Effect of drying parameters on water activity of pink oyster mushroom (*Pleurotus djamor*) powder

Harapriya Nayak, Archana Kushwaha, NC Shahi, Khan Chand, KPS Kushwaha, Kalpana Kulshrestha and CS Chopra

Abstract

Pink oyster mushroom (*Pleurotus djamor*) has a short shelf life owing to its high moisture content. Preserving mushrooms in dried form extends the shelf life, reduces the post-harvest losses, increases the nutrient density and enhances its utilization in various food products. Water activity of dried product is an important quality parameter which influences the product stability, shelf life and results in reduced microbial load during the storage. In view of above, the present research was carried out to study the effect of drying parameters viz. temperature, blanching time and concentration of KMS on water activity of oyster mushroom (*Pleurotus djamor*) powder. The result showed that minimum water activity (0.236) was found at temperature 60°C, blanching time 2 min and 1% KMS concentration. Dried oyster mushroom powder thus obtained showed high potential for use in the preparation of different value added food products.

Keywords: *Pleurotus djamor*, drying, temperature, blanching time, water activity

Introduction

Oyster mushroom (*Pleurotus sp.*) has occupied the second position among globally cultivated edible mushrooms [4]. The world’s mushroom production increased more than 25 fold (1 billion kg to 27 billion kg) from 1978 to 2013 [23]. The total mushroom production in India has increased from 100MT in 1970 to 120,000 MT in 2013 as a result of wide spread cultivation. Among the different species of oyster mushroom, *Pleurotus djamor* commonly known as the pink oyster mushroom, is commonly consumed due to its taste, flavor, high nutritional values, anti-oxidant, anti-microbial and medicinal properties [8, 12, 24]. The oyster mushroom (*Pleurotus djamor*) contained moisture 89-91g, crude protein 19-31g, lipid 4-6.5g, ash 7 -9.5g, carbohydrate 33-55g, crude fiber 20-25g, iron 40.52-43.60 mg and calcium 21.19-23.54 mg per 100g on dry weight basis when grown on different substrates [12]. The mushrooms are highly perishable commodities and have a short shelf life of about 24 hours at ambient temperature due to high moisture content [12, 19]. Besides nutrients, fresh mushroom contain mineral salts, vitamins, flavor compounds and various enzymes including polyphenol oxidases which are mainly responsible for the brownish color of the diced product [15]. Water activity (a_w) is the amount of free water in food that supports microbial growth and participates in and supports chemical and enzymatic reactions and spoilage processes. It is measured as the ratio of the partial vapour pressure of water in a foodstuff to the partial vapour pressure of pure water at the same temperature. Water activity at a given temperature at different moisture contents are therefore of special interest in the design of food preservation processes such as drying, freeze-drying, mixing, packaging, storage etc., [13]. It is related to microbiological stability and physico-chemical deterioration reactions in any dried food product. Drying combined with some pre-treatments is a cost effective method of preservation for storage of mushroom which involves removal of free water to such a level that the biochemical and microbial activity are checked [17, 21]. Dried mushrooms, packed in airtight containers can have a shelf life of about one year [5]. Effect of pre-treatments viz. blanching and sulphitation and drying temperature affect the quality of dried products [10]. The browning reaction occurs due to enzymatic action of polyphenol oxidase on phenolic substances of mushroom is a major factor contributing to quality losses. The chemical changes like lipid oxidation and non-enzymatic browning are also responsible for changes in the colour and flavour of foods during processing and storage. Water blanching and pre-treatments of mushrooms with potassium metabisulphite (KMS) inactivated the enzymes like polyphenol oxidase that causes enzymatic browning and also prevented non-enzymatic browning of mushroom during drying. It also helped in stabilizing colour, enhancing flavour retention and maintained textural properties [11, 27, 28]. Temperature also played an important role in reducing the water activity and maintaining...
of dried mushroom. Among different drying methods, hot air drying was considered cheaper when employed on commercial scale and mostly used for long term storage of mushroom [20]. The drying temperature ranged between 40-70°C in hot air drying of mushroom [2, 3, 19]. Preserving mushroom in dried form had a pleasant flavor, reduced post-harvest losses, extended shelf life, easier transport and also dehydrated mushrooms served as valuable ingredients in a variety of food formulations such as instant soups, sauces, snacks, pizzas, and meat and rice dishes [6, 11, 14, 18]. According to literature search, studies on optimization of drying conditions to yield a better quality powder from pink oyster mushroom (Pleurotus djamor) are trivial. Keeping in view of above, the present research was carried out to study the effect of drying parameters viz. drying temperature, blanching time and KMS concentration on water activity of pink oyster mushroom (Pleurotus djamor) powder.

