Malays. Appl. Biol. (2020) 49(3): 31–36

EFFECTS OF DRYING METHODS ON THE CHARACTERISTICS OF *Pleurotus sajor-caju* MUSHROOM

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Accepted 11 September 2020, Published online 25 October 2020

ABSTRACT

Mushrooms of the *Pleurotus* spp. are very sensitive and the shelf-life of mushrooms is limited, that is a few days under normal or low temperatures, which is a limitation in the distribution and marketing of fresh products. To extend their shelf life, drying methods need to be applied. Total drying time decreased with increased drying temperatures (960 and 330 min of drying at 40 and 70°C, respectively). The drying curve equations is establised as y=a.exp(-kt) ($R^2 \geq 0.95$). These equations can be applied to predict moisture reduction during drying of *Pleurotus* spp. at the temperature ranges studied. Besides, effect of drying methods (convection, sun and solar drying) was investigated. Results showed that the quality of sample treated with solar drying was higher than others. In the solar drying samples, the highest protein, carbohydrate, flavonoid, β-glucan content (in dry basis) were 16.22%, 24.84% and 5.82 mg QE/gm, 0.41%, respectively. The antioxidant capacity (FRAP and DPPH) was 362.58 mM Fe^{2+}/gm and 62.35%, respectively. The lighter color was obtained for the mushroom dried using a solar dryer.

Key words: *Pleurotus* spp., drying curve, solar drying, antioxidant

INTRODUCTION

Pleurotus spp. is commercially important edible mushrooms commonly known as the oyster mushroom. *P. sajor-caju* is one of the most successfully cultivated species of these mushrooms and it is considered to be delicious (Zang *et al*., 2002). This is also known as grey oyster mushroom, and this name was taken for its physical shape like a seashell. *P. sajor-caju* was first isolated from India (Chang & Miles, 2004; Jandaik, 1974) and this strain was identified as the best strain to cultivate in the tropics and subtropics (Eugino & Anderson, 1968). In An Giang province (Vietnam), *P. sajor-caju* are grown indoors with 2 to 3 crops per year and experience of famers cultivating mushrooms is 1 to 3 years, especially more than 10 years.

In fact, *P. sajor-caju* was said to possess unique nutritional and medicinal values, aroma as well as taste (Dunkwal & Singh, 2007). Antioxidants in mushrooms (polyphenol, flavonoid, alkaloid, terpenoid) can be protective agents to help humans in reducing oxidative damage without any intervention (Halliwell & Gutteridge, 1986). Mushrooms are quite rich in protein, with an important content of essential amino acids and poor in fat (1.1–8.3% – dry weight basis) (Chang & Smiles, 2004). Mushrooms have also been proved as good source of dietary fibre and β-glucan, vitamin B-complex, D and mineral content. β-glucans are associated with its ability to exhibit significant cumulative properties, possess better antioxidant activities and the ability to scavenge against free radicals (Synytsya *et al*., 2008). The dietary fibers present in the mushroom can protect the body from irritable bowel syndrome and colon cancer.

However, mushrooms of the *Pleurotus* spp. are very sensitive and start to degrade within one day of haverst (Apati, Furlan & Laurindo, 2010). Mushrooms can only be stored for several days in cold conditions, which is a limitation for developing of fresh products. Many different drying methods are applied to dry fruits and vegetables such as convection drying, sun drying and solar drying. Therefore, this study is carried out to investigate the

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effect of drying methods on the characteristics of *Pleurotus sajor-caju* mushroom to select an appropriate method for best quality.

MATERIALS AND METHODS

Materials

Pleurotus sajor-caju purchased from Chau Thanh district, An Giang province, Vietnam. Fresh mushrooms were washed with water, drained and then immersed for 15 min in 0.5% citric acid and 0.5% $CaCl_2$ to improve color and structure.

Experimental design

Mushrooms were dried as a single layer at 40, 45, 50, 55, 60, 65, 70°C in oven dryer (ESCO, OFA–110–8, Indonesia). During drying, the sample weight was recorded after 15 min (Giri & Prasad, 2007) until the weight of samples remained constant. Besides that, mushrooms were *dried* using *solar dryers* and by traditional *sun* drying method until the samples attained a constant weight.

Determination of color and texture

Color of samples was measured using a Hunter Lab colorimeter (CR 400, Konica Minolta, Japan). The texture of dried samples was determined using a Texture analyzer (CT3, Brookfield, USA).

