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Effects of Drying Methods on Physico-Chemical Properties and Antioxidant Activity of Shiitake Mushrooms (*Lentinus Edodes*)

Jiang-Lian Duan[1] --- Jian-Guo Xu[2*]

[1,2]College of Food Science, Shanxi Normal University, Linfen, Shanxi, China

Abstract

The effects of different drying methods including natural air-drying (ND), hot air drying (HD), vacuum drying (VD), microwave drying (MD), infra-red drying (ID), and freeze drying (FD) on physico-chemical properties and antioxidant activities of shiitake mushroom were investigated in this paper. The results showed that drying methods had obvious effects on the color, proximate chemical compositions, total phenolics, antioxidant activity of shiitake mushroom. The FD and ND products exhibited the best rehydration and shrinkage ratio; the effect of FD on color was the least, followed by ND, while MD and ID influenced significantly the color of mushroom; six drying methods had no effects on the content of ash, crude fat and carbohydrate of shiitake mushroom. Drying resulted in the decrease of total phenolic content and antioxidant activity of shiitake mushroom. Among them, the mushroom dried with FD had no obvious changes compared with fresh mushroom.

Keywords: *Lentinus edodes*, Drying, Physical property, Chemical property, Phenolics, Antioxidant activity.

Contents

** Corresponding Author*

1. Introduction

In recent years, mushrooms are favorable all over the world not only because of their texture and flavour, their chemical, nutritional and functional properties such as antiallergic, antiatherogenic, antihypoglycemic properties are also well documented [1, 2]. Shiitake mushroom (*Lentinus edodes*) is a good source of nutrition because of its higher protein, dietary fibers and important mineral contents [3]. Besides, shiitake mushroom contains many different phytochemical contents such as phenolic compounds, tocopherols, ascorbic acid and carotenoids [4]. Therefore, mushroom (*L. edodes*) is a healthy food in our daily diet.

However, the shelf life of shiitake mushroom is short because of its high respiration rate, tendency to turn brown and having no physical protection to avoid water loss or microbial attack [5]. As a result, it is necessary to find a method to extend their shelf life. Drying is the most common method for preserving mushrooms, but different drying methods have different effects on the quality of the products because of differences in characteristics and mechanism of drying and materials [6-8]. The effects of different drying methods including natural air-drying (ND), hot air drying (HD), vacuum drying (VD), microwave drying (MD), infra-red drying (ID), and freeze drying (FD) on physico-chemical properties and antioxidant activities of shiitake mushroom are investigated in this paper, which would provide some foundational information for the developing and application of shiitake mushroom.

2. Materials and Methods

2.1. Raw Materials

Fresh mushrooms (*Lentinus edodes*) were purchased form local market in Linfen, China on May 8, 2014. The mushrooms with homogeneous color and size were selected and stored in a refrigerator maintained at 4 ^{o}C. The average initial moisture content of these mushroom samples was 88.4 ± 1.2% (w/w), as determined using a hot air oven at 105 ^{o}C.

2.2. Sample Preparation and Drying

The middle sections of mushrooms were sliced and then were divided into seven portions (accurately 250 g of each) at random. One of the samples was stored at 4 ^{o}C for further use, and other portions were dried by different methods in optimised conditions until the final moisture content was less than 10 % (w/w), respectively. Detailed procedures for each drying method are described below: (a) natural air-drying (ND) at 23–30 °C by sunshine and flowing air; (b) hot air drying (HD) at 45 °C; (c) microwave drying (MD) in a microwave oven at 240 W; (d) vacuum drying (VD) in a vacuum drying oven at 45 °C and vacuum of 0.08 MPa; (e) infra-red drying (ID) in an IR moisture analyzer at 45 °C; (f) freeze drying (FD) in a freeze drier at 20 °C with the condenser temperature and chamber vacuum at -55 °C and 30 Pa. The dried samples were packaged in aluminum foil bags for further quality analysis.

