Biotechnological Communication

Physical and Antioxidant Properties of Oyster Mushroom *Pleurotus florida* in Response to Different Drying Methods

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ABSTRACT

Drying is a traditional unit operation employed for shelf-life extension of perishable food item. Oyster mushroom being a potent source of bioactive components is highly perishable owing to its high moisture content. The aim of this work was to extend the shelf life of oyster mushroom and to preserve its bioactive components. In this study the impact of different drying methods on physical and bioactive components was analysed. The prepared mushroom slices were subjected to different drying methods viz., sun, solar, oven (40°C), microwave (300 W), freeze (-60°C) and osmotic drying (14% salt solution). The highest and lowest L* value of 81.02 and 58.19 were recorded for freeze and microwave dried oyster mushroom, respectively. All the drying methods caused a significant reduction in the water activity (aw) which is the principle underlying the preservation by drying. The least water activity (0.45) was recorded for freeze-dried oyster mushroom, while as sun dried sample depicted highest value (0.62). The reduction in water activity in response to drying methods followed the order as Freeze drying<Osmotic drying<Microwave drying<Oven drying<Solar drying<Sun drying. The antioxidant potential in terms of total phenols, total flavonoids, DPPH scavenging activity (IC50) and reducing power (EC_{50}) was found to be highest for freeze-dried oyster mushroom corresponding to values of 408.562 mg GAE/100g, 146.231 mg QE/100g, 0.068 mg/ml and 0.142 mg/ml, respectively. All the drying methods affected physical and bioactive components significantly. The freeze dying resulted in better retention of antioxidant potential and colour attributes of oyster mushroom in contrast to other drying methods.

KEY WORDS: DPPH SCAVENGING ACTIVITY, FREEZE DRYING, MICROWAVE DRYING, REDUCING POWER.

INTRODUCTION

Oyster mushroom, a popular food product, is a rich source of proteins containing all the essential amino acids. It belongs to class Basidomycetes and family Agaricaceae with *P. ostreatus, P. florida, P. eryngii, P. tuberegium* and *P. sajor-caju* being common species (Kues and Liu 2000; Deepalakshmi and Mirunalini 2014). These mushrooms are low in fat (0.8-7%) and serve as an excellent source of non-starchy carbohydrates, dietary fiber, minerals and vitamins. Pleurotus mushrooms apart from providing traditional nutrients offer health promoting benefits due to the presence of biologically active substances like alkaloids, phenols, terpenes, antioxidants and, consequently, are regarded as functional foods. They also exert anti-diabetic, anti-carcinogenic and hepatoprotective benefits when consumed (Randive 2012; Thatoi and Singhdevsachan 2014; Maheshwari et al. 2020).

However, the 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 (Randive 2012; Thatoi and Singhdevsachan 2014; Maheshwari et al. 2020). 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; Piskov et al. 2020).

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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 the preservation of oyster mushroom like oven drying, sun, solar, microwave osmotic and freeze drying (Piskov et al. 2020). 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, reduce the drying times but at the same time degrade heat sensitive components like vitamin C and antioxidants (Gąsecka et al. 2020). The microwave drying, despite being faster, induces physical and textural changes in food materials (Bashir et al. 2020).

The freeze drying method employs vacuum and low temperatures thereby retaining physical and chemical properties of food, but the associated high cost and longer drying times limit its application (Izli 2017). A study carried out by Ucar and Karadag (2019) concluded freeze drying as most the favourable methods for retention of physical components in contrast to vacuum drying. However,5 the studies comparing impact of the six drying methods (sun, solar, oven (40°C), microwave, freeze and osmotic drying on the bioactive and physical components of oyster mushroom (*P. florida*) are limited (Izli 2017; Ucar and Karadag 2019). The purpose of the study was to compare the effect of six different drying methods (sun, solar, oven (40°C), microwave, freeze and osmotic drying) on quality parameters of oyster mushrooms with focus on bioactive components.