Mathematical Modeling of drying curves (Thakor *et al*., 1999)

The moisture ratio (MR) (kg H_20/kg dry matter) of *Pleurotus sajor-caju* was calculated using Equation 1:

$$MR = \frac{M_{H_2O}}{M_{DM}} \qquad (1)$$

Where, M_{H2O} = the weight of moisture, kg
M_{DM} is the mass of dry matter, kg

Determination of protein, carbohydrate, lipid, β-glucan

The protein, lipid and carbohydrate contents were analysed according to standard methods, as described by AOAC (Association of Official Analytical Chemists, 2010). β-glucan content was analysed by Phenol-Sulfuric method (John & Sons, 2001).

DPPH (2,2-diphenyl-1-picrylhydrazyl) scavenging activity

DPPH was measured according to Molyneux (2004) and calculated using Equation 2:

$$\text{Inhibition of DPPH radical (\%)} = 100 \times (A_{control} - A_{sample})/A_{control} \qquad (2)$$

Where, $A_{control}$ = the absorbance of the control
A_{sample} = the absorbance of the sample

Determination of Ferric reducing antioxidant assay (FRAP)

FRAP assay (mM of $FeSO_4$/gm dry matter) was measured by Sudha *et al*. (2012). This method is based on the reduction of tripyridyltriazine complex ($Fe(TPTZ)^{3+}$) to blue colored $Fe(TPTZ)^{2+}$ by antioxidants in acidic medium.

Determination of total phenolic content

Total phenolic content (mg TAE/gm) was determined using Folin-Ciocalteau reagent based on method of Singleton *et al*. (1999). The concentration of total phenolic compounds was calculated as equivalent to standard tannic acid graph (TAE), y = 0.0021x + 0.0064 (R^2 = 0.99).

Determination of total flavonoid content

This assay was described by Barros *et al*. (2008) with some modifications. The concentration of total flavonoid was calculated as equivalent to standard quercetin graph (QE), y = 8.2634x + 0.0182 (R^2 = 0.99).

RESULTS AND DISCUSSIONS

Drying curves

The shelf life of mushrooms is from 10 to 14 days (Kalac, 2009). To reduce the postharvest loss and extend their life time, drying methods should be applied. *Pleurotus sajor-caju* were dried at 40, 45, 50, 55, 60, 65 and 70°C in oven with air velocity at 1.0 m/s; besides, mushrooms dried by sun (40°C) and solar drying (45-47°C). The moisture content versus drying time are presented in Figure 1. The drying rates of mushroom samples were affected by the temperatures and increased with increasing in temperatures. As shown in Figure 1, total drying time decreased with increased in drying temperature.

Drying time of samples were calculated as 960, 840, 750, 600, 480, 420, 330 mins at 40, 45, 50, 55, 60, 65 and 70°C, respectively for the samples reached a final moisture content 0.101 ± 0.008 (kg H_20/kg dry matter). As the temperature increased, the phase transition is fast, so the evaporation is faster. According to Giri *et al*. (2007), heating at temperature of 40°C and 70°C, the ability to drain moisture at 70°C is higher than 40°C. According to the study of Chong *et al*. (2008), the drying time is inversely proportional to the drying temperature,

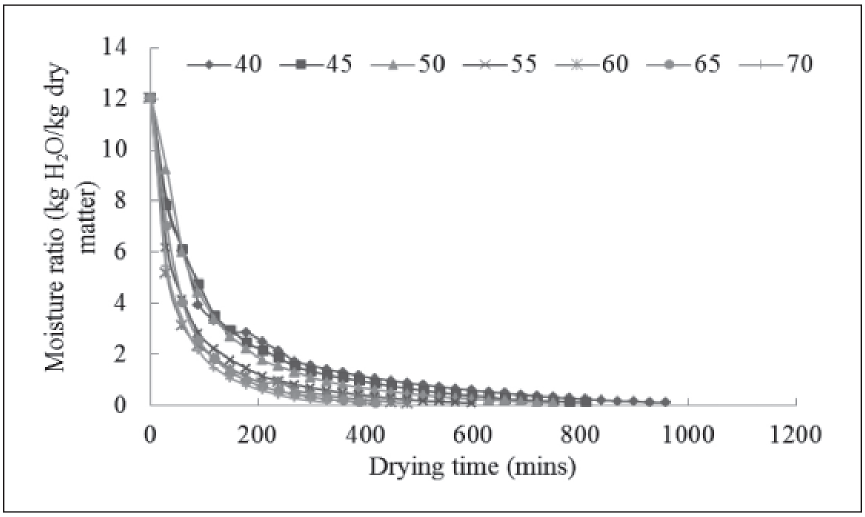

Fig. 1. Effect of drying temperature and time on moisture ratio of mushrooms.