2.3. Rehydration Ratio (RR)

The RR of dried mushroom was determined by immersing the dried samples in distilled water (50 mL of water per gram of mushroom) at room temperature for 30 min. Following this, the samples were taken out from the water, and the excess water was removed from the surface using a dry blotting paper and the mass of the samples was measured. The RR was calculated according to the formula [9] $RR= (W_1-W_0)/Wo$, where W_1 and Wo are the mass values of the rehydrated and dried samples, respectively. The RR values were determined in triplicate.

2.4. Shrinkage Ratio

The volume of the test sample was measured using an excluding method, and the clean sea sand was selected as filling material [10]. The mean particle diameter of sand is about 0.6 mm. Five replicates were performed for each sample and mean value was calculated. The shrinkage ratio was calculated as: $RS\ (\%)=100\times(V_0-V_1)/V_0$, where *RS* is the shrinkage ratio of the sample, V_0 is the initial volume of the sample before drying, V_1 is the volume of the dried sample.

2.5. Surface Colour Measurement

The colour of sample was measured through the CIE L*a*b* system using a CR-330 Minolta Colorimeter (Minolta, Ramsey, NJ) calibrated with a white standard tile. The results were expressed as Hunter colour values of *L**, *a** and *b**, where *L** was used to denote lightness, *a** redness and greenness, and *b** yellowness and blueness. Hunter values of the fresh and dried samples were measured in triplicate.

2.6. Chemical Analysis

The crude protein, fat, fibre and ash were determined following the AOAC procedures [11]. The crude protein content (N×4.38) of the samples was estimated by the macro-Kjeldahl method; the crude fat was determined by extracting a known weight of the sample with petroleum ether, using a Soxhlet apparatus; the crude fibre was estimated by acid/alkaline hydrolysis of insoluble residues; the ash content was determined by incineration at 600±15 °C; the carbohydrate content was calculated by subtracting the other proximate compounds from 1 g dry sample. The content of all compositions are expressed as grams per 100 gram dry matter basis (DM).

2.7. Antioxidant Activity

2.7.1. Determination of Total Phenolic Content (TPC)

The ground samples are blended with methanol and shaken at 25 °C at 150 rpm for 2 h, and then the homogenates are centrifuged for 15 min at 4 ^{o}C and 5 000 g. After centrifugation, the supernatants are vacuum-evaporated to dryness at 40 ^{o}C, redissolved in methanol at 10 mg/mL, and stored at 4 ^{o}C for further use.

The TPC was determined based on the Folin-Ciocalteu colourimetric method as described by Hu and Xu [12]. Briefly, an aliquot (0.5 mL) of the suitable diluted extracts, 2.5 mL of deionized water and 0.5 mL of 1.0 M Folin-Ciocalteu reagent were mixed within 10 mL volumetric flasks and vortexed. After 8 min, 1.5 mL of 7.5% sodium carbonate solution was added and mixed thoroughly. The absorbance of the reaction mixtures was measured using a spectrophotometer at 765 nm wavelength after incubation for 2 h at room temperature. Extraction solvent was used as the blank and gallic acid (GA) was used for calibration of standard curve. Phenolic content was expressed as milligrams of gallic acid equivalents (GAE) per 100 g of DM.

2.7.2. Antioxidant Activity by DPPH Radical Scavenging Assay

DPPH radical scavenging activity was determined according to the method of Hu and Xu [12] with some modifications. Briefly, each of sample solutions **(**1 mg/mL in methanol**)** was serially diluted to various concentrations in methanol respectively, and then a 0.5 mL of samples was mixed with 2.5 mL of 60 μM DPPH dissolved in methanol. The mixture was shaken vigorously and left to stand for 30 min in the dark, and the absorbance was measured at 517 nm against a solvent blank. The scavenging rate on DPPH radicals was calculated according to the formula, scavenging rate (%) = $[(Ao-A_1)/Ao]\times100$, where Ao is the absorbance of the control solution, A_1 is the absorbance in the presence of samples in DPPH solution.

