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Effect of different drying methods on functional and sensory parameters of oyster mushroom (*Pleurotus florida*)

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Abstract
This study was conducted to evaluate the effects of different drying methods viz., sun, solar, oven (40 °C), microwave (300 W), freeze (-60 °C) and osmotic drying (14% salt solution followed by drying at 40 °C) on functional properties and sensory attributes of oyster mushroom. Significant differences in functional parameters (browning index, rehydration ratio, water solubility index and bulk density) and sensory attributes (appearance, aroma, texture and overall acceptability) were observed in response to different drying techniques. The least browning index of 0.22 was reported for freeze dried mushroom while as microwave dried oyster mushroom recorded highest browning index of 0.62. The study concluded freeze drying as most suitable method of preserving mushroom with rehydration ratio, water solubility index, bulk density and overall acceptability value of 5.21, 1.91 per cent, 0.31 g per ml and 8.09, respectively.

Keywords: Rehydration ratio, sensory attributes, bulk density, freeze drying, microwave drying

1. Introduction

Oyster mushroom also known as "*Dhingri*" in India is a protein enriched food cultivated on lignocellulosic wastes. The oyster mushroom proteins are good quality proteins with good balance of essential amino acids thereby having potential to overcome protein energy malnutrition prevalent in developing countries (Deepalakshmi and Mirunalini, 2014) [13]. Furthermore, these are low in fat (0.8-7%) and are loaded with vital vitamins, minerals and dietary fiber (Randive, 2012) [39]. *Pleurotus* mushrooms also serve as source of functional ingredients like alkaloids, phenols, terpenes and antioxidants that offer health promoting benefits and therefore can act as functional foods (Thatoi and Singhdevsachan, 2014) [42]. The unique flavour of these oyster mushrooms, make them an integral parts of various dishes (Dunkwal *et al*. 2007) [14]. However, presence of large amounts of water (80-85%) makes them highly perishable with shelf life of only 2-3 days which is further reduced at temperatures of 18 °C and above. Of all the preservation methods, drying is an important preservation technique which can be employed for long term preservation of oyster mushroom as it offers a number of advantages like low operating cost, mass and volume reduction of food product thereby minimizing packaging, handling, storage and transport costs (Arumuganathan *et al*., 2010) [9]. Drying is a unit operation involving simultaneous mass and heat transfer thereby reducing water activity and consequential shelf life extension. However, drying induces a no. of changes in physical and chemical composition of foods like colour deterioration, enzymatic changes, degradation of antioxidant components. A number of drying methods can be employed for preservation of oyster mushroom like oven drying, sun, solar, microwave osmotic and freeze drying. Each of these drying methods has got their own advantages and limitations specific to them. The uncontrolled operating condition like temperature and relative humidity during sun and solar drying accelerate the physical and chemical changes occurring in foods. The high temperatures employed during oven and osmotic drying though reduce the drying times but at the same time degrade heat sensitive components like vitamin C and antioxidants. The microwave drying despite being faster induces physical and textural changes in food materials. The freeze drying method employs vacuum and low temperatures thereby retaining physical and chemical properties of food but high cost and longer drying times associated limit its application (Izli, 2017) [20].

2. Materials and methods

2.1 Drying experiment Experimental design

The drying experiment was involved six drying methods (sun, solar, oven, microwave, freeze and osmotic drying) with details given in Table 1.

Table 1: Details of drying experiment

Treatment	Drying method	Temperature
T_1	Sun drying	Ambient
T_2	Solar drying	Ambient
T_3	Oven drying	40 ˚C
T_4	Microwave drying using Samsung CE137NEL microwave convective oven with the technical specifications of 230 V, 50 Hz and 3100 W.	40 ˚C
T_5	Freeze drying using a freeze drier (Martin Christ Type 101041) with chamber temperature of -60 °C, under vacuum (<13 Pa of total pressure) and a condenser temperature of -50 °C	-60 ˚C
T_6	Osmotic dehydration (brining) 14 per cent salt solution followed by oven drying	40 ˚C

2.1.1 Analysis of mushroom powder

2.1.1.1 Functional parameters

a) Browning index

Browning index (BI) of sample was determined according to the method used by Akhtar *et al*. (2015) [3].

b) Rehydration ratio

A method described by Lidhoo and Agrawal, 2008 was employed for determination of rehydration ratio of samples.

c) Water solubility index

Water solubility index of dried samples was determined in accordance to method used by Yousf *et al*., 2017 [45].

d) Bulk density

A method described by Amandikwa (2012) [6] was used for the determination of bulk density.

