Journal of Technical Education Science No.48 (07/2018)
Ho Chi Minh City University of Technology and Education

EXPERIMENTAL STUDY OF DRYING MUSHROOMS (VOLVARIELLA VOLVACEA, PLEUROTUS OSTREATUS, LENTINULA EDODES, PLEUROTUS ERYNGEII, AGARICUS BISPORUS, FLAMMULINA VELUTIPES)

NGHIÊN CỨU THỰC NGHIỆM SẤY NẤM ĂN (NẤM RƠM, NẤM BÀO NGƯ, NẤM ĐÔNG CÔ, NẤM ĐÙI GÀ, NẤM MỠ, NẤM KIM CHÂM)

Trinh Van Dung, Luong Thanh Danh
Faculty of Chemical Engineering, Ho Chi Minh City University of Technology, Vietnam

Received 25/05/2018, Peer reviewed 20/06/2018, Accepted for publication 10/07/2018

ABSTRACT

This paper presents the results of experimental study on drying popular edible mushrooms (volvariella volvacea, pleurotus ostreatus, lentinula edodes, pleurotus eryngeii, agaricus bisporus, flammulina velutipes). This study determines the dynamic parameters of drying by experiment corresponding to those mushrooms such as:

Critical moisture (U_{th},%):3.14; 7.92; 9.0; 9.0; 5.94; 8.4;

Equilibrium moisture (U, %): 0.05; 0.025; 0.70; 0.25; 0.25; 0.205;*

Constant drying rate (N_o, g/g dry solid.min): 2.35; 7.98; 2.30; 4.11; 2.32; 13.23.

From those results, drying time (τ) is also given, bases on 2-period-drying model (constant-rate and falling-rate period): $\tau = \frac{U_1 - U_{th}}{N_0} + \frac{U_{th} - U^*}{N_0}\ln\left(\frac{U_{th} - U^*}{U_2 - U^*}\right)$. *The difference between calculated τ_{TT} and experimental τ_{TN} drying time is approximately (1.0 ÷ 9.3)%. The results show that this model can be used to calculate the process and design dryer to preserve those mushrooms. In addition, the study also showed that if the ones are dried at 50°C, the drying time will be significantly shorten, especially, when drying at two temperatures: 50°C for the first two hours and 70°C for the rest.*

Keywords: *dynamic parameters of drying; drying mushroom; volvariella volvacea, pleurotus ostreatus; lentinula edodes; pleurotus eryngeii; agaricus bisporus; flammulina velutipes.*

TÓM TẮT

Bài báo trình bày kết quả nghiên cứu sấy các loại nấm ăn phổ biến (nấm rơm; nấm bào ngư, nấm đông cô, nấm đùi gà, nấm mỡ, nấm kim châm) bằng thực nghiệm. Kết quả xác định được các thông số động học sấy từ thực nghiệm, ứng với các loại nấm nêu trên lần lượt bằng:

Độ ẩm tới hạn (Uth, %): 3.14; 7.92; 9.0; 9.0; 5.94; 8.4;

Độ ẩm cân bằng (U, %): 0.05; 0.025; 0.70; 0.25; 0.25; 0.205;*

Tốc độ sấy đẳng tốc (N_o, g/g_{VLK}.phút): 2.35; 7.98; 2.30; 4.11; 2.32; 13.23.

Trên cơ sở đó xác định thời gian sấy theo mô hình sấy hai giai đoạn, sấy đẳng tốc và sấy giảm tốc: $\tau = \frac{U_1 - U_{th}}{N_0} + \frac{U_{th} - U^*}{N_0}\ln\left(\frac{U_{th} - U^*}{U_2 - U^*}\right)$. *Sai lệch giữa quả thời gian sấy tính toán τ_{TT} với thực nghiệm τ_{TN} trong khoảng (1.0 ÷ 9.3) %. Kết quả cho thấy có thể dùng mô hình này để tính toán quá trình và thiết kế máy sấy dùng trong sấy nấm, để bảo quản các loại nấm nêu trên. Ngoài ra, nghiên cứu cũng cho thấy với các loại nấm trên nên tiến hành ở 50°C sẽ rút ngắn được thời gian sấy đáng kể, đặc biệt tiến hành sấy ở hai nhiệt độ: hai giờ đầu ở 50°C, sau đó ở 70°C.*

