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Impact of different drying methods on proximate and mineral composition of oyster mushroom (*Pleurotus florida*)

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Mushrooms well known for their delicacy and flavor are highly perishable due their high moisture content. In this study the changes in proximate and mineral components of oyster mushroom in response to 6 drying methods, viz., sun, solar, oven, microwave, freeze and osmotic drying were studied. The moisture and ash content of dried oyster mushrooms ranged from 8.84 to 5.16% and 8.12 to 9.37%, respectively. The highest crude protein of 23.74% was recorded for freeze dried oyster mushroom while as highest crude fiber content of 25.38% was found in microwave dried samples. On comparing the mineral content of dried oyster mushroom, freeze dried oyster mushroom recorded highest iron, calcium, magnesium, potassium content of 5.10, 16.12 and 2309.01 mg/100 g, respectively while least iron, magnesium and potassium content of 3.80, 15.06 and 1394.38 mg/100 g, respectively was observed in sun dried oyster mushroom. The study concluded better retention of proximate components in freeze dried oyster mushroom while as sun drying resulted in greater loss of nutrients. The best dried oyster mushroom can be used in formulation of functional foods conferring health benefits.

Keywords: Freeze drying, Microwave drying, Osmotic drying, Oyster mushroom

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Oyster mushrooms are edible fruiting fungi associated with the genus *Pleurotus* and are popularly known as *dhingri* in India. Oyster mushroom belongs to class Basidomycetes and family Agaricaceae. The *Pleurotus* genus is comprised of about 40 species but *P. ostreatus*, *P. florida*, *P. eryngii*, *P. tuberegium* and *P. sajor-caju* are common ones[1]. Oyster mushrooms are rich source of proteins (17-42%) containing all the essential amino acids[2]. These mushrooms are low in fat ranging from 0.8-7.0% depending upon species. Furthermore these mushrooms act as a good source of non-starchy carbohydrates and dietary fiber and are rich in minerals and vitamins[3]. However, the presence of large amount of moisture in *Pleurotus* mushrooms makes them highly susceptible to spoilage with a shelf life of only 2-3 days.

Dehydration is a traditional method of food conservation, based on the principle that the reduction of the water activity during drying inhibits microbiological and physicochemical changes responsible for spoilage[4]. A number of methods can be employed for drying of oyster mushrooms, sun and solar drying being traditional ones. The sun and solar drying have disadvantages of fluctuating temperature, uncontrolled humidity and unhygienic conditions resulting in poor quality food products[5]. The conventional oven drying is one of the economical and controlled ways of drying, but at a higher temperature, it may lead to deterioration of colour and heat labile nutrients like vitamin C. Microwave drying is also gaining popularity nowadays due to uniform energy distribution and short drying time while it has some disadvantages like changes in texture and irregular heating[6]. Osmotic dehydration is employed for partial removal of water from food materials by steeping them in aqueous solutions of high osmotic pressure such as sugar and salts followed by conventional drying. The main disadvantages of osmotic drying are leaching of soluble components from food material into steeping solution and longer drying times. The freeze drying method based on the principle of sublimation employs low temperature and vacuum thereby preserving natural colour, maximum nutrients, original flavour, texture and aroma of food products[5]. Freeze drying minimizes lipid oxidation and degradation of bioactive components and is therefore, applied for long-term storage of foods on industrial scale[7].

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Materials and methods

Drying of oyster mushroom

Freshly harvested oyster mushrooms (*Pleurotus florida*) were obtained from the Division of Plant Pathology, SKUAST-Jammu. The procured oyster mushrooms were trimmed and washed thoroughly under running water to remove adhering soil and dirt. The washed mushrooms were drained and sliced into small pieces (about 3 mm thickness). The oyster mushroom slices (500 g) were then divided into six lots and subjected to different drying methods as given below (Table 1)

Analysis of proximate and mineral composition

The moisture, crude protein, crude fat, crude fiber and total ash content of dried oyster mushroom were determined according to AOAC[8]. The mineral contents (Potassium, phosphorus, magnesium, calcium and iron) were determined after the ash determination as per AOAC[8] procedure. The ash residue of each formulation was digested with perchloric acid and nitric acid (1:4) solution. The samples were left to cool and contents were filtered through Whatman filter paper 42. Each sample solution was made up to a final volume of 25 mL with distilled water. The aliquot was used separately to determine the mineral contents of potassium, phosphorus, calcium, magnesium and iron by using an Atomic Absorption Spectrophotometer (Spectra AA 220, USA Varian).