2.1.1.2 Sensory attributes

The samples were analyzed on the basis of appearance, aroma, texture and overall acceptability by semi-trained panel (10 judges; 5 Men & 5 Women) using 9 point hedonic scale assigning scores 9-like extremely to 1-dislike extremely.

2.1.1.3 Statistical analysis

The data pertaining to functional parameters was analysed statistically via completely randomized design (CRD) with three replications using Opstat software while as Sensomaker software based on principal component analysis was employed for analysis of data corresponding to sensory attributes.

3. Result and Discussion

3.1 Functional parameters of oyster mushrooms as affected by different drying methods

A glance of Fig.1 (a-d) reflects the impact of different drying methods on functional parameters of oyster mushroom.

a) Browning index

The different drying methods resulted in browning of oyster mushrooms to different extent. The least browning index value of 0.22 was observed in oyster mushrooms subjected to freeze drying followed by mushrooms subjected to osmotic, oven, solar, sun and microwave drying [Fig 1(a)]. The results are consistent with the findings of Karaman *et al*. (2014) [23] reporting least browning index value in freeze dried persimmon in comparison to oven dried samples. The browning in foods might be the result of action of polyphenolase enzyme acting on phenolic components or due to brown pigments resulting from maillard reaction or because of pigment degradation (Perera, 2005) [36]. In freeze drying presence of vacuum and low temperature limit such browning reactions giving low values of browning index. The highest browning index value of 0.62 was reported in microwave dried sample which might be because of disintegration of cellular structure causing pigment breakdown and consequential browning (Inchuen *et al*., 2010) [19]. These results coincide with the findings of Coklar *et al*. (2018) [12] reporting higher value of browning index in microwave dried hawthorn fruits. The sun dried samples depicted higher value of browning index in comparison to oven dried samples which might be because of uneven temperature and prolonged drying times associated with sun drying. Furthermore, during oven drying, the high temperatures employed inactivate the enzyme responsible for browning thereby resulting in less browning (Ali *et al*., 2016) [5]. The osmotic dried oyster mushroom depicted less browning index than oven dried samples coinciding with the findings of Sharma and Bhat (2018) [40] which might be because of leaching out of soluble substances producing brown colour when acted upon by enzyme polyphenol oxidase (Kaur *et al*., 2014) [24].

b) Rehydration ratio

Rehydration ratio is an important quality parameter of dehydrated foods. It is an indicator of physical and chemical changes occurring during drying. The impact of different drying methods on rehydration characteristics is presented in [Fig 1(b)]. The highest rehydration ratio of 5.21 was found in freeze dried mushroom which could be attributed to its porous and intact cell structure resulting from direct sublimation of frozen moisture to vapour (Argyropoulos *et al*., 2011) [8]. The oven dried mushroom powder exhibited higher rehydration ratio of 3.19 in comparison to sun and solar dried mushrooms accounting to rehydration ratio of 2.86 and 2.93, respectively. The higher rehydration in oven dried mushroom than the solar and sun dried mushroom might be because of uniform and efficient heat transfer and faster water removal causing less damage to cellular structure (Bin Hameed *et al*., 2016) [10]. The rehydration ratio of osmotic dried sample was found to be lower than oven dried sample which might be because of increased bulk density and lower porosity resulting from solute uptake. This is similar to findings of Lewicki *et al*. (1998) [29] reporting lesser rehydration in osmotic dried onion than the hot air and microwave assisted convection drying. According to Kim and Toledo (1987) [25] decrease in the rehydration ratio of osmotic dried rabbit eye blueberries with the increase in osmotic treatment might be because of solid gain during osmotic dewatering. The rehydration ratio of microwave dried mushrooms was found to be less than oven dried mushrooms which might be because of irreversible disruption of cellular structure caused by microwaves (Munaza, 2018) [33]. These findings are in agreement with the results of Maskan (2001) [32] reporting higher rehydration capacities in oven dried kiwi fruit slices than the microwave dried. Kumar and Barmanray (2007) [28] reported that the formation of outer crust (case hardening) due to very high temperatures resulting from microwave result in lesser rehydration capacity of button mushrooms in comparison to sun and solar dried samples thus confirming our results.