Từ khóa: *Động học sấy; nấm rơm; nấm bào ngư; nấm đông cô; nấm đùi gà; nấm mỡ; nấm kim châm; sấy nấm.*

1. INTRODUCTION

The edible mushrooms (volvariella volvacea, pleurotus ostreatus, lentinula edodes, pleurotus eryngeii, agaricus bisporus, flammulina velutipes) are highly nutritious foods that are grown and used for many days all over the world. Therefore, the preservation of those mushrooms is an urgent need. Using the cold preservation method such as refrigeration, preservation time is quite short, about 24 ÷ 72 hours (maximum 120 hours), depending on the ambient temperature and types of mushrooms [1, 2]. While, if dried mushrooms are preserved properly, their usage time can be extended up to 3 years [3]. Therefore, drying is the best method to improve the value of edible mushroom after harvesting. However, the technology and model data used to calculate and design mushroom dryer are not fully developed, especially the dynamic parameters of the drying process. Besides, selecting an appropriate drying temperature is also of great concern in drying those objects which contain high level of nutrition and moisture such as mushrooms.

2. EQUIPMENT, TOOLS, MATERIALS AND RESEARCH METHODS

2.1. Experimental equipment and tools

Experimental dryer was convection dryer (see Figure 1): volume 20 L. Its technical components includes: wet bulb thermometer (t_w), dry bulb thermometer (t_k) with a temperature measuring range of 0 ÷ 100°C; the temperature controller with the error of ±1 °C; technical balance with a mass measuring range of 1000 grams and 1 gram resolution; drying cabinet with the volume 20 L and 2 stainless steel mesh trays 25x40 cm for stacking material; a digital stop-watch used to measure time; and a caliper with 1 mm resolution.

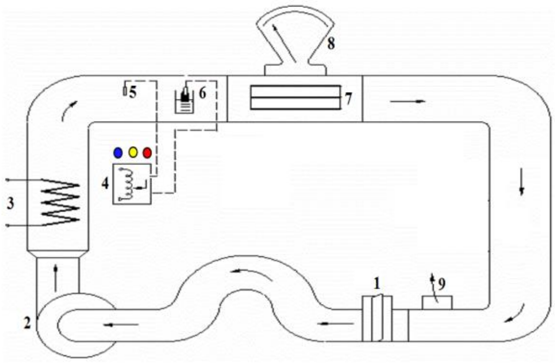

Figure 1. *Diagram of experimental dryer*

1. Air recirculation valve; 2. Pan; 3. Heat exchanger; 4. Temperature controller; 5. Dry bulb thermometer; 6. Wet bulb thermometer; 7. Cabinet; 8. Balance; 9. Air outlet

2.2. Experimental materials (mushrooms)

The mushrooms which were used in the drying experiments, were provided by THIEN AN import – export investment and development Joint Stock Company – TIANIMEX, address 11/10B Tien Lan Hamlet, Ba Diem Commune, Hoc Mon District, Ho Chi Minh City. The mushrooms used in the experiments were cut off from the roots, shaped in figure 2. Then they were cut to certain size in table 1.

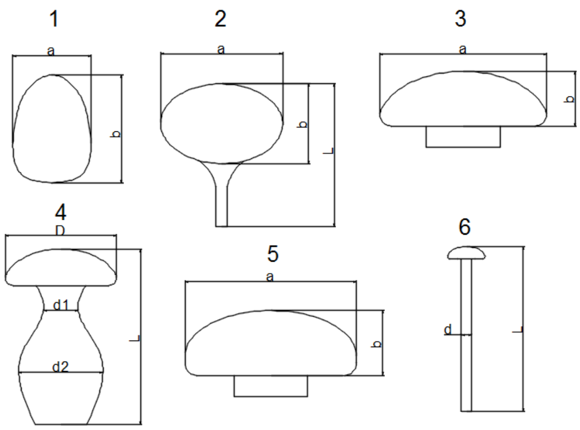

Figure 2. *Shapes of the mushrooms*

1. Volvariella volvacea; 2. Pleurotus ostreatus; 3. Lentinula edodes; 4. Pleurotus eryngeii; 5. Agaricus bisporus; 6. Flammulina velutipes

