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ความชื้นสมดุลของถั่วเหลืองภายใต้การอบแห้งแบบฟลูอิไดซ์เบดโดยใช้รังสีอินฟราเรดคลื่นสั้นร่วมกับอากาศร้อน

Equilibrium Moisture Content of Soybean Grains under Combined Near-infrared Radiation and Hot-air Fluidized-bed Drying

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Abstract

The equilibrium moisture content of soybean grains under combined near-infrared radiation and hot-air fluidized-bed drying was determined. The equilibrium moisture content for soybean grains was measured by using the static method in the controlling ranges of temperatures and relative humidity between 40 to 60°C and 11 to 81%, respectively. The experimental equilibrium moisture content and relative humidity data were used for determining the desorption isotherms of soybean grains. Afterward, the desorption isotherms data were compared with five equations, namely, modified Henderson, modified Oswin, modified Halsey and modified Chung-Pfost. Apparently, modified Helsay's equation was found to satisfactorily describe for the estimation of the equilibrium moisture content of soybean grain, providing the highest R^2 (0.972780) and the lowest SSE (0.01612).
Key words: Equilibrium moisture content, Fluidized-bed drying, Isotherms, Near-infrared radiation, Soybean

บทคัดย่อ

วัตถุประสงค์ของงานวิจัยนี้เพื่อหาความชื้นสมดุลของเมล็ดถั่วเหลืองภายใต้การอบแห้งแบบฟลูอิไดซ์เบดโดยใช้รังสีอินฟราเรดคลื่นสั้นร่วมกับอากาศร้อน ค่าความชื้นสมดุลของเมล็ดถั่วเหลืองจะวัดโดยใช้วิธีทางสถิติในช่วงของอุณหภูมิและความชื้นสัมพัทธ์ที่ควบคุมอยู่ระหว่าง 40 ถึง 60 °C และ 11 ถึง 81% ตามลำดับ ผลการทดลองของความชื้นสมดุลและความชื้นสัมพัทธ์จะนำมาหาค่าการคายน้ำไอโซเทอมของเมล็ดถั่วเหลือง และนำผลการทดลองของค่าการคายน้ำไอโซเทอมมาเปรียบเทียบกับสมการต่างๆ ดังนี้ modified Henderson modified Oswin modified Halsey และ modified Chung-Pfost ผลการศึกษาพบว่า สมการ modified Halsey สามารถอธิบายพฤติกรรมสำหรับการประมาณค่าของความชื้นสมดุลของถั่วเหลืองสอดคล้องกับผลการทดลองมากที่สุดโดยมีค่า R^2 ที่สูงที่สุด (0.972780) และ SSE ที่ต่ำที่สุด (0.01612)
คำสำคัญ: ความชื้นสมดุล การอบแห้งแบบฟลูอิไดซ์เบด ไอโซเทอม รังสีอินฟราเรดคลื่นสั้น ถั่วเหลือง

Introduction

The desorption isotherms data, which show the equilibrium relationship between the relative humidity and the moisture content at constant temperatures and pressures are useful in the drying analysis. The two classic procedures for obtaining moisture equilibrium are static and dynamic methods. In the first approach, motionless air surrounds the material and in the second approach, the fluid is moved mechanically. The advantage of the static method is that constant conditions can be more easily achieved (Barrozo et al., 1994). In this method, samples are placed in an environment maintaining relative humidity (RH) and temperature constant. When the change in the weight of the sample is insignificant, the moisture of the samples is measured and adopted as the equilibrium moisture content value. Therefore, the objective of the present study was to determine the desorption isotherms of soybean grains under combined near-infrared radiation and hot-air fluidized-bed drying base on static method.

