 90 days and lowest as 16.912 for HDPE-R after 15 days of storage. The hue angle varied between 68.446-71.58. The statistical analysis also supported the fact that the values L, a, b and ΔE values was significantly ($p \leq 0.05$) affected by the packaging material during storage. The values of L, a and b obtained from the experimental data were fitted to kinetics models i.e. zero order and first order (Table 1 and 2). For the mathematical modeling of colour values, the a, b, ΔE , Hue and Chroma values were fitted to the zero-order kinetic model; on the other hand, the values of L followed a first-order kinetic model. The kinetic rate constant of L, a and b were more when stored in ambient condition as compared to refrigerated condition. This implies that with variation in storage condition from refrigeration to ambient, the degradation rate of colour became faster as a result of high moisture absorption inside the food under ambient.

Table 1: The estimated kinetic parameters and the statistical values of zero and first order models for L, a and b value under different storage conditions for salt-sugar osmosed dehydrated mushrooms

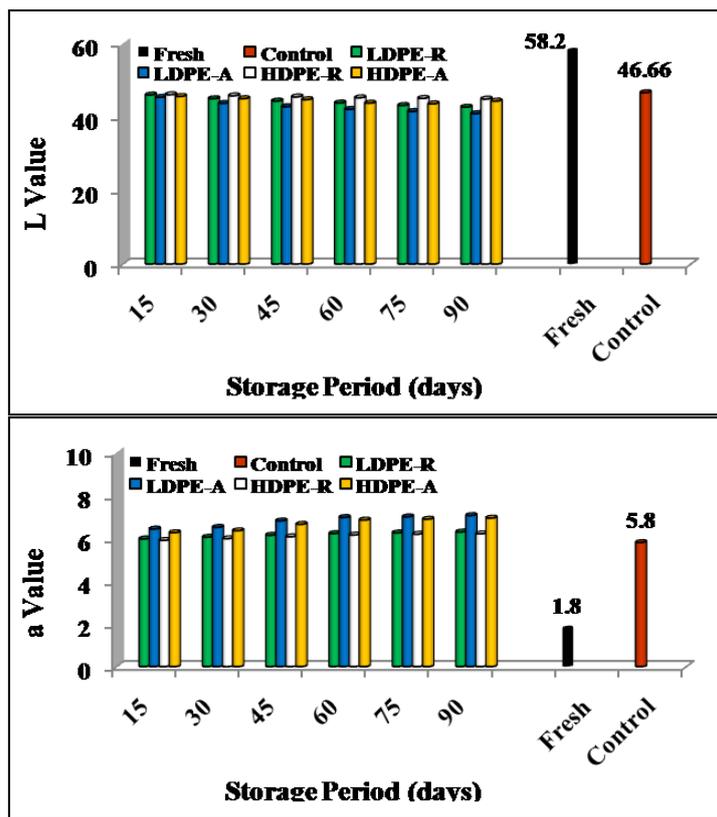
Stored samples	Colour parameter	Zero order			First order		
		C ₀	k ₀	R ²	C ₀	k ₁	R ²
LDPE-R	'L' value	46.45	0.043	0.986	46.499	0.001	0.988
LDPE-A		45.73	0.056	0.952	45.827	0.001	0.958
HDPE-R		46.284	0.016	0.984	46.291	0	0.985
HDPE-A		45.687	0.022	0.651	45.705	0	0.655
LDPE-R	'a' value	5.947	-0.004	0.943	5.95	0	0.942
LDPE-A		6.319	-0.009	0.913	6.334	-0.001	0.907
HDPE-R		5.88	-0.004	0.864	5.884	0	0.859
HDPE-A		6.135	-0.01	0.919	6.154	-0.001	0.912
LDPE-R	'b' value	15.601	-0.037	0.975	15.691	-0.002	0.97
LDPE-A		15.903	-0.056	0.949	16.094	-0.003	0.943
HDPE-R		15.437	-0.024	0.966	15.473	-0.001	0.966
HDPE-A		15.31	-0.041	0.986	15.406	-0.002	0.987

Note: LDPE-R = Low Density Poly Ethylene – Refrigerated storage; LDPE-A = Low Density Poly Ethylene – Ambient storage; HDPE-R = High Density Poly Ethylene – Refrigerated storage; HDPE-A = High Density Poly Ethylene – Ambient storage.