c) Water solubility index (WSI)

Water solubility index is an important parameter determining the behaviour of dried materials in an aqueous phase and serve as important criterion for determining the reconstitution quality (Jafari *et al*., 2017) [22]. Water solubility index reflects the starch degradation during processing; the greater the solubility index the greater is the starch degradation (Que *et al*., 2008) [38]. The freeze dried mushroom powder exhibited highest value of least value of water solubility index (1.91%) [Fig 1(c)]. Hsu *et al*. (2003) [17] and Que *et al.* (2008) [38] while carrying out studies on yam and pumpkin flours, respectively reported higher least water solubility index values for freeze dried samples than the oven dried mushroom confirming our results. This might be because of low temperatures employed during freeze drying than the oven drying leading to lesser starch degradation (Sruthi and Shanmugam, 2017) [41]. The highest water solubility index (3.21%) was reported in osmotic dried oyster mushroom followed by microwave, oven, solar, sun and freeze dried samples. The microwave dried samples reflected higher water solubility index than the oven dried mushrooms consistent with the findings of Abou-Arab *et al*. (2017) [1] investigating impact of drying methods on water solubility index of citrus peel. The microwave treatment might have resulted in molecular rearrangement leading to lesser interaction between starch granules and water resulting in greater solubility index (Uthumporn *et al*., 2016) [43]. In comparison to sun and solar dried samples, oven dried oyster mushroom exhibited higher water solubility index values consistent with the findings of Hussein *et al*. (2016) [18] in tomatoes. This might be because of weakening of micellar structure of starch during high temperatures of oven drying (Akintunde and Tunde-Akintunde, 2013) [4]. Furthermore, maillard reaction is more prominent during sun and solar drying that involves reaction between reducing sugars and free amino acids thereby making them unavailable for degradation and leading to lower water solubility index values (Hussein *et al*., 2016) [18]. The osmotic dried samples reflected higher water solubility index than the oven dried samples which might be because of the changes in cellular structure in response to osmotic treatment.

d) Bulk density

The bulk density of a food material influences the selection and design of storage and packaging material. The bulk density is affected by the size, density and geometry of individual particle (Kolawole *et al*., 2016) [27]. The drying process resulted in decrease in bulk density of oyster mushroom which is similar to findings of Jadhav and Patil, (2008) [21]. During drying the lower values of bulk density are indicators of lower shrinkage and better retention of textural properties (Gong *et al*., 2007) [16]. The bulk density values ranged from 0.31 to 0.73 g per ml [Fig 1(d)]. The minimum value of bulk density (0.31 g/ml) was recorded for freeze dried oyster mushroom followed by microwave, oven, osmotic, solar and sun dried oyster mushrooms. Caliskan *et al*. (2015) [11] while investigating the impact of different drying methods on bulk density of kiwi fruit also reported least bulk density values for freeze dried samples than the microwave dried samples, confirming our findings. Giri and Prasad (2009) [15] reported least bulk density value for freeze dried button mushroom than the microwave-vacuum and air dried ones similar to the results of present study. Liu *et al*. (2017) [31] while comparing the effect of freeze drying and oven drying on bulk density of orange peel dietary fiber reported lower bulk density values in freeze dried samples than the air dried ones. In freeze drying, the least bulk density values might be associated with sublimation of frozen moisture directly to vapour resulting in porous structure, minimum shrinkage and better retention of shape (Argyropoulos *et al*., 2011) [8].

