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แบบจำลองคุณภาพทางโภชนาการของถั่วเหลืองภายใต้การอบแห้งด้วย NIR ร่วมกับฟลูอิไดซ์เบด

Nutritional Quality Models of Soybean Grains under Combined NIR and Fluidized-bed Drying

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Abstract

The nutritional quality models of soybean grains were investigated under combined near-infrared radiation (NIR) and fluidized-bed drying. In this study, follwing parameters were set for investigation, near-infrared radiation powers of 4-8 kW, drying air velocity of 3.3 m/s, drying air temperature of 40°C, soybean bed depth of 6 cm and initial moisture content of soybean grains of 20 % dry basis. The nutritional quality, e.g. protein solubility and residual urease activity, were determined according to the AOCS method (1979) and Rasmussen's method (2002), respectively. The experimental drying data for both protein solubility and residual urease activity were applied to various drying models such as quadratic, cubic, logistic, experimental modified and experimental 3 parameter models. The experimental results showed that the protein solubility was moderately decreased from initial protein solubility of 91% to the final in a range of 79-84%, which was above the standard requirement of 73% for the feed meal. Residual urease activity was rapidly decreased at the beginning of the drying period and then slowly decreased to the final residual urease activity in a range of 33-60%. The change of protein solubility was satisfactorily described by exponential modified model. The coefficient of correlation was more than 0.9686. Besides, the exponential 3 parameter model was found best for describing the residual urease activity of soybean grains for whole range of near-infrared radiation power. The coefficient of correlation was more than 0.9595.

Keywords: Fluidized-bed, Near-infrared radiation, protein solubility, residual urease activity

บทคัดย่อ

แบบจำลองคุณภาพทางด้านโภชนาการของถั่วเหลืองภายใต้การอบแห้งด้วยรังสีอินฟราเรดคลื่นสั้น (NIR) ร่วมกับฟลูอิไดซ์เบดจะถูกตรวจสอบ โดยกำหนดให้กำลังของการแผ่รังสีอินฟราเรดคลื่นสั้นระหว่าง 4-8 kW ความเร็วของอากาศ 3.3 m/s อุณหภูมิ 40°C ความสูงเบดของถั่วเหลือง 6 cm และความชื้นเริ่มต้นของถั่วเหลือง 20% d.b. คุณภาพทางด้านโภชนาการ เช่น ค่าการละลายโปรตีนและปริมาณเอนไซน์ยูรีเอสที่เหลืออยู่สามารถหาตามขั้นตอนและวิธีการของ AOCS (1979) และ Rasmussen (2002) ตามลำดับ โดยข้อมูลของค่าการละลายโปรตีนและปริมาณเอนไซน์ยูรีเอสที่เหลืออยู่จากการทดลองได้นำมาประยุกต์ใช้ในแบบจำลองที่แตกต่างกัน เช่น quadratic, cubic, logistic, experimental modified และ experimental 3 parameter จากผลการทดลองพบว่า ค่าการละลายโปรตีนจะลดลงพอประมาณจากเริ่มต้นที่ 91% ถึงสุดท้ายในช่วงระหว่าง 79-84% ซึ่งสูงกว่ามาตรฐานทางอาหารที่ต้องการคือ 73% ในกรณีของปริมาณเอนไซน์ยูรีเอสที่เหลืออยู่พบว่าจะลดลงอย่างรวดเร็วในช่วงแรกของการอบแห้งและหลังจากนั้นจะลดลงอย่างช้าๆ ถึงค่าสุดท้ายของปริมาณเอนไซน์ยูรีเอสที่เหลืออยู่ในช่วงระหว่าง 33-60% การเปลี่ยนแปลงค่าการละลายโปรตีนสามารถอธิบายได้ดีโดยแบบจำลอง exponential modified สัมประสิทธิ์ค่าความเชื่อมั่นมากกว่า 0.9686 นอกจากนี้ exponential 3 parameter สามารถอธิบายการเปลี่ยนแปลงของปริมาณเอนไซน์ยูรีเอสที่เหลืออยู่ได้ดี โดยมีค่าความเชื่อมั่นมากกว่า 0.9595

คำสำคัญ: ฟลูอิไดซ์เบด รังสีอินฟราเรดคลื่นสั้น ค่าการละลายโปรตีน ปริมาณเอนไซน์ยูรีเอสที่เหลืออยู่

Introduction

Soybean grain (*Clycine Max* (L.) Merrill.) is considered as one of the most important crops in many countries. Soybean grain is harvested usually at high moisture levels. High moisture content is one of the most

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important factors affecting the quality of soybean grains during storage and subsequent handling. The moisture content level of soybean grains at the time of harvest may be as high as 35% dry basis and this must be reduced to about 14% dry basis. Therefore, the drying is necessary to prevent quality deterioration. In Thailand the hot-air fluidized-bed dryer is in use the drying of the soybean grains, at a commercial level due to high heat and mass transfer rates between the hot-air convective and the soybean grains (Prachayawarakorn et al., 2006). However, hot-air convective drying usually extends over a long period and causes many undesirable changes in the soybean grains such as, cracking, breakage, and nutritional quality deterioration. In recent years, the infrared radiation was applied in the drying process (Meeso et al., 2004; Abe and Afzal., 1997). This was because of the infrared radiation has several advantages such as, decreased drying time, high energy efficiency, high quality of finished products, uniform temperature in the product while drying, and a reduced necessity for air flow across the product (Dostie at al., 1989; Mongpreneet et al., 2002). The application of combined infrared radiation and hot-air fluidized-bed drying may offer a hight efficient than radiation or hot-air drying alone. Nutritional quality model is important for optimum management of operating parameters and prediction of performance of the drying system. In addition, modelling the nutritional quality changes during thermal processing may be useful in monitoring the quality of the final product. Therefore, the purpose of this present study was to investigate the nutritional quality models of soybean grains under combined near-infrared radiation and fluidized-bed drying.