Table 2: The estimated kinetic parameters and the statistical values of zero and first order models for

colour change, chroma and hue value under different storage conditions for salt-sugar osmosed dehydrated mushrooms

Stored samples	Colour parameter	Zero order			First order		
		C ₀	k ₀	R ²	C ₀	k ₁	R ²
LDPE-R	Colour change	13.944	-0.055	0.984	14.15	-0.003	0.976
LDPE-A		14.784	-0.077	0.961	15.162	-0.004	0.945
HDPE-R		13.992	-0.026	0.987	14.04	-0.002	0.984
HDPE-A		14.488	-0.041	0.892	14.619	-0.002	0.88
LDPE-R	Chroma	69.339	-0.026	0.937	69.35	0	0.936
LDPE-A		68.533	-0.031	0.76	68.549	0	0.759
HDPE-R		69.298	-0.013	0.889	69.3	0	0.889
HDPE-A		68.301	-0.016	0.779	68.302	0	0.78
LDPE-R	Hue value	16.686	-0.036	0.977	16.768	-0.002	0.972
LDPE-A		17.107	-0.056	0.956	17.286	-0.003	0.95
HDPE-R		16.51	-0.024	0.968	16.544	-0.001	0.968
HDPE-A		16.491	-0.042	0.986	16.587	-0.002	0.986



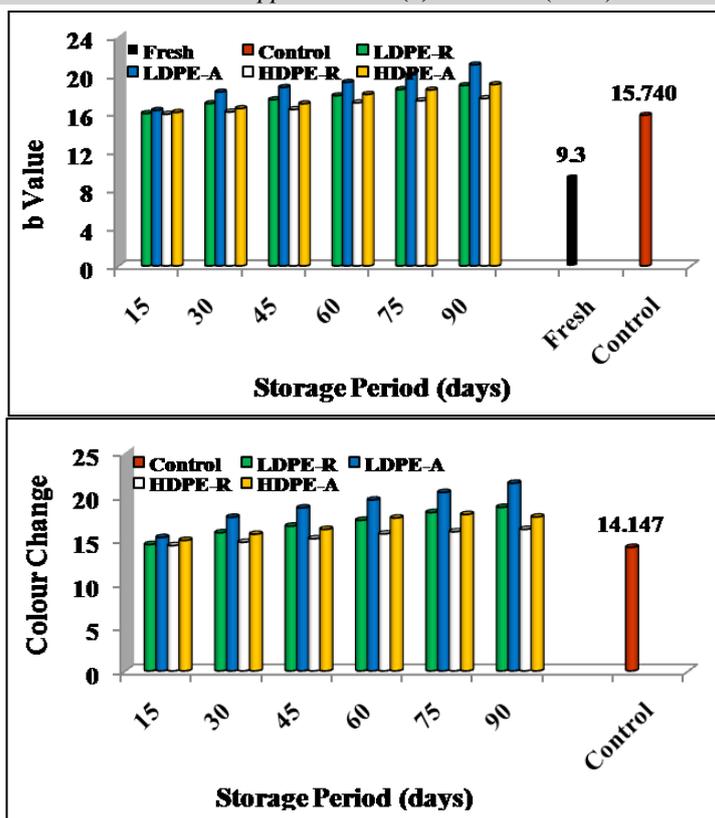
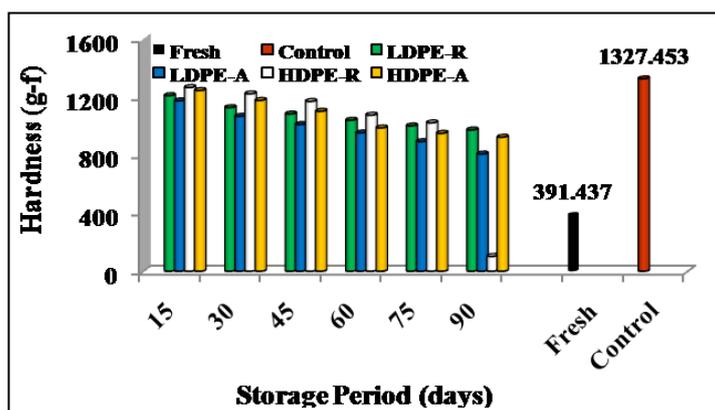