MATERIAL AND METHODS

Freshly harvested oyster mushrooms (*Pleurotus florida*) were obtained in a single lot 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 (Bashir et al. 2020). The oyster mushroom slices (500g) were then divided into six lots and subjected to different drying methods as given in Table 1. The moisture loss of samples was recorded periodically with an electronic moisture analyzer (Citizon MB 50C). The colour attributes (L*, a*, b*) of samples were measured in accordance with the method described in the past (Roueita et al. 2020). The water activity of samples was measured as per the method of AOAC, 2005 using an Aqualab water activity meter (Model series 3TE) with the readings corrected at 20°C. For determination of anti-oxidant components, a methanolic extract of samples was prepared according to the method described in previous studies (Jeena et al. 2014; Roueita et al. 2020).

Table 1. Details of drying experiment

Treatment	Drying method	Temperature
T1	Sun drying	Ambient
T2	Solar drying	Ambient
T3	Oven drying	40˚C
T4	Microwave drying using Samsung CE137NEL microwave convective oven with the technical specifications of 230 V, 50 Hz and 3100 W.	40˚C
T5	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
T6	Osmotic dehydration (brining) 14 per cent salt solution followed by oven drying	40˚C

The anti-oxidant activity in terms of free radical scavenging activity (IC_{50}; mg/ml) and Reducing power (EC_{50}; mg/ml) was estimated as per methods described by Jeena et al. (2014) and Mujic et al. (2009), respectively. The Folin-Ciocalteau (FC) method based on electron transfer as given by Ahmed and Abozed (2015) was employed for estimation of total phenolic content of samples. A suitable calibration curve prepared from different concentrations of standard Gallic acid solution was prepared, and the total phenolic content of samples was expressed as mg Gallic acid equivalents (GAE) per gram of sample. A method described by Dewanto et al. (2002) was used for quantification of the total flavonoid content of sample extract using standard calibration curve of Quercetin and was expressed as mg Quercetin (QE) per gram of sample. Statistical analysis was carried out using Opstat software. A completely randomized design with three replications with three sub-samples of all experiments was carried out. Significant differences between different drying methods were determined at the significance level of $p<0.05$ (Dewanto et al. 2002; Mujic et al. 2009; Jeena et al. 2014; Ahmed and Abozed 2015; Bashir et al. 2020).

RESULTS AND DISCUSSION

Physical parameters: Colour: In dried foods colour is a quality indicator as it gives an idea related to the comparative change in colour of fresh and dried material

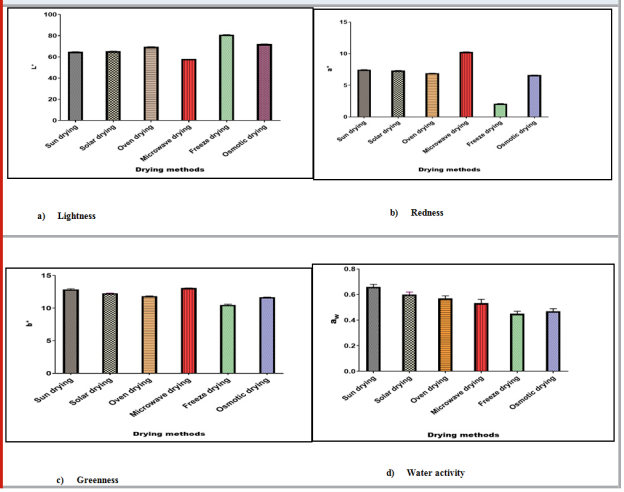
(Bansal et al. 2013; Xu et al. 2021). The different drying methods resulted in decrease in L* (lightness), an increase of a * (greenness) and b* (redness) values [(Figure 1 (a), (b) and (c)]. This is in accordance with the findings of previous studies (Duan and Xu 2015). During the drying process, the colour changes in oyster mushroom could be correlated with enzymatic and non-enzymatic (maillard) reactions. The freeze-dried samples exhibited the highest (81.02) L* value followed by osmotic, oven, sun, solar and microwave dried mushrooms. The least a* value (2.09) was reported in freeze-dried oyster mushroom followed by osmotic, oven, solar, sun and microwave dried mushroom powders.