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Materials and Methods

The soybean grains used in the desorption isotherms experiments were grown in Loei province, Thailand, and harvested between January and February 2007. The static gravimetric method was used to determine equilibrium moisture contents of soybean grains for this work, which is based on the use of saturated salt solutions (Spiess & Wolf, 1987; Wolf, Spiess, & Jung, 1985; AIR Mohamed, L., Kouhila, M., Jamali, A., Lahsasni, S., Mahrouz, M. 2005). The samples used in desorption studies were sealed up in small glass cylindrical containers with base diameter of 80 mm and height of 125 mm. Each of these vessels contained a different saturated salt solution of KCl, NaBr, NaCl, $MgCl_2$ $6H_2O$, LiCl, corresponding to a range of relative humidity of 11-81%. The weight of soybean grains sample recording period was about 4 days. This procedure was continued until the weight was constant shown in the Table 1 that was investigated with the experimental data. The suitability of the equations has been evaluated and compared using the statistical parameters the sum of squared error (SSE) and the determination coefficient (R^2).

Results and discussion

The experimental results of the equilibrium moisture content at 40, 50, and 60 ^{o}C (±0.1 ^{o}C) and at five relative humidities are given in Table 2. Apparently, the modified Halsey model was found to be the best fit model to describe the desorption isotherms of soybean grains. This model gave the highest R and R^2 of 0.95340 and 0.97639, respectively, and the lowest SSE of 0.01612. Fig. 1 illustrates the phenomenon of changed in equilibrium moisture content with relative humidities. It appears that, the equilibrium moisture content increases with decreasing temperature at constant relative humidity. The behaviour of desorption experiments of soybean obtained from our present study were similar to those of several plants and foods materials, reported by previous studies. (Belghit, Kouhila and Boutabeb, 2000; Aregba, 2001; Basunis and Abe, 2001; Kouhila, Belghit, Daguenet, and Boutaleb, 2001; Kouhila, Kechaou, Oumai, Fliyou and Lahsasni, 2002; Lahsasni, Kouhila, Mahrouz, and Fliyou, 2003).

Table 1 Equilibrium moisture content models used in this work

Model name	Model expression	References
modified Henderson	$RH = 1 - \exp[-A(T+B)]M^{C}$	Thompson et al., 1986
modified Chung-Pfost	$RH = \exp\left[\frac{-A}{T+B}\right]\exp(-CM)$	Pfost et al., 1976
modified Halsey	$RH = \exp\left[\frac{-\exp(A+BT)}{M^{C}}\right]$	Iglesias and Chirife, 1976
modified Oswin	$RH = (A+BT)\left(\frac{RH}{1-RH}\right)^{C}$	Oswin, 1946

Note M is the equilibrium moisture content in % d.b., RH is the equilibrium relative humidity as a decimal

Table 2 Model parameters in fitting of desorption isotherms of soybean grains.

Model name	Control temperature (°C)	Constant parameters & Correlations					
		A	B	C	R	R^2	SSE
modified Henderson	40	0.00016	1.91887	-4.54272	0.92404	0.96127	0.02629
	50	0.00028	1.60567	2.26287	0.93029	0.96451	0.02413
	60	0.00019	1.78483	-2.44475	0.93530	0.96742	0.02239
	Average				*0.92987*	*0.96440*	*0.02427*
modified Chung and Pfost	40	40.89532	0.18055	-33.05338	0.93910	0.96907	0.02108
	50	19.55464	0.16162	-45.16751	0.93273	0.96578	0.02329
	60	415.9354	0.19032	27.48268	0.94096	0.97003	0.02044
	Average				*0.93760*	*0.96829*	*0.02160*
modified Halsey	40	-14.4749	0.48140	2.12398	0.97277	0.98629	0.00942
	50	-147.036	3.01096	1.66667	0.94537	0.97230	0.01891
	60	-196.382	3.33611	1.83465	0.94206	0.97059	0.02005
	Average				0.95340	0.97639	*0.01612*
modified Oswin	40	-205.179	5.425997	2.638694	0.93986	0.96946	9.44346
	50	170.8984	-3.207365	2.200346	0.94605	0.97265	9.93832
	60	-43.3758	0.887455	2.511566	0.95300	0.97621	5.78253
	Average				*0.946308*	*0.972780*	*8.38810*

