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The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.03
TPI 2019; 8(3): 327-330

www.thepharmajournal.com
Received: 16-01-2019
Accepted: 21-02-2019

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Microwave assisted fluidized bed drying of oyster mushroom (*Pleurotus* spp.)

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Abstract
Mushrooms are non-green, edible fungi. Mushrooms are a good source of non-starchy carbohydrates, dietary fiber, protein, mineral and vitamins. Mushrooms are seasonal and highly perishable crop and contain about 90% (w.b.) moisture content. In present study we conducted the experiment to evaluate the drying behavior of the mushroom. Evaluation of impact of microwave power and different temperature on drying and rehydration were studied. Fresh oyster mushrooms (*Pleurotus* spp.) were procured from local market. The initial moisture content varied from 90-92% w.b., mushroom slices 10mm in thickness were taken for microwave assisted Fluidized bed drying. During microwave drying, power levels were kept as 480, 640 and 800 W. Samples were dried in Fluidized bed dryer at 45, 55 and 65 °C and 3.5 m/s air velocity. Before drying, samples were pretreated in 1% KMS solution for 15 minutes. Weights of the samples were recorded after an interval of one minute for microwave drying and 10 minutes for Fluidized bed drying. The dried samples were subjected to rehydration by immersing the dried samples into boiling water for 2 minutes. The best rehydration ratio was obtained for sample dried at 640W microwave power and 65 °C temperature in the Fluidized bed dryer.

Keywords: Microwave, Fluidized bed dryer, mushroom, rehydration ratio

1. Introduction
Mushrooms are non-green, edible fungi. They are a large heterogeneous group having various shapes, sizes, appearance and edibility. Mushrooms are a good source of non-starchy carbohydrates, dietary fiber, protein, mineral and vitamins. Mushrooms are a seasonal and highly perishable crop and contain about 90% (w.b.) moisture content.After harvesting, moisture loss, shrinkage and rapid spoilage in terms of color and texture takes place. The shelf life of mushroom is only about 2 to 5 days depending upon the variety. There are many methods for preservation and enhancement of shelf life of mushrooms. The most common processes include canning, freezing and drying. Although canning is widely used on a commercial scale, it is quite expensive.

Pleurotus spp., commonly known as oyster fungi, is a common primary degrader of wood and vegetable residues (Zadrazil and Kurtzman, 1981) [28]. It can be found in tropical and subtropical regions and in rainforests, and can also be artificially cultivated (Maziero *et al*., 1992) [18]. Appreciated because of its delicious taste, these fungi contain high quantities of proteins and carbohydrates, minerals (calcium, phosphorus, iron, etc), and vitamins (thiamin, riboflavin and niacin) as well as low fat content (Sturion and Oetterer, 1995; Justo *et al*., 1998; Manzi *et al*., 1999) [24, 10, 15]. Once deteriorated, these fruiting bodies can cause severe gastrointestinal discomfort. Under ideal climatic conditions, shelf life of these mushrooms is about 10 days, their quality being affected predominantly by storage temperature. The shelf life can be reduced from 9 days at 2 °C to 3 days at 18 °C (Lukasse and Polderdijk, 2003) [14]. Therefore, cooling the fresh mushrooms can be an alternative regarding their distribution and sale, thus increasing their shelf life (Villaescusa and Gil, 2003) [26]. For long periods of conservation, the traditionally used method for *Pleurotus* genus mushrooms is the convective drying at 45-65 ºC (Pal and Chakraverty, 1997; Arora *et al*., 2003) [3,, 6, 7].

Dehydration is a classical method of food conservation, based on the principle that the reduction of the water activity of the product must be conducted until defined levels that guarantee the microbiological and physicochemical stability (Cao *et al*., 2003; Krokida *et al*., 2003) [5, 12]. Different drying methods are used in the drying of fruits and vegetables. Hot-air drying is the most common method in the drying of foodstuffs. However, this method leads to serious injuries such as the worsening of the taste, colour and nutritional content of the product, decline in the density and water absorbance capacity and shifting of the solutes from