Statistical analysis

The results obtained were statistically analyzed using completely randomized design (CRD) and through analysis of variance (ANOVA). The significance of treatments was calculated at 5% probability level.

Table 1 — Drying procedures of oyster mushroom

Treatment	Drying method	Temperature
T_1	Sun drying	Ambient
T_2	Solar drying	Ambient
T_3	Oven drying	40˚C
T_4	Microwave drying	40˚C
T_5	Freeze drying	-60˚C
T_6	Osmotic dehydration (brining) 14 per cent salt solution	40˚C

Results and discussion

Proximate components

All the drying methods resulted in a steep decline in moisture content of oyster mushrooms. The highest moisture content of 8.84% was found in sun dried sample followed by solar dried sample depicting moisture content of 8.08% (Table 2). The moisture content of 7.32% was found in oven dried oyster mushroom lower than sun and solar dried ones which is in agreement with the findings of Maray *et al*.[9]. This might be because of fluctuating temperature and relative humidity during sun drying than oven drying that employs uniform temperature for effective moisture removal Muyanja *et al*.[10]. In contrast to oven dried oyster mushroom, osmotic dried mushrooms exhibited lower moisture content of 6.23% which might be because of greater water loss during osmosis[11,12]. Freeze drying involves sublimation of frozen moisture to direct vapours resulting in greater water loss in contrast to other drying methods. The results are compatible with the findings of Hsu *et al*.[13] and Ali *et al*.[5] reporting greater water loss in freeze drying in contrast to other drying methods in yam and guava, respectively confirming our results.

The different drying techniques had a significant impact on the crude protein content of oyster mushrooms (Table 2). The freeze dried oyster mushrooms had higher crude protein content (23.74%) followed by oven dried oyster mushroom that exhibited crude protein content of 22.86% while as least crude protein content was recorded in sun and osmotic dried oyster mushroom consistent with the results of Oni *et al*.[14] and Munaza[15] while studying the effect of different drying methods on various botanicals and quince, respectively. During oven drying, the higher temperature employed might be

Table 2 — Effect of drying methods on proximate composition of oyster mushroom

Drying methods	Moisture (%)	Crude protein (%)	Crude fat (%)	Crude fiber (%)	Total ash (%)
T_1 (Sun drying)	8.84	20.36	3.46	24.09	8.12
T_2 (Solar drying)	8.08	21.05	3.54	24.15	8.27
T_3 (Oven drying)	7.32	22.86	3.89	25.26	8.48
T_4 (Microwave drying)	6.97	22.54	3.68	25.38	8.36
T_5 (Freeze drying)	5.16	23.74	4.06	25.01	8.82
T_6 (Osmotic drying)	6.23	21.79	3.72	22.83	9.37
Mean	7.10	22.06	3.73	24.45	8.57
$CD_{0.05}$	0.11	0.90	0.09	0.17	0.14

responsible for protein denaturation and consequential protein loss in contrast to freeze drying resulting in better crude protein retention[11, 16]. The uniform exposure and short drying times associated with oven drying might be responsible for lesser protein deterioration in contrast to sun and solar drying[17]. Ngabo *et al*.[18] while investigating the impact of drying methods on protein content of mushrooms reported higher protein content in mushroom subjected to freeze drying than the mushrooms subjected to osmotic treatment and oven drying thus confirming our results. The crude protein content of microwave dried mushroom was found to be less than oven dried samples which might be because of accelerated browning reactions involving proteins accounting to protein loss. Similar results were reported by Meng *et al.*[19] in *Dendrobium officinale*. The crude protein content of osmotic dried mushroom was found to be less than the mushroom subjected to oven drying quite consistent with the findings of Tolera and Abera[11] reporting low protein content in osmotic treated oyster mushroom than the oven dried mushroom. The leaching of low molecular weight soluble protein fractions during steeping step of osmotic treatment might be responsible for greater reduction in crude protein[9].