2.8. Statistical Analysis

All results are expressed as mean ± SD (n=3). In order to evaluate the significant differences between sample means, one-way analysis of variance (ANOVA) and Duncan's test were performed with significant level being considered at $p < 0.05$.

3. Results

3.1. The Effects of Drying Methods on Rehydration Ratio

Colour, rehydration and shrinkage ratio are three important factors to evaluate appearance and texture of dehydrated products. The rehydration capacities of mushroom samples dried with different drying methods are presented in Fig. 1. Among all the treatments, MD got the lowest rehydration radio which reaches at 5.2-fold of dried body, whereas FD and ND got the highest rehydration radio which reaches at 8.7 and 8.4-fold of dried body respectively. This may be due to the changes in the structure and texture of the samples during different drying processing [13, 14]. We postulated that FD and ND provides enough interval time, leading the internal moisture diffuse to the surface which avoids the shrinking of surface. For all samples, rehydration radio is fast at the beginning of re-watering process and falling to equilibrium state at the end, which was been reported by other authors [15, 16].

3.2. The Effects of Drying Methods on Shrinkage Ratio

Fig. 1 showed effects of different drying methods on the shrinkage ratio of mushroom samples, and the influence of drying methods on the shrinkage ratio was evident. Contrary to the results of rehydration ratio, shrinkage ratio of mushroom dried with FD and ND were the smallest, and were 14.5% and 15.2%, respectively. The shrinkage ratio of other samples ranged from 18.5% to 28.6%. This is because much more moisture of samples was removed rapidly at higher temperature, which resulted in greater changes of shrinkage ratio under the same drying condition. Therefore, temperature of drying may be the main factor affecting the shrinkage ratio of dried mushroom. The changes in shrinkage ratio also directly affect rehydration ratio of samples.

3.3. The Effects of Drying Methods on Color

The effects of drying methods on color of dried mushroom are shown in Table 1. CIE L*, a*, and b* values were significantly different among drying methods. As an objective evaluation of dehydrated products, CIE L* values appear to be important and sensitive to color evaluation, which can be an indicator of lightness of color. The CIE a* value indicates the redness (positive a*) and greenness (negative a*), while the CIE b* value indicates the yellowness. The CIE L*, a*, and b* values of fresh mushroom were 26.33, 0.95, 1.13 respectively. However, after drying CIE L*, a*, and b* values ranged from 31.56 to 42.34, from 1.08 to 3.86, and from 2.51 to 6.31, respectively. These changes in the CIE L*, a*, and b* values implied that drying treatment had obvious effects on the color of dried mushroom. Among them, the effect of FD on color was the least, followed by ND, while MD and ID influenced significantly the color of dried mushroom. The phenomenon can be attributed to the enzymatic browning which may be the main reason for brown stain of the products [17, 18].

3.4. The Effects of Drying Methods on Proximate Chemical Compositions

The effects of drying methods on the chemical compositions of dried shiitake mushroom are shown in Table 2. Based on dry weight, it can be easily seen that the crude ash ranged from 6.3 to 6.6 g/100 g DW, crude fat ranged from 4.2 to 4.8 g/100 g DW, and the carbohydrate ranged from 54.1 to 54.7 g/100 g DW, which indicate that six drying methods had no effects on the content of ash, crude fat and carbohydrate of shiitake mushroom. The content of crude fiber of fresh mushroom was 11.2 g/100 g DW, and it increased and ranged from 11.5 to 16.1 g/100 g DW after drying, especially MD and ID. The protein are found in high levels and varied between 18.5 to 20.6 g/100 g DW. ND and FD had no obvious effect on protein content compared with fresh mushroom, while other drying methods can result in decrease of protein. Overall, FD is the best drying method which basically retains the proximate chemical compositions of fresh mushroom, followed by ND.