the higher the temperature, the faster the time to drain moisture. Results are good in agreement with the earlier observations of drying the various products (Nguyen *et al.*, 2018; Yahya, 2011). From Figure 1, the moisture content rapidly reduced at the beginning of the drying process (about 120 min) and then slowly decreased with increasing in drying time. Drying curve equations at different temperatures are presented in Table 1.

Table 1. Drying curve equations at different temperatures

Drying temperature (°C)	Equation	R^2
40	$y = 6.557e^{-0.004x}$	0.9791
45	$y = 7.332e^{-0.005x}$	0.9870
50	$y = 7.359e^{-0.006x}$	0.9830
55	$y = 6.251e^{-0.007x}$	0.9792
60	$y = 6.277e^{-0.009x}$	0.9746
65	$y = 7.9243^{-0.011x}$	0.9855
70	$y = 8.215e^{-0.013x}$	0.9871

Effect of drying methods on the characteristic of *Pleurotus sajor-caju*

The nutritional composition and antioxidant capacity of dried mushroom samples at different drying methods are presented in Table 2. All nutritional values of samples dried by different drying methods were significantly ($p \leq 0.05$) different from each other, except β-glucan. It is clear from the experimental and statistical data that the quality of the sample treated with solar drying was higher than others. Significantly highest protein, carbohydrate, flavonoid, β-glucan content (dry basis) (16.22%, 24.84% and 5.82 mg QE/gm, 0.41%, respectively) was observed for the sample dried by solar drying. No significant difference of lipid, total phenolic content were observed in solar dried sample and in oven dried at 45°C (dry basis) (1.49 and 1.53%; 40.04 and 48.38 mg TAE/gm, respectively). It can be concluded that drying at different methods but at the same temperature [solar drying (45-47°C) and drying at 45°C] did not affect the lipid and total phenolic content. In this study, antioxidant capacity was determined using ferric reducing antioxidant power (FRAP) and free radical scavenging activity of DPPH. The results showed that no significant difference about FRAP and DPPH was observed for the samples at different drying methods. Therefore, it can be inferred that drying methods have no significant effect on the antioxidant activity. The highest FRAP (426.51 mM Fe^{2+}/gm db) and DPPH (68.51%) was determined in dried sample at 45°C and 40°C, respectively. The antioxidant capacity of solar drying is lower than samples at 45°C and 40°C (362.58 mM Fe^{2+}/gm db and 62.35%, respectively). Various methods can be used to dry fruits and vegetables. Convection drying is the most commonly used method in the food industry because of the ease of controlling the process (Mundada *et al.*, 2010). However, this method could damage both nutrition quality and texture, also requires a long period of drying that causes discoloration and has to be run under comparatively high temperatures (Figiel, 2010). Besides that, mechanical driers require fossil fuel an electrical energy. Sun dryers and solar dryers have the potential for adoption and application in An Giang province, Vietnam.

The color of samples was expressed as lightness (L*), coordinate green-red (a*) and coordinate yellow-blue (b*). In general, the L* value of samples at 40 to 70°C decreased with increasing temperature and a*, b* value of samples increased with increasing temperature. The overall color parameters

Table 2. Nutritional composition and antioxidant activitiesof *Pleurotus sajor-caju* by different drying methods

