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สมการอบแห้งชั้นบางและความชื้นสมดุลของเห็ดขอนขาว

Thin layer drying equation and equilibrium moisture content of Khon Khao mushroom

ณัฐพล ภูมิสะอาด[1] และละมุล วิเศษ[1]

Nattapol Poomsa-ad[1] and Lamul Wiset[1]

Abstract

The objective of this research was to investigate the thin layer characteristic and equilibrium moisture content of Khon Khao mushroom (*Lentinus squarrosulus* Mont.). The equilibrium moisture content was conducted at various air temperatures of 40-60 °C with the relative humidities of 10-80%. The results found that equilibrium moisture content decreased at the higher air temperature and the lower relative humidity. Oswin's equation was the best equation to predict the equilibrium moisture content. The thin layer drying was studied at the drying temperatures of 40-60 °C and at a constant air velocity of 0.6 m/s. The drying rate increased with the drying temperature. The two term's equation was the most adequate in describing thin layer drying tests.

Keywords: drying rate, equilibrium moisture content, mushroom

บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาลักษณะการอบแห้งชั้นบางและความชื้นสมดุลของเห็ดขอนขาว โดยทำการทดลองหาความชื้นสมดุลที่อุณหภูมิในช่วง 40-60 °C ความชื้นสัมพัทธ์ของอากาศ 10-80% ผลการทดลองพบว่าค่าความชื้นสมดุลลดลงเมื่ออุณหภูมิสูงขึ้นและความชื้นสัมพัทธ์ของอากาศต่ำลง สมการของ Oswin เป็นสมการที่สามารถทำนายค่าความชื้นสมดุลได้ถูกต้องมากที่สุด ในส่วนของการอบแห้งชั้นบางทำการศึกษาที่อุณหภูมิระหว่าง 40-60 °C และความเร็วในห้องอบแห้งคงที่ที่ 0.6 m/s พบว่าอัตราการอบแห้งเพิ่มขึ้นตามอุณหภูมิ สมการสองเทอมมีความเหมาะสมที่นำมาใช้ทำนายอัตราการอบแห้งเห็ดขอนขาว

คำสำคัญ: อัตราการอบแห้ง ความชื้นสมดุล เห็ด

Introduction

Khon Khao mushroom (*Lentinus squarrosulus* Mont.). is abundantly grown in North East of Thailand. Due to high nutritional values for consuming, it is applied as ingredient in food recipe for many cooking. However, the fresh mushroom, with as high as moisture content of about 896-899% dry basis or over during harvest, is needed to reduce the moisture level down to 30-35% with necessary artificial drying to assure good preservation. To develop an adequate drying technique, thin layer drying and equilibrium moisture content studies have been previously carried out (Pal and Chakraverty, 1995; Basunia and Abe, 2001 and El-Ghetany, 2006). The objective of this work was to find a model to describe the thin layer drying and equilibrium moisture content of Khon Khao mushroom. The effect of drying air temperature on color was also evaluated.

Material and Methods

Equilibrium Moisture Content

In this study, the EMC of the products were determined at various air temperatures of 40-60 °C and at the different relative humidities ranging from 10-80% by the static gravimetric method. The freshly products were put in hygrostats with five saturated salt solutions. Samples were weighed (balance, sensitivity 0.001 g) every three days. Equilibrium was acknowledged when three consecutive weight measurements showed a difference less

[1] คณะวิศวกรรมศาสตร์ มหาวิทยาลัยมหาสารคาม ตำบลขามเรียง อำเภอกันทรวิชัย จังหวัดมหาสารคาม 44150

[1] Faculty of Engineering, Mahasarakham University, Kramriang, Kantarawichai, Mahasarakham, Thailand, 441500

than 0.01 g. The moisture content of each sample was determined by the oven method at 103^{O}C for 72 hours by means of triplicate measurements.

Five EMC models as introduced in American Society of Agricultural Engineering standards (ASAE Standard,1999a) were selected for fitting the experimental data. Those models are Henderson, Chung-Pfost, Halsey, Oswin and GAB models. Each of the five equations could be solved explicitly for relative humidity as a function of temperature and EMC, or for EMC as a function of temperature and relative humidity. The parameters of those models were solved using non linear regression analysis. The commercial statistics software packages were used to fit these experimental data. The suitability of the equations was evaluated and compared using the coefficient of determination (R2) and sum of square error (SSE).

Thin layer drying

The drying tests were conducted at the drying media flow rate of 0.6 m/s with drying temperatures of 40, 50 and 60^{o}C. It was obvious that the initial moisture content of all runs were not the same and ranged between 812-960 % dry basic. During drying, the sample was placed in a thin layer on the mesh tray. The mass change was recorded every 3-10 min by the balance. The drying process was ended when the mass of the sample remained constant. Under each set of drying conditions, tests were conducted in duplicates.

In order to normalize the drying curves, the experimental data in percentage dry basis moisture content versus time were transformed to a dimensionless parameter called the moisture ratio (MR) versus time. The empirical drying equations as mention in American Society of Agricultural Engineering standards (ASAE Standard,1999b) were selected to study. Those equations were Semi theoretical, Henderson, Two term, Page and logarithmic. Using non-linear regression, the parameters in the empirical drying equation were initially determined for each set of drying conditions. From the regression results, the quadratic functions were formulated to provide the exact fitting relationship between the drying temperatures with the parameters in the drying equation. The sum square error (SSE) was the criteria to select the best equation to account for variation in the drying curves of dried samples. It was used to determine the quality of the fit. The lower value of SSE was chosen as the criteria for goodness of fit.