The highest b* (12.89) value was reflected by sun dried oyster mushroom and the least b* (10.41) was recorded for freeze-dried sample. The b* value of osmotic, oven, solar, sun and microwave dried mushroom was recorded in increasing order corresponding to values of 11.68, 11.85, 12.29, 12.89 and 13.09, respectively. The least colour change was reflected by freeze-dried oyster mushroom while microwave dried mushroom exhibited the highest colour change. Ali et al. (2016) while working on guava drying reported similar results of minimum colour change in freeze-dried samples followed by oven, sun and microwave dried guava slices (Duan and Xu 2015; Ali et al. 2016; Xu et al. 2021). Coklar et al. (2018) also reported greater colour change in microwave and oven-dried hawthorn fruit than freeze-dried. The minimum colour changes during freeze-drying might be because of the sublimation of frozen ice directly to vapour, reduced availability of oxygen and inactivation of polyphenoloxidase enzyme due to low temperature preventing enzymatic browning reactions thereby stabilizing colour (Henriquez et al. 2013). The osmotic dried oyster mushrooms in comparison to oven-dried mushrooms were less dark in colour exhibiting higher values of L* and lower a* and b* values (Henriquez et al. 2013; Coklar et al. 2018; Nowak and Jakubczyk 2020).

The solute uptake during osmotic treatment reducing oxygen transfer to surface results in lesser oxidation of colour pigments and leaching of soluble substances during steeping step of osmotic drying that otherwise act as a substrate for browning reactions might be responsible for better colour retention in osmotic dried oyster mushroom (Velickova et al. 2014). Kaur et al. (2014) while working on osmotic convective drying of oyster mushrooms also reported that osmotic treatment resulted in better retention of colour. The sun and solar dried oyster mushrooms reflected greater colour change than the oven-dried sample, which might be because of the accelerated browning reactions, mainly oxidation of phenolic compounds by polyphenolase enzyme catalysed UV- radiations of sun light (Ginat and Alghamdi 2013; Kaur et al. 2014; Nowak and Jakubczyk 2020).

Furthermore, in comparison to sun and solar drying, higher temperatures employed during oven drying might have resulted in inactivation of enzyme catalysing browning reactions (Karabulut et al. 2007). The sun-dried samples exhibited lesser colour change than the microwave dried samples similar to findings already available, while studying colour changes in apricot pestil in response to different drying treatments (Suna et al. 2014; Nowak and Jakubczyk 2020).

Figure 1: Effect of different drying methods on physical parameters of oyster mushroom



Water activity (aw): The different drying methods decreased the water activity of oyster mushrooms to different levels represented in Figure 1(d). The least water activity (0.45) was reflected by freeze-dried oyster mushroom followed by osmotic and microwave dried oyster mushrooms corresponding to values of 0.47 and 0.52, respectively. Similar results were reported in past studies, while studying the effect of different drying methods on water activity of apple slices, respectively (Baysal et al. 2015; Nowak and Jakubczyk 2020).

The least water activity value of freeze-dried mushroom might be because of greater removal of moisture content as a result of sublimation of moisture. The highest value of water activity was recorded for the sun-dried sample depicting a value of 0.62 (Ali et al. 2016). This might be because of fluctuating temperature and humidity resulting in less effective heat transfer, thereby leading to lesser removal of water (Muyanja et al. 2012). The osmotic drying decreased water activity to a greater extent than microwave and oven drying, which might be because of solute uptake during steeping in brine solution resulting in a concentration gradient thereby facilitating greater water removal (Salim et al. 2016). Similar results were reported in the past studies during the drying of oyster mushrooms (Aishah and Rosli 2013; Sharma and Bhat 2018; Nowak and Jakubczyk 2020).