Table 1. *Parameters regarding initial characteristics and preliminary processing of pre-treated mushrooms*

Parameters \ The mushrooms	Volvariella volvacea	Pleurotus ostreatus	Lentinula edodes	Pleurotus eryngeii	Agaricus bisporus	Flammulina velutipes
Preliminary processing	Cut ½	Original	Original	Cut ½ and ¼	Cut ¼	Original
Size axb(xLxD), mm	24x32	64x44x104x-	32x15(-x-)	27x43x46x111	47x22(-x-)	2x102
Color	white	gray white	gray	white	gray white	yellow white
Humidity, %	90,19	92,30	90,13	87,15	92,64	92,64

2.3. Research methods

a) Determination of drying temperature

Set the drying temperature corresponding to the test samples (volvariella volvacea and lentinula edodes) as shown in table 2. Start the dryer (test thermometer, balance, turn on fan, resistor).

When the temperature was stable, the mushrooms have been preliminarily treated, put in cabinet, each sample was 400 grams, placed on 2 mesh trays (25x40cm). Each time after 5 minutes, the sample weight and drying temperature (wet bulb and dry bulb) were measured, until the sample weight remained constant after 3 continuous measurements. The results are shown in Table 2 and Figure 3.

Table 2. *Experiment to determine the drying temperature*

Parameters \ Drying mode		One temperature				Tow temperature
Temperature t, °C		40	50	60	70	50 (2 h), 70
Time, Min.	Volvariella volvacea	640	335	280	240	250
	Lentinula edodes	470	320	320	300	230

b) Determination dynamic parameters of drying

Determining the dynamic parameters of drying for the six types of mushrooms were conducted with obtained data as shown in Table 3.

Table 3. *Experiments to determine the dynamic parameters of drying*

Parameters \ The mushrooms	Volvariella volvacea	Pleurotus ostreatus	Lentinula edodes	Pleurotus eryngeii	Agaricus bisporus	Flammulina velutipes
Temperature t, °C	50	50	50	50	50	50
Weight G_0, gam	400	400	400	400	400	400
Time τ, Min	425	310	600	440	520	150

From the experimental data, the drying curves and the drying rate curve were calculated. Based on the drying rate curve, the critical moisture U_{th} (subsequent moisture of constant-rate period), equilibrium moisture U* (subsequent moisture of falling-rate period) and the constant drying rate N_o were determined for each type of mushrooms. The results are shown in Table 4 and Figure 4.

c) Choice drying dynamic model

Form the obtained results of U_{th}, U* and N_o, the drying time was also calculated, bases on the 2-period-drying model:

$$\tau = \frac{U_1 - U_{th}}{No} + \frac{U_{th} - U^*}{No} \ln \frac{U_{th} - U^*}{U_2 - U^*} \qquad (1)$$

The calculated results are also shown in Table 4 and Figure 5

3. RESULTS AND DISCUSSION

3.1. Mushroom drying temperature

The influence of temperature on the experimental drying time is shown in Table 2 and Figure 3