Fig. 1: Effect of packaging material, storage condition and duration on L, a, b and colour change (ΔE) of dried mushroom flakes

Texture

Texture is one of the most important properties connected to quality of the product. Changes to the texture of dried foods with time are an important indication of quality deterioration. Factors that affect texture impairment include moisture content, composition, variety, pH, maturity and sample dimensions. The method of dehydration also influences texture of the product. It was noted that hardness decreased with increase in storage duration in all storage packs at different storage conditions (Fig. 2). The lowest hardness of dehydrated sample was observed as 808.657 g-f for LDPE-A and

highest as 1257.46 for HDPE-A after 90 and 15 days of storage. The vast variation in hardness was due to the absorption of moisture that might have plasticizing effect providing elasticity to the solid matrix of material during storage. Comparable trend were also noticed for white button mushrooms¹¹ and for oyster mushrooms¹⁴ in an earlier investigation. The statistical analysis indicated that there existed no significant ($p \leq 0.05$) difference existed with respect to hardness of the flakes as well as between different packaging materials along storage duration at different storage conditions.



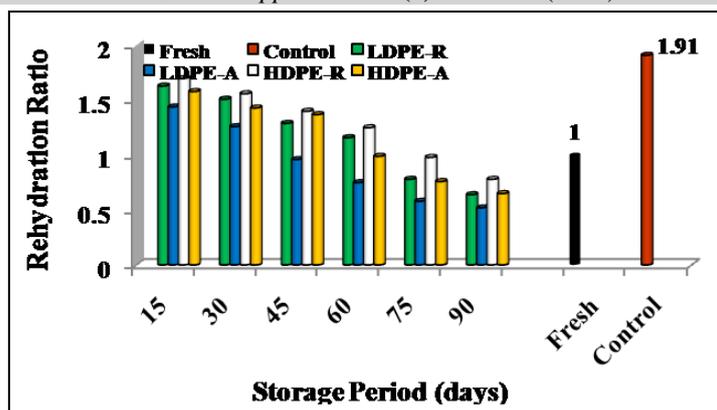


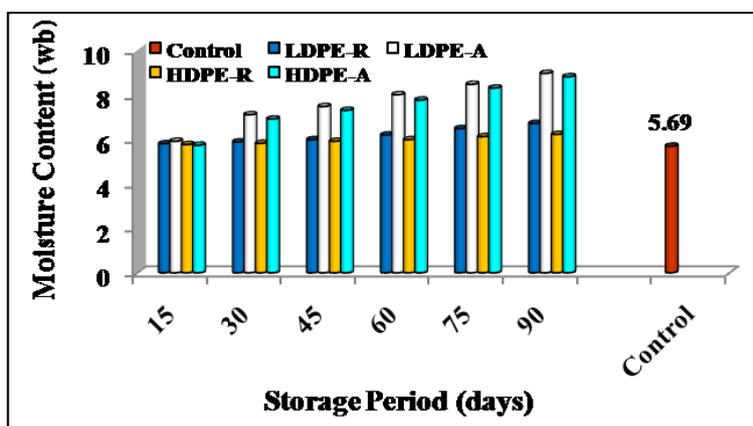
Fig. 2: Effect of packaging material, storage condition and duration on hardness and rehydration characteristics of dried mushroom flakes

Rehydration characteristics

Rehydration is considered to be a complex process aimed at the restoration of raw material like properties when dried material is contacted with water. Pre-drying treatments, subsequent drying and rehydration characteristics induce many changes in structure and composition of food, which results in impaired reconstitution properties of the product. Hence, rehydration is considered as a measure of injury to the material caused by drying and treatments preceding dehydration. In present study rehydration ratio reduced with increase in storage duration in all storage packs (Table 2 / Fig. 2). The most favourable rehydration ability was observed for mushroom flakes in HDPE as compared to samples stored in LDPE packaging materials. The lowest rehydration ratio of dehydrated sample (0.52) was observed for LDPE-A and highest (1.7) for HDPE-R after 90 and 15 days of storage respectively. The CV was found to be 175.03.