Materials and Methods
The research work was carried out at Department of Foods and Nutrition, GBPUAT Pantnagar, Uttarakhand during September 2016 to February 2017. The pink oyster mushroom (Pleurotus djamor) was procured from the Mushroom Research and Training Centre, GBPUAT, Pantnagar. The whole fruiting bodies of mushroom was cleaned of inedible extraneous material, washed properly in running water and used in further experiments. Hot water blanching was carried out at temperature 98±1°C. The water was drained and the blanched mushroom was dipped in KMS solution. The water was removed and mushroom was spread in bloating paper for removal of surface moisture. Further, drying was carried out using tray dryer (Sanco Ltd.). Based on review of literature for optimization of drying of mushroom the levels of independent variables namely drying temperature (40-60°C) (X₁), blanching time (2-4min) (X₂) and concentration of KMS solution (0.5-1.5%) (X₃) were optimized against water activity of dried mushroom powder as response. Box- Behnken Design (BBD) was used for response surface optimization to evaluate the combined effects. Total number of experiments was performed as per equation 1.

\[ N = k^2 + k + c_p \]  

Where,  
N = Total number of experiments  
k = Number of independent variables  
c_p = Number of replications of central point

The experimental plan and design of experiment has been shown in Table 1.

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Code</th>
<th>Levels</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Drying temperature (°C)</td>
<td>X₁</td>
<td>40 50 60</td>
<td>Water activity</td>
</tr>
<tr>
<td>2. Blanching time (min)</td>
<td>X₂</td>
<td>2 3 4</td>
<td></td>
</tr>
<tr>
<td>3. Concentration of KMS solution (%)</td>
<td>X₃</td>
<td>0.5 1 1.5</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Effect of Independent process parameters on \( a_w \) of oyster mushroom (Pleurotus djamor) powder

<table>
<thead>
<tr>
<th>S. No</th>
<th>Temperature (X₁)</th>
<th>Blanching time (min) (X₂)</th>
<th>Concentration of KMS (%) (X₃)</th>
<th>Water activity (( a_w ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>60</td>
<td>4</td>
<td>1</td>
<td>0.298</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>3</td>
<td>1</td>
<td>0.392</td>
</tr>
<tr>
<td>3</td>
<td>40</td>
<td>3</td>
<td>0.5</td>
<td>0.343</td>
</tr>
<tr>
<td>4</td>
<td>50</td>
<td>3</td>
<td>1</td>
<td>0.398</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
<td>2</td>
<td>1</td>
<td>0.421</td>
</tr>
<tr>
<td>6</td>
<td>50</td>
<td>4</td>
<td>1.5</td>
<td>0.394</td>
</tr>
</tbody>
</table>

The dried mushroom was made into powder by grinding in mixer (Remi Anupam Mixie) followed by sieving in 60 mesh sieve. The mushroom powder was kept in sealed LDPE polythene pouches (50µm) and kept in desiccator. The water activity was measured by water activity meter (Rotronic Hygrolab 3). About 5 g of sample was put into the instrument and \( a_w \) was measured automatically after starting the program. The corresponding temperature was also recorded. Second-order quadratic regression models were established for the independent variables to fit experimental data for each response using Design-Expert software version 10.0.1.

\[ Y = \beta_0 + \sum_{i=1}^{n} \beta_i X_i + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \beta_{ij} X_i X_j + \sum_{i=1}^{n} \beta_i X_i^2 \]

Where,  
\( \beta_0, \beta_i, \beta_{ij} \) and \( \beta_i \) are constants  
\( X_i, X_j \) are variables (coded)

Data was analyzed by multiple regression analysis and statistical significance of the terms was examined by analysis of variance (ANOVA) for the response. The adequacy of regression model was checked by correlation coefficients. The lack of fit test was used to judge the adequacy of fit of the model.

Results and Discussion
Effect of independent process parameters on \( a_w \)
The effect of independent process parameters on \( a_w \) of oyster mushroom (Pleurotus djamor) powder was studied. The \( a_w \) of dried mushroom powder ranged from 0.236 to 0.436. Minimum \( a_w \) was observed at drying temperature 60°C and maximum at 40°C with atmospheric temperature of 32.04 to 32.60°C (Table 2). The lower \( a_w \) showed that the oyster mushroom powder is safe from microbial spoilage. Reducing \( a_w \) below 0.6 prevents microbiological spoilage; however, other deteriorative reactions, such as enzymatic activity, non-enzymatic browning and lipid oxidation can be prevented in a dried food with \( a_w \) values near 0.3 [9, 22]. Aishah and Rosli (2013) reported the \( a_w \) of oyster mushroom (Pleurotus sajor-caju) dried in hot air oven at 50°C temperature was 0.57 ± 0.01 [11].
Concentration of KMS = 1.456
Blanching Time = 3.106