Oyster mushrooms are very low in fat content. The data presented in Table 2 reflects the impact of different drying methods on crude fat content of oyster mushrooms. The drying methods caused a decrease in crude fat content of oyster mushrooms which might be attributed to oxidative losses as mushroom fat is mainly composed of polyunsaturated fatty acids mainly susceptible to oxidation when mushroom slices are exposed to drying medium[10]. The freeze drying method retained higher amount of crude fat content (4.06%) in contrast to other drying methods similar to results of Oni *et al*.[14] reporting better crude fat retention in freeze dried edible botanicals in contrast to sun and oven drying. The lesser crude fat loss in shitake mushrooms (*Lentinusedodes*) was reported by Duan and Xu[20] subjected to freeze drying in comparison to oven, microwave and sun drying thus confirming our results. The osmotic dried oyster mushroom in contrast to oven dried samples exhibited lower crude fat content coinciding with the results reported by Tolera and Abera[11] while studying the impact of different drying methods on quality of oyster mushrooms. The greater decrease in crude fat content during osmotic drying might be attributed to leaching losses taking place during steeping[21]. The microwave dried oyster mushroom in contrast to oven dried mushroom reflected a low crude fat content of 3.68%. The greater decrease in crude fat content of microwave dried oyster mushrooms could be attributed to fat oxidation and fatty acid isomer formation (trans fat) resulting from microwaves[22,23]. Similar effect of microwave drying on crude fat content was reported by Inchuen *et al*.[24] during microwave drying of Thai red curry.

The dried oyster mushrooms exhibited crude fiber content in the range of 22.83 to 25.38% (Table 2). These values are in accordance with the values reported by Alam *et al*.[25] in dried *Pleurotus florida* mushroom. The crude fiber content followed the order of microwave dried oyster mushroom>oven dried oyster mushroom>freeze dried oyster mushroom>solar dried oyster mushroom>sun dried oyster mushroom>osmotic dried oyster mushroom. These results are in line with the findings of Morais *et al*.[26] reporting higher crude fiber in peels of oven dried avocado and melons than the samples subjected to freeze drying. Sengupta *et al*.[27] and Chauhan *et al*.[28] also reported higher crude fiber in microwave dried okra and *karonda*, respectively, than oven dried one thus confirming our results. This might be because of the increased susceptibility of lignocellulosic substances to enzymatic activity in response to microwaves[29]. The crude fiber content of sun and solar dried samples were found to be 24.09 and 24.15%, respectively which is less than the oven dried mushroom. Similar results were reported by Aishah and Rosli[30] and Tolera and Abera[11] while studying the effect of sun and solar drying in oyster mushroom. The oven drying method in comparison to sun and solar drying methods might be responsible for greater cellular disruption leading to greater susceptibility to enzymatic activity thereby increasing the crude fiber content[31]. The osmotic dried oyster mushroom exhibited lower crude fiber content in contrast to oven dried sample consistent with the findings of Omolayo *et al*.[32] and Tolera and Abera[11] reporting decrease in crude fiber content with the osmotic treatment in bitter leaf (*Vernonia amygdalina*) and oyster mushroom, respectively. This might be attributed to changes in cellular structure like degradation of pectin and diffusion of solutes during osmotic treatment[21].