The lower bulk density value of microwave dried oyster mushroom than oven dried mushroom powder coincide with the observations of Aghilinategh *et al*. (2015) [2] while investigating the effect of oven and microwave drying on bulk density of apples. This might be because of the volumetric heating during microwave drying that causes increased vapour pressure gradient responsible for expansion or puffiness in the product (Giri and Prasad, 2009) [15]. The osmotic dried oyster mushroom exhibited higher bulk density values than the oven dried mushroom thus indicating greater shrinkage which might be because of greater water loss and uptake of salt during osmotic treatment that occupy external pores and consequently lead to higher bulk density value (Koc *et al*., 2008) [26]. The highest bulk density value was recorded for sun dried oyster mushrooms quite consistent with the findings of Ogunlakin *et al*. (2012) [35] reporting highest bulk density value in sun dried yam flour than oven dried flour. This might be because of greater moisture content in sun and solar dried samples as a result of which particles adhere to each other leaving greater interspace and consequently a greater bulk volume. Furthermore, prolonged drying periods in sun and solar drying might have led to greater shrinkage and textural changes (Amandikwa, 2012) [6]. Hussein *et al.* (2016) [18] also reported lower bulk density values for hot air dried samples than the sun and solar dried tomatoes.

3.2 Sensory attributes as affected by different drying methods

The different drying methods affected the sensory attributes of oyster mushroom to different extents (Fig. 2). The mean sensory scores of appearance, aroma, texture and overall acceptability were found to be least for microwave dried sample. The overall acceptability of 6.55 was reported in microwave dried sample while as highest overall acceptability value of 8.09 was recorded for freeze dried oyster mushroom. This is in good agreement with the findings of Naik *et al.* (2006) while investigating impact of different drying methods on sensory qualities of oyster mushroom. The collapse of cellular structure resulting from intense heat during microwave drying might be responsible for reduced sensory quality (Phongsomboon and Intipunya, 2009) [37]. The higher scores for sensory attributes in freeze dried oyster mushroom might be because of sublimation of ice under vacuum retaining the original structure and aroma of product (Arumuganathan *et al*., 2010) [9]. Furthermore, the porous structure of freeze dried mushrooms resulted in luminous and brighter product due to greater reflection of light thereby leading to better appearance (Phongsomboon and Intipuniya, 2009) [37]. The mean overall acceptability values of sun and solar dried mushroom powders were recorded to be 7.12 and 7.26, respectively that were lower than the mean overall acceptability value of 7.38 as reflected by oven dried mushroom powder. Anu *et al.* (2011) [7] while investigating the impact of different drying methods on organoleptic properties of oyster mushroom reported least scores of sensory attributes in sun dried mushroom than oven dried sample confirming our results. The dirt, insects and temperature fluctuations associated with sun and solar drying accelerated the undesirable enzymatic and non- enzymatic reactions leading to colour, aroma and textural changes (Dunkwal *et al.*, 2007) [14]. The osmotic dried oyster mushroom in contrast to oven dried exhibited higher appearance score which might be because of leaching of soluble substances acting as substrate for enzymatic action responsible for colour change (Velickova *et al.*, 2014) [44]. The osmotic drying resulted in lower (7.34) score for texture than the oven dried sample which might be attributed to solute uptake during osmosis that leads to hardness and textural changes (Arumuganathan *et al.*, 2010) [9].

4. Conclusion

Amongst the different drying methods, freeze dried mushroom powder depicted least browning index value of 0.22 while as highest browning index of 0.62 was recorded in microwave dried oyster mushroom. The freeze drying in contrast to other drying methods gave better results in terms of rehydration ratio corresponding to value of 5.21 indicating lesser structural damage. On the basis of sensory attributes, the highest scores for appearance (8.00), aroma (8.12), texture (8.16) and overall acceptability (8.09) were recorded in freeze dried oyster mushroom while as microwave dried oyster mushroom in contrast to other samples recorded least scores for colour (6.19), aroma (6.59), texture (6.87) and overall acceptability (6.55).

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