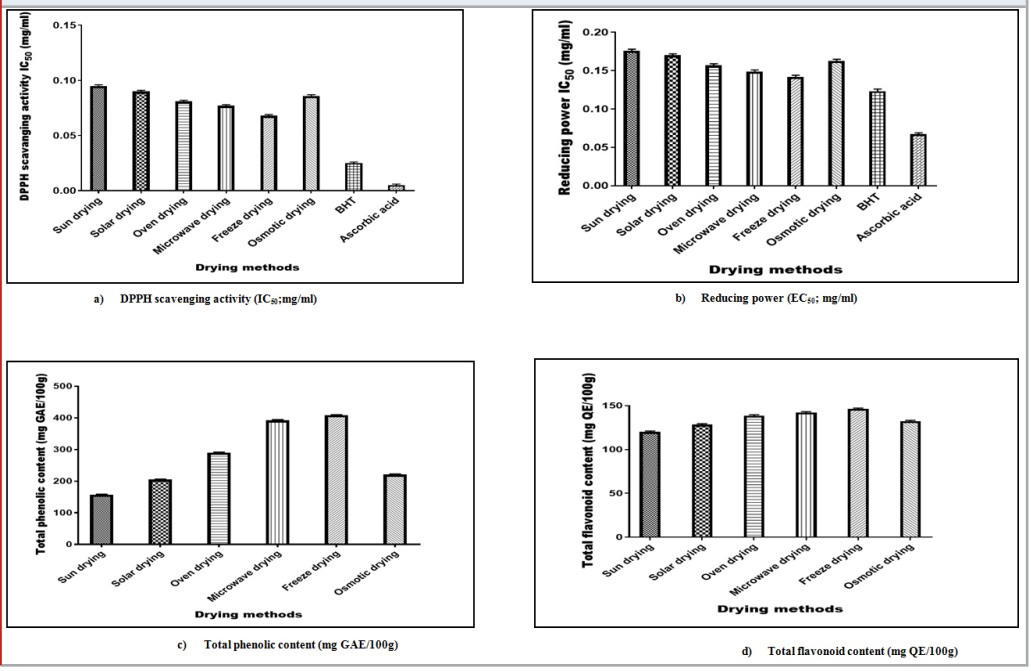
Bioactive components: Antioxidant activity: The data pertaining to the effect of drying methods on antioxidant activity of oyster mushroom is presented in Figure 2 (a). The drying methods in general resulted in decrease of antioxidant activity of oyster mushroom. The decrease in antioxidant activity during drying might be attributed to thermal degradation of ascorbic acid and polyphenols mainly responsible for antioxidant activity. Lim and Murtijaya (2007) also reported a decrease in antioxidant activity of *Phyllanthus amarus* extract in response to various drying

methods (Lim and Murtijaya 2007; Ruvini et al. 2017). The DPPH scavenging activity was expressed in terms of IC50, the concentration required for 50 per cent inhibition. The lower the value of IC50, the greater is the antioxidant activity. The IC50, value of DPPH scavenging activity followed the order of sun drying>solar drying>osmotic drying>oven drying>microwave drying>freeze drying.

The highest antioxidant activity was reflected by freeze-dried oyster mushroom corresponding to IC_{50} value of 0.068 mg per ml. Zhang et al. (2009) while studying the effect of drying methods on antioxidant activities of shitake mushroom also reported better retention of antioxidant activity in order of freeze-dried shitake mushroom followed by microwave, oven and sun-dried mushroom, thus confirming our results. Ji et al. (2012) also reported higher radical scavenging activity in freeze-dried button mushroom followed by hot air- and sun-dried button mushroom similar to our results. The oven-dried mushroom exhibited higher antioxidant activity and lower IC50, value of 0.081 mg per ml in comparison to sun and solar dried samples. Mechlouch et al. (2012) while studying the effect of sun and solar drying on antioxidant activity of tomato also reported higher radical scavenging activity in solar dried sample than sun dried one similar to our findings. The microwave dried mushroom reflected higher radical scavenging activity compared to oven-dried oyster mushrooms (Nowak and Jakubczyk 2020).