On assessing the effect of drying methods on the ash content, the highest total ash content was reported in osmotic dried mushroom corresponding to a value of 9.37% (Table 2). Similar results were reported by Sharma and Bhat[12] while studying the impact of different drying methods on total ash content of oyster mushrooms. This might be because of diffusion of sodium ions from brining/steeping solution into mushroom slices during steeping process as water migrates out of mushroom slices[9]. The total ash content of freeze dried sample was found to be higher (8.82%) than the oven and microwave dried samples reflecting total ash values of 8.48 and 8.36%, respectively. This might be because of low temperatures and vacuum employed during freeze drying resulting in better retention of minerals and thereby giving higher values of total ash[33]. Hsu *et al.*[13] reported higher ash content in freeze dried yam flourin comparison to oven dried samples compatible with our findings. Ajayi *et al*.[34] reported higher ash content in oven dried ginger than microwave dried samples indicating higher mineral losses during microwave drying similar to our results. The formation of stable compounds such as aluminium or ferric oxides in response to microwaves might be responsible for greater mineral loss and consequential low ash content of microwave dried oyster mushroom than the oven dried one[35]. The sun dried oyster mushrooms reflected least value of total ash corresponding to value of 8.12 per cent. Eissa *et al*.[36] reported low ash content inzucchini (green squash) rings subjected to sun drying than the oven drying thus confirming our findings. Ukegbu and Okereke[37] while comparing the effect of sun and solar drying on total ash content of okra reported higher values for sun dried samples than the solar dried samples similar to our findings. The relatively lower ash contents of sun and solar dried oyster mushroom in contrast to other drying methods might be attributed to prolonged exposure to air and the fluctuating temperature and humidity leading to greater mineral loss[38]. Similar results were reported by Muyanja *et al*.[10] in oyster mushroom, Chauhan *et al*.[28] in *karonda* and Wijewardana *et al*.[39] in *bael* fruit.

Mineral components

The different drying methods affected the mineral content of oyster mushroom to different extents (Table 3). The freeze dried mushrooms displayed higher values of mineral components than the oven dried oyster mushroom quite consistent with the findings of Tyagi and Pal[40] reporting higher values of calcium, magnesium, phosphorus and iron content in freeze dried *amla* fruit in contrast to samples subjected to other drying techniques. The higher retention of minerals in freeze dried oyster mushroom might be because of low temperature and vacuum employed that minimised the biochemical and microbial reactions leading to mineral losses. Furthermore the greater loss of minerals in oven dried mushroom in contrast to freeze dried samples could be co-related with the biochemical modifications like occurrence of side reactions induced by high temperature[33]. Microwave drying resulted in lesser mineral retention than the oven drying which is similar to the results reported by Arslan *et al*.[35] while working on peppermint. This might be because of incidence of side reactions leading to formation of stable metallic oxides like iron oxide resulting in their losses and better solubility of minerals in oven drying because of convective energy linked with the oven drying[35]. The osmotic dried mushrooms reflected minerals in lesser amounts than the oven dried samples which might be because of leaching of minerals from cell membranes of food matrix during osmotic treatment[41]. The least mineral content was recorded for sun dried samples consistent with the findings of Leghari *et al*[42] reporting higher amounts of calcium in oven dried mango powder than the sun dried one. Eissa *et al*.[36] reported higher iron content in oven dried green squash rings than the solar dried

Table 3 — Effect of drying methods on mineral content of oyster mushroom

Drying methods	Potassium (mg/100 g)	Phosphorus (mg/100 g)	Magnesium (mg/100 g)	Calcium (mg/100 g)	Iron (mg/100 g)
T_1 (Sun drying)	1394.38	597.86	15.06	3.09	3.80
T_2 (Solar drying)	1539.81	599.81	15.43	3.12	3.92
T_3 (Oven drying)	1769.25	604.19	15.63	5.38	4.69
T_4 (Microwave drying)	1674.89	601.96	15.59	5.08	4.12
T_5 (Freeze drying)	2309.01	609.92	16.12	6.78	5.10
T_6 (Osmotic drying)	1619.12	601.91	15.16	4.09	3.98
Mean	1717.74	602.61	15.50	4.59	4.27
$CD_{0.05}$	6.69	2.28	0.08	0.06	0.04

sample similar to our results. Chauhan *et al*.[28] also reported higher calcium, phosphorus and iron content in microwave dried *karonda* fruit than the sun dried one hence supporting our findings. The higher mineral content was reported for solar dried sample than the sun dried sample which might be because of higher temperature, lower humidity and shorter drying time in solar drying than the sun dried mushroom. Similar trend was reported by Ukegbu and Okereke[37] while comparing the mineral content of amaranth leaves affected by sun and solar drying.

Conclusion

Drying is a traditional method of food preservation. Depending on the operational conditions of different drying methods losses to different extent occur in nutrients. The freeze drying employs low temperatures and vacuum resulting in lesser nutrient loss while as sun drying because of fluctuating environmental conditions result in greater loss. The dried oyster mushroom can serve as functional ingredient and can be employed for preparation of various value added products.

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