Drying methods	Protein (% db)	Carbohydrate (% db)	Lipid (% db)	β-glucan (%)	Total phenolic (mg TAE/ gm db)	Flavonoid (mg QE/ gm db)	Frap (mM Fe^{2+}/ gm)	DPPH (%)
40°C	13.89^{abcd}	21.92^{bc}	1.27^{ef}	0.13^{a}	38.47^{abc}	3.22^{ab}	279.81^{ab}	68.51^{bcd}
45°C	15.76^{bcd}	22.59^{bc}	1.53^{f}	0.22^{a}	48.38^{c}	2.65^{a}	426.51^{bcd}	59.02^{b}
50°C	10.05^{a}	20.08^{abc}	1.01^{de}	0.20^{a}	37.84^{abc}	2.52^{a}	336.20^{bc}	68.09^{bcd}
55°C	10.67^{abc}	18.61^{ab}	0.35^{a}	0.18^{a}	36.12^{abc}	3.32^{ab}	306.09^{ab}	63.77^{bc}
60°C	10.55^{ab}	18.25^{ab}	0.64^{abcd}	0.17^{a}	31.00^{a}	2.21^{a}	221.12^{a}	74.54^{d}
65°C	13.62^{abcd}	16.32^{ab}	0.78^{bcd}	0.16^{a}	32.24^{a}	2.28^{a}	357.20^{bc}	48.55^{a}
70°C	9.59^{a}	15.94^{a}	0.42^{ab}	0.17^{a}	28.35^{a}	3.51^{ab}	331.12^{abc}	73.52^{cd}
Sun drying (~40°C)	15.92^{cd}	22.59^{bc}	1.02^{de}	0.24^{a}	38.31^{abc}	4.17^{b}	314.54^{ab}	62.91^{bc}
Solar drying (45-47°C)	16.22^{d}	24.84^{c}	1.49^{f}	0.41^{a}	40.04^{bc}	5.82^{c}	362.58^{bc}	62.35^{bc}

Different letters represent the significant difference in each column with $p \leq 0.05$.

Table 3. The color and texture of dried mushroom by different drying methods

Drying method	Color parameters			Texture (gm force)
	L*	a*	b*	
Fresh mushroom	80.40	1.39	3.52	
40°C	69.75^{d}	1.76^{bc}	6.07^{b}	8611.83^{b}
45°C	69.28^{d}	2.28^{cd}	7.17^{bc}	6261.80^{a}
50°C	56.92^{c}	2.68^{cde}	8.22^{bc}	6600.00^{ab}
55°C	53.05^{c}	2.98^{efg}	8.85^{c}	7412.33^{ab}
60°C	36.68^{ab}	3.12^{efgh}	13.36^{d}	7398.50^{ab}
65°C	35.75^{ab}	3.89^{gh}	13.37^{d}	8286.67^{ab}
70°C	32.96^{a}	4.02^{hi}	17.09^{d}	8155.33^{ab}
Sun drying	70.66^{d}	1.81^{ab}	3.65^{a}	5883.75^{a}
Solar drying	76.79^{e}	1.24^{a}	3.49^{a}	7007.75^{a}

Different letters represent the significant difference in each column with $p \leq 0.05$.

of mushrooms samples were more influenced by drying methods. Non-enzymatic Maillard reaction that occurs between proteins or amino acids and reducing sugars during heating may be responsible for the formation of brown compounds (Nguyen & Schwartz, 1999). It is clear that more browning occurred during drying because of non-enzymatic Maillard reaction. Kotwaliwale *et al*. (2007) noted that the increased darkening of mushroom samples dried at high temperatures could be attributed to the negative influence of high temperature on mushroom pigments.

The color and texture of dried mushroom samples by different drying methods are presented in Table 3. Our results also showed that the best color was obtained (L*=76.79, a*=1.24, b*=3.49) for samples dried by the solar drying, that were closest to those of fresh mushrooms samples (L*=80.40, a*=1.39, b*=3.52) (Figure 2). The results are consistent with some research (Soto *et al*., 2001; Nour *et al*., 2011), they reported that the color of dried mushroom samples were a critical quality parameter to the acceptance of final product and products with high L* values being preferred by consumers.

There is no significant difference in firmness between samples at different drying methods at 40°C, the shear force is highest (8611.83 gm force). Increasing drying temperature (from 45 to 70°C) caused increased firmness of the product probably because the mushrooms dried faster thus the time for the breakdown of the cell structural components like pectin or cellulose were reduced (Suhaila & Tok, 1994). Besides that, the shear force tend to increase when the drying time was longer (Yung-Sang *et al*., 2015).

Fig. 2. Mushroom samples at different drying methods.

CONCLUSION

This research has been useful for verification of the influence of difference drying methods on the characteristic of *Pleurotus sajor-caju*. It was found that when changing the drying temperature from 40°C to 70°C, the drying time is shortened from 960 to 330 min. Besides, the solar drying gave the best mushroom quality. The use of this drying method can be economic, low energy consumption and environmentally friendly alternative of An Giang province (Vietnam) to help reduce the postharvest loss and increase the consumption availability of products.

ACKNOWLEDGEMENT

We gratefully acknowledge Can Tho University and An Giang University, Vietnam for supporting our research.

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