3.5. The Effects of Drying Methods on Phenolics

The effects of drying methods on phenolic content of shiitake mushroom are shown in Fig. 2. The results showed that the drying methods had a satisfactory effect on the phenolic content of shiitake mushroom. The total phenolic of

fresh shiitake was 35.3 mg/100 g. A reduction in total phenolic contents of dried samples was found. During FD, the loss of phenolics was the lowest, followed by VD, ND, MD, HD, and ID. Investigates its reason, the loss may be come from enzymatic and non enzymatic reaction of phenolic compounds during the drying process [19]. The internal temperature of materials was very high although the heating time was short during microwave drying process, while the heating time was longer during hot air drying. Therefore, the higher drying temperature and the longer drying time lead to oxidation of phenolic compounds.

3.6. The Effects of Drying Methods on Antioxidant Activities

The effects of drying methods on the antioxidant activities of shiitake mushroom are shown in Fig. 2. The results showed that the drying methods had obvious effects on the antioxidant activities of shiitake mushroom, and the effect was similar to TPC. The drying resulted in the decrease of scavenging activity on DPPH radicals. The scavenging rate of fresh shiitake on DPPH radicals was 75.4%, while the scavenging activity of FD products on DPPH radicals was the near to fresh shiitake with 70.5%, followed by VD, ND, MD, ID and HD. In addition, we found that the content of phenolics was highly associated with antioxidant activity, indicating that the phenolic compounds contributed significantly to the antioxidant activity of shiitake mushroom, which was in agreement with the previous studies [19, 20].

4. Conclusions

In conclusion, this work showed that drying methods had obvious effects on the color, proximate chemical compositions, total phenolics, antioxidant activity of mushroom. The FD and ND products exhibited the best rehydration and shrinkage ratio; the effect of FD on color was the least, followed by ND; six drying methods had no effects on the content of ash, crude fat and carbohydrate of shiitake mushroom. Drying resulted in the decrease of total phenolics, antioxidant activity of shiitake mushroom. Among them, the mushroom dried with FD had no obvious changes compared with fresh mushroom.

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Table-1. The color of fresh and dried shiitake mushroom

	L*	a*	b*
Fresh	26.33 ± 0.55 f	0.95 ± 0.05 d	1.13 ± 0.06 c
ND	33.32 ± 1.46 de	1.13 ± 0.08 cd	2.56 ± 0.14 b
HD	35.11 ± 1.65 cd	1.85 ± 0.52 cd	2.64 ± 0.52 b
VD	37.27 ± 1.25 bc	2.18 ± 0.34 bc	2.93 ± 0.31 b
ID	40.55 ± 1.54 ab	3.25 ± 0.25 ab	5.84 ± 0.55 a
MD	42.34 ± 1.13 a	3.86 ± 0.84 a	6.31 ± 0.24 a
FD	31.56 ± 0.82 e	1.08 ± 0.10 cd	2.15 ± 0.13 b

Numbers represent mean values of three independent replicates ± SD. Different letters indicate statistically significant differences between the means ($P < 0.05$) for each parameter.

Table-2. Proximate compositions (g/100 g DM) of fresh and dried shiitake mushroom