Moisture content

To retain superior quality, stored product should have moisture contents below 8% (wb). The packaging material used for the storage of dried products has much influence by the product moisture variation during storage. The effect of storage duration on moisture content of dehydrated oyster mushroom flakes stored at LDPE and HDPE, and stored under ambient and refrigeration conditions has been shown in Fig. 3. Moisture content increased with increase in storage duration irrespective of packaging materials and storage conditions. The highest moisture content was observed as 9.64% for LDPE-A and as 5.73% for HDPE-A after 90 and 15 days of storage. Packaging under appropriate storage condition plays an important role on protecting dehydrated food as it also influence from outside atmosphere and other damages. The CV was found to be 104.00. The CD was 6.26 between the packaging materials and there existed no significant difference along storage duration at different storage condition.



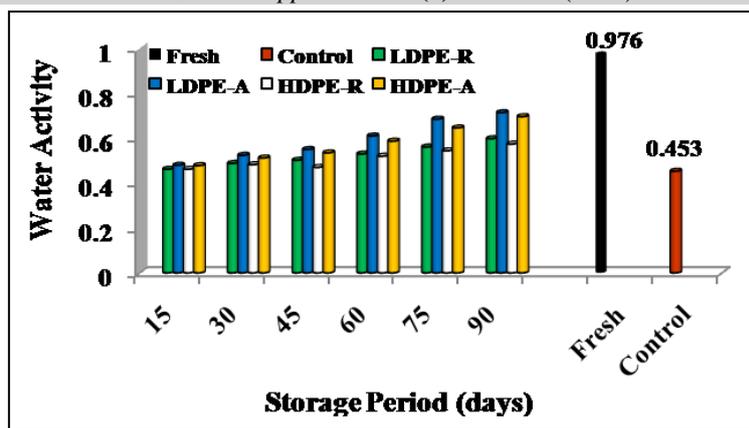


Fig. 3. Effect of packaging material, storage condition and duration on moisture content and water activity of dried mushroom flakes

Water activity

Dehydrated foods usually have moisture content below 10% and a water activity 0.6 or below. They are hard and firm, resistant to microbial deterioration and fungal attacks. Water activity is an important factor in product preservation because physical-chemical and microbiological alterations that can occur during processing and storing of a food product depend on it. The effect of storage period on water activity of dehydrated mushroom flakes in LDPE and HDPE, and kept under ambient and refrigeration conditions have been shown in Fig. 3. It was showed that there was a similar change in water activity of the stored product occurred as in the moisture content. Hence, water activity is directly proportional to moisture content. The water activity was found to increase with increase in storage duration in all stored packs. The highest water activity was observed as 0.714 for LDPE-A and lowest as 0.462 for HDPE-R after 90 and 15 days of storage respectively.

Ascorbic acid

Food products usually lose nutrients more during preparation than drying or storage. The water-soluble vitamins can be expected to be partially oxidized. Ascorbic acid are soluble until the moisture content of the food falls to below critical levels and react with solutes at higher rates as drying proceeds. Ascorbic acid is sensitive to higher temperatures at higher moisture contents. Several studies have shown

that the maximum amount of ascorbic acid degradation occurs at specific (critical) moisture levels⁴. The critical moisture level appears to vary with the different products (product being dried and/or the dehydration process). Short drying times, low temperature storage, and low moisture and oxygen levels during storage are necessary to avoid quality deterioration. To optimize ascorbic acid retention, the product should be dried at a low initial temperature when the moisture content is high since ascorbic acid is highly heat sensitive at higher moisture contents. The temperature can then be increased along progress in drying and ascorbic acid becomes more stable due to reduction in moisture⁴. It was observed that ascorbic acid decreased with increase in storage time in all storage packs. Similar trend were also noticed for *Flammulina velutipes* mushrooms⁹ and for oyster mushrooms¹⁴ in an earlier investigation. This was probably due to permeability of moisture inside the packaging material, and oxidation reaction must have taken place in packages during storage of oyster mushroom flakes. The lowest ascorbic acid content of dehydrated sample was observed as 0.94 mg 100 g⁻¹ dried flakes for LDPE-A. However, the highest ascorbic acid content of stored sample was observed as 1.49 mg/100g in HDPE-R. The effect of storage temperature, duration of storage and packaging material on ascorbic acid content of stored product was observed and presented in Fig. 4.