The osmotic dried mushroom reflected higher IC50, value of 0.086 mg per ml indicating lesser antioxidant activity than oven-dried mushroom. Similar results were reported in past studies in guava (Patel et al. 2016). The reductones/reducers in a substance act as an antioxidant by donating the hydrogen atom, thereby terminating the free radical chain or by reacting with precursors of peroxide and preventing their formation (Ma et al. 2013). The reducing power of dried mushroom extracts was expressed in terms of EC_{50}, values, i.e., concentration at 50 per cent of absorbance. The lower the value of EC50, the greater is the reducing power or antioxidant potential.

Figure 2: Effect of different drying method on bioactive components of oyster mushroom



a) DPPH scavenging activity (IC_{50};mg/ml)

b) Reducing power (EC_{50}; mg/ml)

c) Total phenolic content (mg GAE/100g)

d) Total flavonoid content (mg QE/100g)

The reducing power of dried oyster followed the order of freeze-dried oyster mushroom>microwave dried oyster mushroom>oven-dried oyster mushroom>osmotic dried oyster mushroom>solar dried oyster mushroom>sun dried oyster mushroom as reflected in Fig 2(b). Similar trend was reported by Ji et al. (2012) in *Robinia pseudoacacia* flowers. Chan et al. (2009) while studying the effect of different drying methods on antioxidant activity of *Alpinia zerumbet* leaves observed greater loss of reducing power in oven-dried material than microwave dried samples. Que et al. (2008) also reported higher reducing power in freeze-dried pumpkin powder than the oven-dried one. Siriamornpun et al. (2014) while working on papaya also reported greater loss of reducing power during osmotic drying than oven drying (Siriamornpun et al. 2014; Nowak and Jakubczyk 2020).

The better retention of antioxidant activity in freeze drying might be attributed to low temperature and vacuum associated with freeze drying that does not cause thermal degradation and oxidation of polyphenolic substances (Zhang et al. 2009). The lesser antioxidant activities reflected by sun and solar dried samples might be because of inefficient inactivation of polyphenolase enzyme and accelerated oxidation catalyzed by UV-radiations of sun leading to excessive loss of phenolic substances and ascorbic acid contributing to antioxidant activity. The disruption of cellular structure and release of bound phenolics might

be responsible for higher antioxidant activity during microwave drying (Incheun et al. 2010; Kankara et al. 2014; Liu et al. 2020). The leaching of soluble antioxidant components like vitamin C and some phenolic acids from food matrix during osmotic drying might be responsible for low antioxidant activity in osmotic dried mushroom in comparison to oven (Phisut et al. 2013; Liu et al. 2020).

Total phenolic content: The effect of different drying methods on total phenolic content of oyster mushrooms is represented in Figure 2 (c). The drying process caused a decrease in the total phenolic content of oyster mushroom. The exposure of food products to high temperatures for longer times and the enzymatic processes catalysed by light and air might be responsible for reduction in total phenolic content during drying (Youssef and Mokhtar 2014). This is in accordance with the findings of Henriquez et al. (2013) reporting a decrease in total phenolic content of apple peel subjected to different drying processes. The reduction in total phenolic content of oyster mushrooms was highest in sun drying followed by solar drying, osmotic drying, oven drying, microwave drying and freeze drying. The highest total phenolic content was reflected by freeze-dried oyster mushroom corresponding to a value of 408.562 mg GAE per 100 g dry matter followed by microwave and oven-dried oyster mushroom depicting a value of 392.001 and 290.172 mg GAE per 100g, respectively (Liu et al. 2020).