the internal part of the drying material to the surface, due to the long drying period and high temperature (Bouraout, Richard, & Durance, 1994; Drouzas,Tsami, & Saravacos, 1999; Feng & Tang, 1998; Lin, Durance, & Seaman, 1998; Maskan, 2001; Yongsawatdigul & Gunasekaran, 1996) [4, 7, 13, 27]. The use of microwave rays in the drying of products has become widespread because it minimizes the decline in quality and provides rapid and, effective heat distribution in the material as well (Dı´az, Martı´nez-Monzo, Fito, & Chiralt, 2003) [6]. Furthermore, high quality product is obtained via microwave drying in addition to the decline in drying period and energy conservation during drying (Feng, 2002) [2].
In the present study we evaluate the influence of pretreatment (1% KMS solution) and different drying conditions namely microwave (at different power 480W, 640W and 800W) and then Fluidized bed drying at different temperatures (45 °C, 55 °C and 65 °C) with air velocity of 3.5 m/s. Rehydration ratio of dried oyster mushroom slices was also evaluated.

2. Materials and methods

2.1 Materials

Freshly harvested oyster mushrooms were procured from local market and they were sorted according to their size and appearance. Mushrooms were washed to remove dirt and any other foreign materials and cut into strips of 10±1mm width.

2.2 Pre-treatment

Pre-treatment of mushrooms was done with 1% KMS solution for 15 minutes at room temperature.

2.3 Measurement of Moisture Content

The initial moisture contents of the cumin seed and clove were determined by the vacuum oven method at 70 °C and 100mm of Hg until constant weight was obtained (Ranganna, 1986).

$$\text{Moisture Content (\% db)} = \frac{(W_1 - W_2)}{w2} \times 100$$

W_1 = weight of the sample before drying, g
W_2 = weight of the sample after drying, g

2.4 Microwave Drying Of Oyster Mushroom

First stage drying of mushrooms is carried out in microwave oven. Sample slices were kept in a microwave oven for drying. Drying of mushroom was carried out at different powers viz. 480, 640 and 800 W. Samples were taken out and weighed after every 1 minute. They were dried till about 70% moisture was removed as on further drying burning of mushrooms occurs. The dried sample was taken out for second stage drying.

2.5 Fluidized Bed Drying Of Oyster Mushroom

Second stage drying is carried out in Fluidized bed dryer at a constant air velocity of 3.5 m/s and at different temperatures 45 °C, 55 °C and 65 °C. Readings were taken after regular intervals of 10 minutes and the drying was continued until no weight change was observed.

2.6 Rehydration Ratio

Rehydration experiments were performed by immersing a 2 gram dried sample of oyster mushroom into boiling water for 2 minutes. Then the rehydrated sample was weighed. The rehydration ratio, described as ratio of weight of rehydrated sample to the weight of the dried sample.

3. Results and discussions

Oyster Mushroom slices were dried using microwave assisted Fluidized bed drying. The drying parameters such as microwave power and temperature in Fluidized bed dryer were optimized on the basis of least drying time and maximum rehydration ratio. Drying rate showed a fast increase at the beginning of the process and a subsequent decrease afterwards.

3.1 Drying of Oyster Mushroom

A sudden decrease in drying rate was observed when samples partially dried in microwave were subjected to Fluidized bed drying. This is because of the fact that drying rate is much higher in microwave and initially moisture content of sample is also high. Hence, drying rate was decreased when samples were first dried in microwave and then were subjected to Fluidized bed drying. Initially drying rate keeps on increasing and then after sometime it starts decreasing and tends to zero when sample is completely dried. Time taken for drying decreases with increase in power of microwave and temperature of Fluidized bed dryer. The sample dried in microwave at 800 W and in Fluidized bed at 65 °C had least drying time.

Table 1: Moisture content of sample in microwave assisted Fluidized bed drying at power 480 W and temperature 65 °C (initial moisture content = 1017.318%(d.b.))

Time (minute)	Weight of Sample(g)	Weight of Moisture(g)	Moisture Content (%,d.b.)	Moisture Ratio	Drying rate
0	85.18	77.556	1017.318	1.000	
1	83.67	76.046	997.511	0.980	1.510
2	79.58	71.956	943.862	0.927	4.090
3	74.42	66.796	876.177	0.860	5.160
4	67.32	59.696	783.046	0.768	7.100
5	59.17	51.546	676.141	0.661	8.150
6	50.62	42.996	563.990	0.550	8.550
7	45.03	37.406	490.665	0.477	5.590
8	37.97	30.346	398.058	0.385	7.060
9	31.12	23.496	308.206	0.296	6.850
10	25.47	17.846	234.094	0.223	5.650
Sample now dried in Fluidized bed dryer					
20	11.59	3.920	51.105	0.043	1.205
30	10.20	2.530	32.983	0.025	0.139
40	9.40	1.730	22.553	0.014	0.080
50	8.80	1.130	14.730	0.006	0.060

60	8.60	0.930	12.123	0.004	0.020
70	8.40	0.730	9.515	0.001	0.020
80	8.30	0.630	8.212	0.000	0.010

Table 2: Moisture content of sample in microwave assisted Fluidized bed drying at power 640 W and temperature 65 °C (initial moisture content = 1017.318%(d.b.))