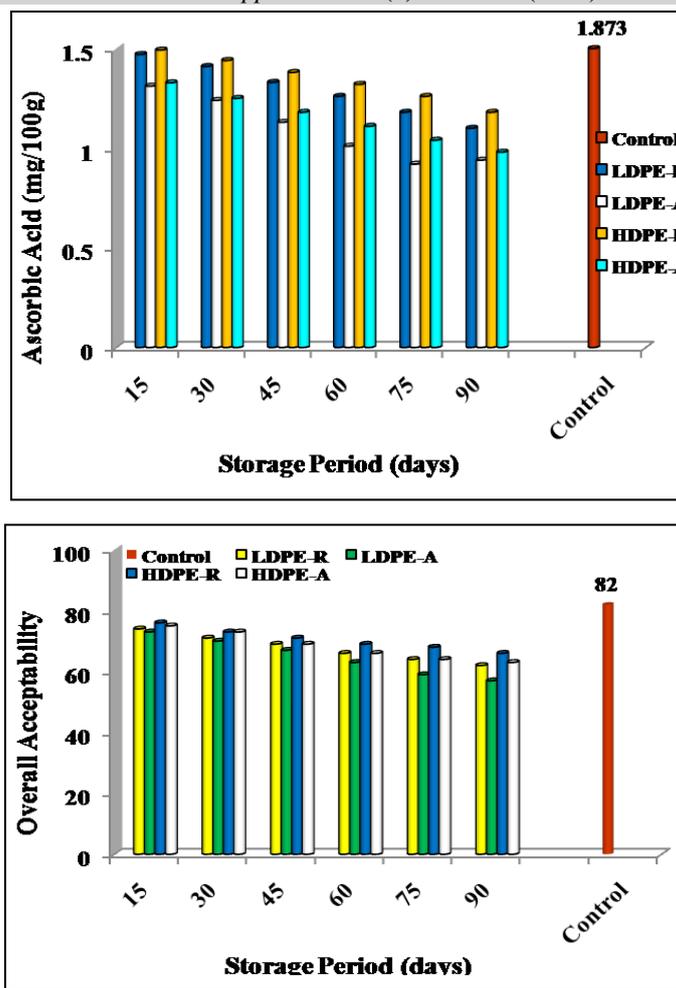


Fig. 4: Effect of packaging material, storage condition and duration on ascorbic acid and overall acceptability of dried mushroom flakes

Overall acceptability

Sensory or organoleptic scores indirectly signify product shelf-life and stability, which refers to the end of consumer acceptability, and is the time at which majority of consumers are displeased with the product quality¹². Darkening and loss of flavour are the major types of deteriorations of dried food products during storage. The major factors affecting storage stability are storage temperature, light, packaging material, moisture content, anti-microbial treatment and trace elements present in the dried product. Sensory evaluation of the dried mushroom flakes was carried out to obtain preliminary information on consumer preference. The osmo-cum-microwave dehydrated mushroom flakes was acceptable in all sensory quality parameters and showed a small decrease in overall acceptability values with change in packaging material and storage

temperature with passage of time. The highest product acceptability of was observed as 76% for HDPE-R and lowest as 57% (considering hedonic rating of 9=100 %; whereas 1=9 %) for LDPE-A after 15 and 90 days of storage respectively (Fig. 4). Nevertheless, the overall acceptability for all the samples reduced with storage duration. The effect of storage temperature, duration of storage and packaging material on ascorbic acid content of stored product was observed and presented in Figure 4. The CV was found to be 47.15. The CD was found to be non-significant between different packaging materials, along storage duration at different storage conditions.

CONCLUSION

Storage conditions are of vital importance in relation to maintenance of quality. Storage of dried products at relatively low temperatures

maximizes storage life. Packaging material used and the package environment is another major factor in terms of storage stability. Effects of packaging material along confined storage duration at different storage conditions on quality of dried oyster mushroom (*Pleurotus sajor-caju*) flakes were studied. Prior to storage mushrooms pre-treated with salt-sugar were dried by microwave drying technique to a moisture content of around 6 % (w.b.). Assessment of quality attributes; colour, texture, rehydration, moisture variation with storage duration, water activity, ascorbic acid and organoleptic evaluation was carried out systematically. These quality attributes contributes for overall consumer acceptability. Mushroom flakes stored in HDPE were also found be acceptable up to two months of storage that are stored under refrigerated condition, with minute changes in the quality attributes. However, mushrooms stored in LDPE lost the quality attributes after a month of storage.

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