This is similar to the findings of Assefa and Keum (2017) revealing the highest total phenolic content in freeze-dried yuzu fruit than the microwave and oven-dried sample. The total phenolic content of osmotic dried oyster mushroom was found to be lesser than the oven-dried mushroom, which is similar to the findings of Djendoubi et al. (2013). Among the dried oyster mushrooms, the sun-dried sample exhibited the least total phenolic content of 157.210 mg GAE per 100 g. Vu et al. (2017) reported least phenolic content in the sun-dried banana peel than the oven, microwave and freeze-dried samples. The freeze-drying method resulted in better retention of total phenolic content which might be because of the low temperatures and vacuum employed during freeze drying that inhibit thermal and oxidative degradation of phenolic compounds (Zhang et al. 2013; Ozay-Arancioglu et al. 2021).

Furthermore, during freeze drying the formation of ice crystal in the cellular structure of sample may disrupt the same allowing easy access of solvents and better extraction of phenolic components leading to higher values of total phenolic content (Orphanides et al. 2013). The intense heat generated during microwave drying resulted in high vapour pressure and high temperature in food matrix leading to cellular disruption and consequential release of bound phenolics might be responsible for greater total phenolic content of microwave dried samples. The migration of phenolic compounds in osmotic solution may be responsible for higher reduction of total phenolic in osmotic drying (Stojanovic and Silva 2007; Izli et al. 2018). In sun and solar drying the prolonged drying periods facilitating oxidation and enzymatic degradation might be responsible for greater loss of phenolic components (Orphanides et al. 2013; Ozay-Arancioglu et al. 2021).

Total flavonoid content: Figure 2 (d) reveals the effect of different drying methods on the total flavonoid content of oyster mushrooms. The decrease in total flavonoid content during drying might be because of thermal degradation and oxidation during drying (Chauhan et al. 2015). The flavonoid loss during drying might also be correlated with polymerization and oxidation catalysed by various factors like temperature, pH and enzymes (Si et al. 2016). The loss of total flavonoid content was found to be the least in freeze drying followed by microwave, oven, osmotic, solar and sun drying. Vu et al. (2017) while working on banana peels reported total flavonoid content in order of freeze-dried peel>microwave dried banana peel>oven-dried banana peel>sun dried banana peel quite consistent with the findings of the present study. The greater total flavonoid content of the freeze-dried oyster mushroom might be because of lower temperatures and vacuum associated with freeze drying resulting in better retention (Ibrahim et al. 2013; Vu et al. 2017; Ozay-Arancioglu et al. 2021).

The greater total flavonoid content of microwave in comparison to oven, sun and solar drying might be because of shorter drying times associated with microwave drying. The least total flavonoid content of 120.092 mg QE per 100 g was recorded for sun dried mushroom consistent with the past findings (Shahat et al. 2016). The longer drying times and exposure to oxygen associated with sun and solar drying might be responsible for greater loss in flavonoid content as flavonoid degradation is dependent on exposure time, enzymes, light and oxygen catalysing their breakdown (Ibrahim, et al. 2013). The osmotic dried mushroom in comparison to oven-dried mushroom exhibited lower total flavonoid content which might be because of weakening of cellular structure during osmotic treatment resulting in greater leaching of flavonoid components (Zainol et al. 2009; Ozay-Arancioglu et al. 2021).

CONCLUSION

The findings of the present study depict that the different drying methods had a significant impact on physical parameters and bioactive components of oyster mushrooms. The oyster mushrooms subjected to freeze drying gave best results in respect of antioxidant activity (DPPH scavenging activity; IC_{50}: 0.068 mg per ml and reducing power; IC_{50}: 0.142 mg/ml), total phenols (408.562 mg GAE/100g), total flavonoids (146.231 mg QE/100g). Furthermore freeze-dried oyster mushroom recorded least colour change corresponding to highest L* value of 81.02 and least a* and b* values of 2.09 and 10.41, respectively. The water activity value of dried oyster mushroom ranged from 0.45 to 0.62. The freeze-dried mushroom powder loaded with bioactive components can be used to formulate functional foods and in conventional foods like cakes, breads and noodles as a functional ingredient.

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Conflict of Interest: Authors declare no conflicts of interests to disclose.

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