	Crude Protein	Crude Fat	Carbohydrate	Crude Fiber	Crude Ash
Fresh	20.2 ± 0.4 a	4.5 ± 0.2 ab	57.7 ± 1.8 a	11.2 ± 0.6 de	6.3 ± 0.5 a
ND	20.4 ± 0.2 a	4.4 ± 0.1 ab	56.2 ± 0.9 a	12.5 ± 0.3 d	6.4 ± 0.8 a
HD	18.5 ± 0.1 c	4.7 ± 0.2 a	55.8 ± 1.4 a	14.5 ± 0.2 c	6.4 ± 0.6 a
VD	19.4 ± 0.1 b	4.7 ± 0.1 a	54.7 ± 1.3 a	14.8 ± 0.5 bc	6.3 ± 0.5 a
ID	18.9 ± 0.2 bc	4.8 ± 0.3 a	54.1 ± 0.8 a	15.6 ± 0.1 ab	6.5 ± 0.4 a
MD	18.9 ± 0.3 bc	4.2 ± 0.4 ab	54.2 ± 1.4 a	16.1 ± 0.4 a	6.6 ± 0.2 a
FD	20.6 ± 0.2 a	4.6 ± 0.2 ab	56.9 ± 1.2 a	11.5 ± 0.3 e	6.3 ± 0.5 a

Numbers represent mean values of three independent replicates ± SD. Different letters indicate statistically significant differences between the means ($P < 0.05$) for each parameter.

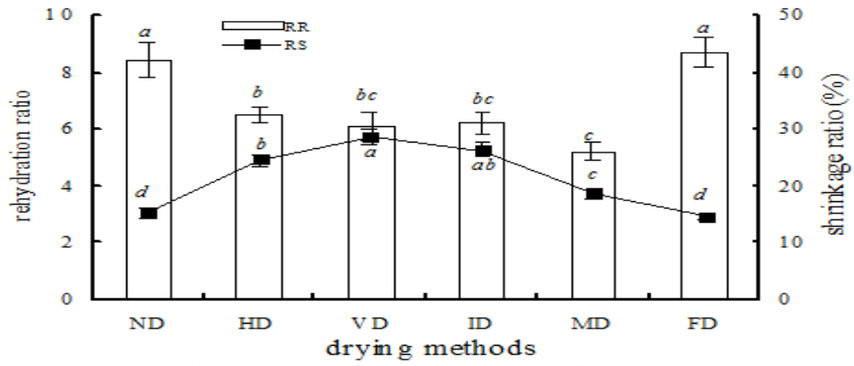

Fig-1. Effect of drying methods on rehydration and shrinkage ratio

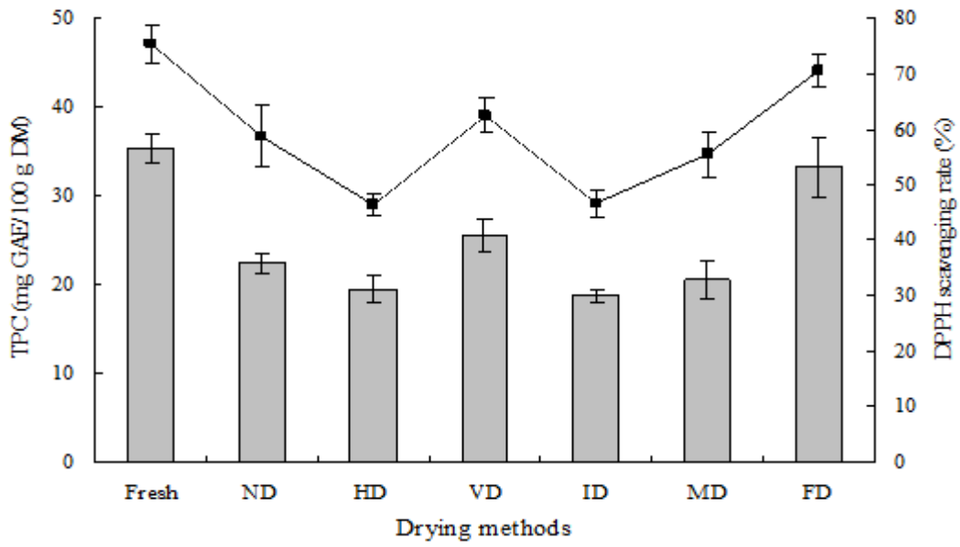

Fig-2. The effects of drying methods on phenolic content and antioxidant activity of shiitake mushroom

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