Color Assessment

The color of initial and dried gray oyster mushroom samples was measured by a Minolta CR300 chromameter. The Hunter L*, a*, b* scale gave measurement of colors in units of approximate visual uniformity throughout the solid. The total color difference (ΔE) was applied to the experimental results to indicate the effect of drying temperature. It was expressed as

$$\Delta E = \sqrt{(L_t - L_0)^2 + (a_t - a_0)^2 + (b_t - b_0)^2}$$

Results and Discussion

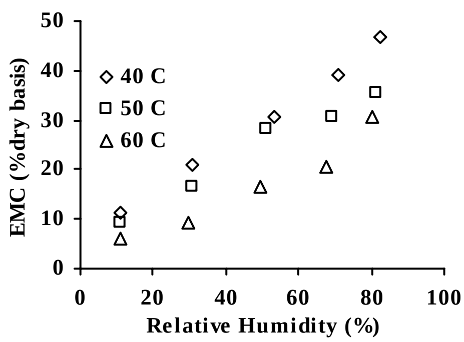

Figure 1 Experimental EMC versus relative humidity at different drying temperatures.

Figure 1 shows that EMC decreases at the higher of air temperature and the lower of relative humidity.

Table 1 The best fitted parameter for the five EMC equations.

EMC equation	R^2	SSE
Modified Henderson	0.95086	6.45635
Modified Chung-Pfost	0.95450	6.27400
Modified Halsey	0.94206	37.16377
Oswin	0.96570	4.79637
GAB	0.78844	119.5379

The coefficients of determination (R^2) for Khon Khao mushroom show the results that the four equations give comparative performance, which is better than the GAB equation. However, the lowest sum of square error (SSE) and the highest coefficients of determination indicates that the Oswin equation is suitable to determine the EMC for Khon Khao mushroom. The suitable equation with equation's parameter is

$$EMC = \frac{A + BT}{\left(RH^{-1} - 1\right)^{\frac{1}{C}}}$$

Where A= 0.49347092, B = -0.00541297 and C = 2.738407694

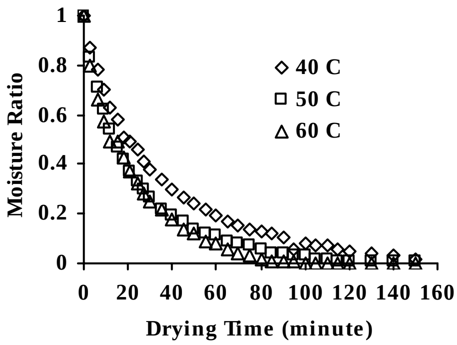

Figure 2 Evolution of experimental moisture ratio values during drying at the different temperatures.

Fig. 2 presents the evolution of the moisture ratio as a function of the drying time at the different temperatures. It can be observed that moisture ratio decreases exponentially with time. Difference between moisture ratios increases gradually as from starting of drying. With increasing the temperature and air velocity, the time required to arrive certain moisture content is decreased.

Table 2 Sum square error (SSE) of the selected drying equations.

Drying equation	SSE
Semi theoretical	0.0008735
Page	0.0000798
Henderson	0.0005989
Logarithmic	0.0001604
Two term	0.0000156

The SSE of MR as shown in Table2 indicates that the regression equations show an acceptable accuracy for fitting the experimental data. However, the two term equation was recommended to describe the drying of Khon Khao mushroom due to low values of SSE. It was expressed as

$$MR = \frac{M_t - M_e}{M_i - M_e} = A_0 \exp(k_0 t) + A_1 \exp(k_1 t)$$

where A0 = -0.00254120T^2-0.26616375T-6.34361471

k0 = -0.00021003T^2-0.02509353T-0.65516041

A1 = -0.00250337T^2+-0.26260827T-7.25609957

k1 = 0.00012894T^2—0.01326781T+0.36021597

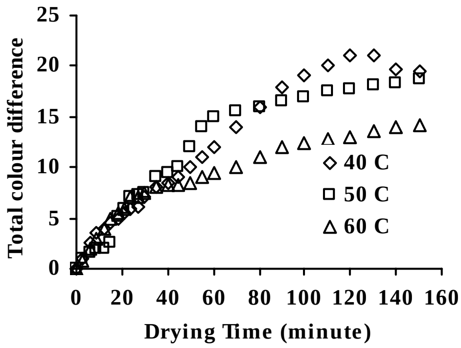

Figure 3 Total color difference values during drying at the different temperatures.

Figure 3 shows that the total color difference value is strongly decreased with the air temperatures and drying times.

Summary

- Oswin equation equation is identified as the most appropriate equation for describing the EMC for Khon Khao mushroom.
- The thin-layer drying characteristic of Khon Khao mushroom is satisfactorily described by two term equation.
- For the color assessment, the results were greatly affected by the drying temperatures.

Acknowledgments

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