Actual Factors
X1 = A: Temperature
Water activity

Factor Coding: Actual

Design-Expert® Software

The results of analysis of variance determined the significance of the model as well as the significance of the linear and interaction effects of the independent variables (p-value) on $a_w$ of the mushroom powder (Table 3). The results revealed that drying temperature had significant effect on $a_w$ at 1% level of significance. Blanching and the interaction terms (Temperature×Blanching time) also had significant effect on $a_w$ at 5% level of significance. However, other terms were non-significant which has been clearly explained by the p-values. Out of all quadratic terms, only temperature of drying was significant at 1% level of significance. The statistical analysis showed that the proposed model was significant (p < 0.0001). The $R^2$ and $R^2_{\text{adj}}$ value for $a_w$ were 0.9872 and 0.9708, respectively which implies that the model could account 98.72% accuracy of data. For a good fit model, $R^2$ should be at least 80% [10]. The non-significant value of lack of fit indicated that the developed model was valid for describing the $a_w$ of oyster mushroom powder.

**Table 3: ANOVA for response surface quadratic model for $a_w$**

<table>
<thead>
<tr>
<th>Source</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>&lt; 0.0001***</td>
</tr>
<tr>
<td>$X_1$: Temperature</td>
<td>&lt; 0.0001***</td>
</tr>
<tr>
<td>$X_2$: Blanching Time</td>
<td>0.0375*</td>
</tr>
<tr>
<td>$X_3$: Concentration of KMS</td>
<td>0.4713ns</td>
</tr>
<tr>
<td>$X_1X_2$</td>
<td>0.0289**</td>
</tr>
<tr>
<td>$X_1X_3$</td>
<td>0.7776ns</td>
</tr>
<tr>
<td>$X_2X_3$</td>
<td>0.8504ns</td>
</tr>
<tr>
<td>$X_1^2$</td>
<td>&lt; 0.0001**</td>
</tr>
<tr>
<td>$X_2^2$</td>
<td>0.0897ns</td>
</tr>
<tr>
<td>$X_3^2$</td>
<td>0.2204ns</td>
</tr>
<tr>
<td>Lack of Fit</td>
<td>0.0726ns</td>
</tr>
<tr>
<td>Cor Total</td>
<td>0.057</td>
</tr>
<tr>
<td>R$^2$square</td>
<td>0.9872</td>
</tr>
<tr>
<td>Adjusted R$s^2$square</td>
<td>0.9708</td>
</tr>
</tbody>
</table>

**p<0.01; * p<0.05; ns: Non-significant**

The second order polynomial equation was developed which represent the response water activity ($a_w$) as function of temperature ($X_1$), blanching time ($X_2$) and concentration of KMS solution ($X_3$). An empirical relationship between the response and input variables can be expressed by the following equation:

Water activity ($a_w$) = $-0.21180 + 0.032825X_1 - 0.00395X_2$
- $0.0501X_2 + 0.0014X_1X_2 - 0.003X_1X_3$
+ $0.002X_2X_3 - 0.000443X_1^2 - 0.0098X_2^2$
+ $0.0268X_3^2$

The equation included both significant and non-significant terms. The predictive equation of the $a_w$ with significant process parameter is given below:

Water activity ($a_w$) = $-0.15258 + 0.03272X_1 - 0.06075X_2$
+ $0.0014X_1X_2 - 0.00045X_1^2$

The negative coefficient of square terms of temperature indicated that with the increase in temperature $a_w$ of the mushroom powder decreased.

**Graphical analysis of $a_w$ for significant interactive terms**

The results in figure 1 showed that with the increase in temperature of drying from 40°C to 60°C, the $a_w$ decreased. A similar finding was also observed by Khalloufi et al., (2000) in freeze drying of shiitake (Lentinus edodes), enoki (Flammulina velutipes), morel (Morchella esculenta) mushrooms, strawberries and blueberries [13].

![Figure 1: Effect of temperature on $a_w$ of dried mushroom powder](image-url)

Figure 2 showed the interactive effect of blanching time and...
drying temperature on $a_w$ of dried mushroom powder at optimum value of KMS concentration (1.456%). It was found that with the increase in blanching time from 2 to 4 minutes there was significant increase in $a_w$. However, an inverse relation was observed among the temperature and $a_w$ of dried mushroom powder. Minimum $a_w$ was observed with the increase in temperature and decrease in blanching time.

**Fig 2:** Effect of blanching time and drying temperature on $a_w$ of dried mushroom powder at optimum value of KMS concentration

**Conclusion**

Temperature and pre-treatment such as blanching and dipping in KMS solution had a significant effect on drying of oyster mushroom and reduction in the $a_w$. Drying at 60°C temperature with 2 minutes blanching time at optimum level of KMS concentration (1.456 %) gave better result for the dried mushroom powder. Water activity of 0.236 indicated good storage stability and decreased microbial load. Adequate packaging and proper storage could further enhance the shelf life of the mushroom. Dried oyster mushroom powder thus obtained showed high potential for use in the preparation of different value added food products.

**References**