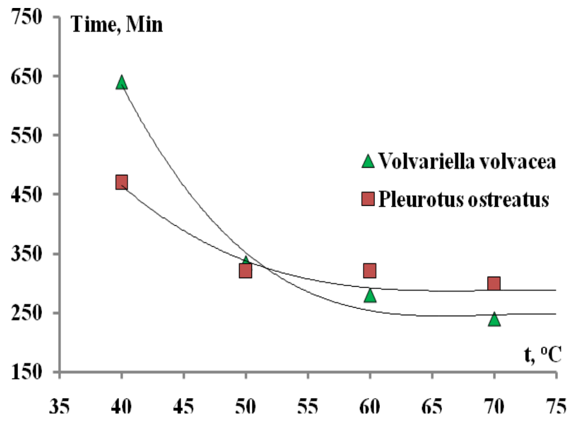

Figure 3. *The influence of the drying temperature on the drying time*

The data in Table 2 and Figure 3 show that: when the drying temperature increases, the drying time decreases, but the drying time decreases sharply when the temperature increases from 40°*C* to 50°*C*. From 50°*C* to 60°*C* and 60 ÷ 70°*C*, the drying time decreases slightly. So, to ensure the quality of dried mushrooms for edible mushrooms, the drying temperature should be operated at

50°*C*, it helps to reduce the drying time while ensuring the requested product. This finding is in consistent with the results obtained by other authors for drying edible mushrooms from 40 ÷ 80°*C* [4, 5].

The data in Table 2 also show that, if the drying process is carried out at 2 temperatures (50°C for the first two hours and 70°C for the rest), the drying time will decrease sharply for both volvariella volvacea and lentinula edodes. Because, in the first two hours, the drying occurs during the constant-rate period, temperature of material is equal to wet bulb temperature of air, is 38 ÷ 42°C, so it does not affect the quality of the dried mushrooms.

3.2. Rate reduction of mushroom's weight when drying

The weight change of 6 mushrooms when drying at 50°C is shown in figure 4.

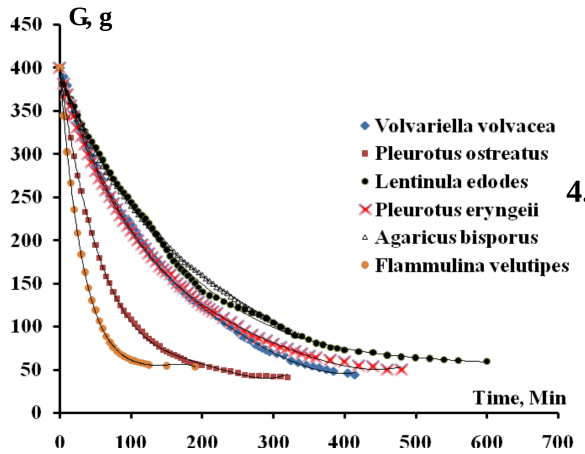

Figure 4. *Weight variation of dried mushrooms*

The result in figure 4 show that, the drying curves have 2 periods clearly: in the constant-rate period, weight of materials decreases rapidly in straight lines, because there is only free moisture evaporation on the surface of the mushrooms. In the falling-rate period, ones decrease slowly according to curve, because the bound moisture evaporation creates surface of evaporation shrinkage. The intersection between these two periods is the critical moisture, the experimental values of one for the six types of mushrooms is shown in Table 4.

3.3. Choice drying dynamic model

The experimental data in table 4, the drying time is calculated bases on 2-period-drying dynamic model (1) [6] and the result is shown in table 4.

The comparison between the calculated drying time and the experimental drying time are show in Table 4 and Figure 5.

Table 4. *The determined dynamic parameters of drying*

Parameters \ The mushrooms		Volvariella volvacea	Pleurotus ostreatus	Lentinula edodes	Pleurotus eryngeii	Agaricus bisporus	Flammulina velutipes
Moisture, %	Critical	3.14	7.92	9	9	5.94	8.4
	Equilibrium	0.05	0.025	0.7	0.25	0.25	0.205
Constant drying rate $N_o.10^2$, g/g dry solid.h		2.35	7.98	2.3	4.11	2.32	13.23
Drying time, Min	Constant rate	149.7	8.1	0	0	79.3	2.7
	Falling-rate	294.4	317.7	606	445.7	446.2	133.3
	Total	444.1	325.8	606	445.7	525.5	136.0
Experimental time, Min		425	310	600	440	520	150
Error. %		4.5	5.1	1.0	1.3	1.1	9.3

In figure 5, error between the drying time obtained by calculation [8] and experiment is abt. 1.0 ÷ 9.3 %. So, this model can be used to calculate the drying process and design of the dryer.