Time (minutes)	Weight of Sample(g)	Weight of Moisture(g)	Moisture Content (%,d.b.)	Moisture Ratio	Drying rate
0	85.36	77.720	1017.318	1.000	
1	82.97	75.330	986.035	0.968	2.390
2	75.69	68.050	890.743	0.872	7.280
3	66.27	58.630	767.440	0.747	9.420
4	56.69	49.050	642.043	0.620	9.580
5	46.89	39.250	513.766	0.669	9.800
6	38.27	30.630	400.935	0.376	8.620
7	29.43	21.790	285.224	0.259	8.840
7.5	25.18	17.540	229.593	0.203	4.250
Sample now dried in Fluidized bed dryer					
17.5	13.15	5.510	72.127	0.044	1.092
27.5	11.16	3.520	46.079	0.017	0.198
37.5	10.56	2.920	38.225	0.010	0.092
47.5	10.26	2.620	34.298	0.006	0.135
57.5	10.13	2.490	32.596	0.004	0.035
67.5	10.05	2.410	31.549	0.003	0.026
77.5	9.86	2.220	29.062	0.000	0.014
87.5	9.85	2.210	28.931	0.000	0.002
97.5	9.84	2.200	28.801	0.000	0.001

Table 3: Moisture content of sample in microwave assisted Fluidized bed drying at power 800 W and temperature 65 °C (initial moisture content = 1017.318%(d.b.))

Time (minutes)	Weight of Sample(g)	Weight of Moisture (g)	Moisture Content (%,d.b.)	Moisture Ratio	Drying rate
0	85.30	77.666	1017.318	1.000	
1	77.37	69.736	913.446	0.896	7.930
2	65.77	58.136	761.501	0.745	11.600
3	53.53	45.896	601.173	0.585	12.240
4	41.90	34.266	448.835	0.433	11.630
5	30.97	23.336	305.666	0.290	10.930
6	26.06	18.426	241.352	0.226	4.910
Sample now dried in Fluidized bed dryer					
16	14.64	7.006	91.765	0.079	1.142
26	11.23	3.596	47.098	0.035	0.341
36	9.95	2.316	30.332	0.018	0.128
46	9.35	1.716	22.473	0.010	0.060
56	8.98	1.346	17.626	0.005	0.037
66	8.75	1.116	14.614	0.002	0.023
76	8.60	0.966	12.649	0.000	0.015
86	8.58	0.946	12.387	0.000	0.002

3.2 Rehydration ratio

During reconstitution of dehydrated products the amount of water absorption determines to a considerable extent the sensorial properties. The sample partially dried in microwave at 640 W and in Fluidized bed dryer at 65 °C showed the maximum rehydration ratio of 3.85.

4. Summary and conclusion

Fresh oyster mushrooms (*Pleurotus* spp.) were procured from local market. The initial moisture content varied from 90-92% w.b. Mushroom slices 10mm in thickness were taken for microwave assisted Fluidized bed drying. During microwave drying, power levels were kept as 480, 640 and 800 W. Samples were dried in Fluidized bed dryer at 45, 55 and 65 °C and 3.5 m/s air velocity. Before drying, samples were pretreated in 1% KMS solution for 15 minutes. Weights of the samples were recorded after an interval of 30 seconds for microwave drying and 20 minutes for Fluidized bed drying and moisture loss was calculated according to the mass balance equation. The dried samples were subjected to rehydration by immersing the dried samples into boiling water for 2 minutes. The rehydration ratio was calculated as the relative weight gain of the sample.

On the basis of experimental results and data analysis it was concluded that:

1. Drying rate showed a fast increase at the beginning of the process and then subsequently reduced, showing two differential falling rate periods.
2. In microwave drying, drying rate increased with an increase in the microwave power and also declined rapidly.
3. The best rehydration ratio was obtained for sample dried at 640W microwave power and 65 °C temperature in the Fluidized bed dryer.

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