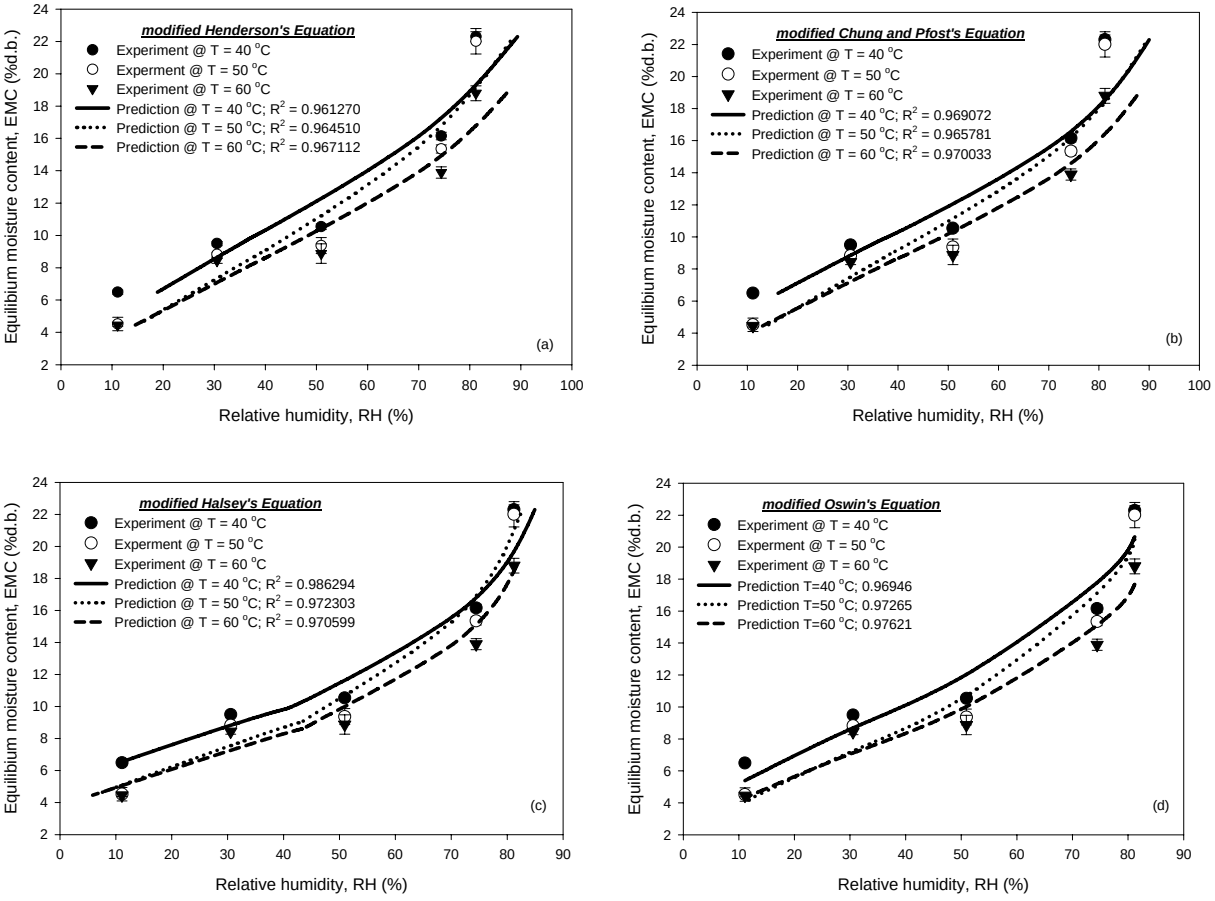

Figure 1 Comparison of the de sorption equilibrium moisture content data for soybean grains at various temperatures the estimates obtained by the (a) modified Henderson, (b) modified Chung and Pfost, (c) modified Halsey, and (d) modified Oswin

Summary

The equilibrium moisture contents of soybean grains have been determined by the static gravimetric method at temperatures and relative humidity control between 40 to 60°C and 11 to 81%, respectively. Among the five desorption models chosen to fit the desorption curves; the modified Halsey model gave the best results for the desorption isotherms of soybean grain, providing the highest R^2 (0.972780) and the lowest SSE (0.01612). At constant relative humidity, the equilibrium moisture content values decreased with an increase in temperature.

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