4. CONCLUSSION

Drying mushrooms is an appropriate method to preserve ones and meet requirements for production, sales and consumption of edible mushrooms, that increases value for the current chain of production, preservation and use of mushrooms.

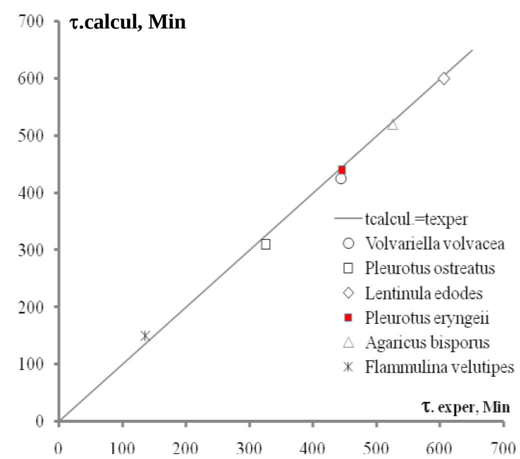

Figure 5. *Error between drying time calculations and experiment*

The mushrooms should be dried at 40 ÷ 70°*C*, corresponds to the drying time of popular edible mushrooms during 6 ÷ 8 hours. In order to reduce the drying time, the drying can be carried out at 2 temperatures (50°C for the first two hours and 70°C for the rest) and it will also ensure the required quality.

The dynamic parameters of the drying process for popular edible mushrooms [7] (volvariella volvacea, pleurotus ostreatus, lentinula edodes, pleurotus eryngeii, agaricus bisporus, flammulina velutipes) by experiment is determined: critical moisture (U_{th}, %): 3.14; 7.92; 9.0; 9.0; 5.94; 8.4; equilibrium moisture (U*, %): 0.05; 0.025; 0.70; 0.25; 0.25; 0.205; constant drying rate (N_o, g/g dry solid.min): 2.35; 7.98; 2.30; 4.11; 2.32; 13.23. These data are the basis for determining the drying time, as well as the design of the dryer.

The 2-period-drying dynamic model can be used to calculate the process and design of the dryer for drying the mushroom from the experimental data obtained mushrooms from experimental data obtained, with an error of about 1.0 ÷ 9.3%.

REFERENCES

[1] FAOSTAT, 2017
[2] V. S. Grzhivo, "Nutritional value and chemical composition of canned food", Moscow: Pishchepromizdat, p. 207, 1997.
[3] A. S. Holmansky, A. Z. Tilov, and E.Yu. Sorokina, "Physico-chemical modeling of the process of drying vegetables and fruits", Modern problems of science and education, Moscow, No 5, p. 8, 2012.
[4] P. Diamantopoulou and A. Philippoussis, "Cultivated mushrooms: preservation and processing", Handbook of vegetable preservation and processing. CRC press, p. 495-525, Florida, 2015.
[5] H. M. Ghodake, T. K. Goswami, and A. Chakraverty, "Mathematical modeling of withering characteristics of tea leaves.", Drying Technology, vol. 24, no. 2, p. 159-164, 2006.
[6] G. Xanthopoulos, G. Lambrinos, and H. Manolopoulou, "Evaluation of thin-layer models for mushroom (Agaricus bisporus) drying", Drying Technology, vol. 25, no. 9, p. 1467–1477, 2007.
[7] G. C. Wakchaure and et al, "Kinetics of thin layer drying of button mushroom.", Journal of Agricultural Engineering, vol. 47, no. 4, p. 41-46, 2010.
[8] Trinh Van Dung, "Applied Informatics in Chemical Technology - Biology – Food", VNU HCMC, 317 p., 2016.

Corresponding author:
Trinh Van Dung, Assoc. Prof., Ph.D.
Ho Chi Minh City University of Technology, Vietnam
E-mail: trinhdung@hcmut.edu.vn