Materials and Methods

The combined near-infrared radiation and fluidized bed dryer were used in this study. Soybean grains (Chiang Mai 60) at initial moisture content of 20% dry basis were used in this experiment. The drying conditions were set as follows; near-infrared radiation powers of 4, 6 and 8 kW, air velocity of 3.3 m/s, air temperature of 40^{o}C, and grain bed depth of 6 cm. During operation, the soybean samples were taken from the drying chamber for the determinations of the protein solubility, and residual urease activity. The protein solubility of soybean samples is determined according to the AOCS method BA 10-36 (AOCS, 1979). Urease activity is determined by Rasmussen's method (Rasmussen, 2002). The experimental protein solubility and residual urease activity data of soybean sample was fitted in to five models as appeared in Table 1. The higher the correlation coefficient (R^2), higher efficiency model values (EF), lower root mean square error (RMSE) and chi-square value are to be considered for good fitting of the model.

Table 1 Protein solubility and residual urease activity models of soybean samples

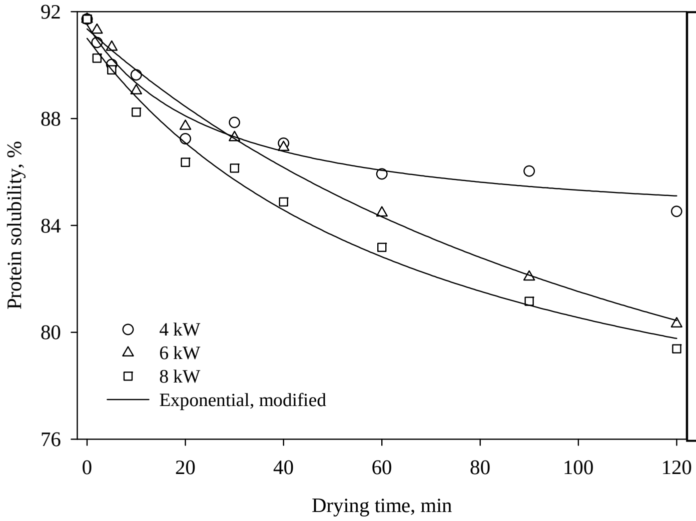
Model no.	Model names	Model equations
1	Quadratic	$C = C_0+(at)+(bt^2)$
2	Cubic	$C = C_0+(at)+(bt^2)+(dt^3)$
3	Logistic	$C = a/(1+(t/x_0)^b)$
4	Exponential, modified	$C = a+\exp(b/(t+d))$
5	Exponential, 3 parameter	$C = C_0+a\exp(-bt)$

Note. C is the variable content studied at time t, C_0 is the value at time zero

Results and Discussions

1. Protein solubility

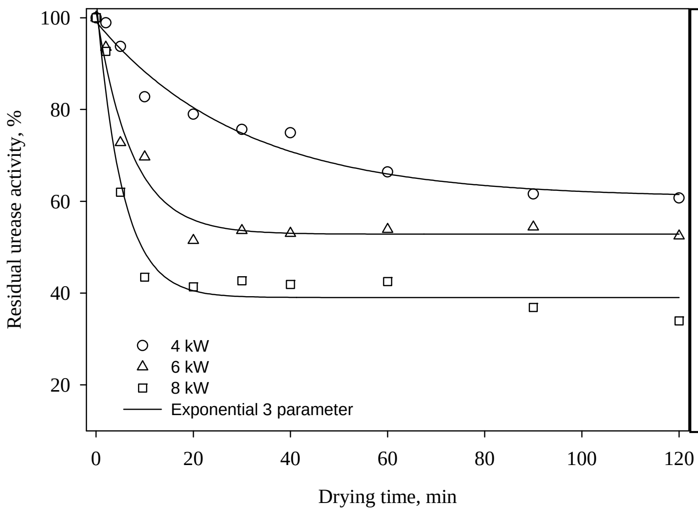
The protein solubility of soybean samples under combined near-infrared radiation and fluidized-bed drying was determined and the results are as shown in Fig 1. It could be seen that the raw soybean sample contained the protein solubility in the range of 91-92%. While drying decreased the protein solubility when increase both the near-infrared radiation powers and the drying time. The final protein solubility in all drying conditions were in a range of 79-84%. The changes in the protein solubility can be described satisfactorily by the exponential modified model. The actual results and the prediction line of the exponential modified model appeared in Fig 1. The values of coefficient of correlation, efficiency model, root mean square error and chi-square were better than 0.9686, 0.9602, 0.4482 and 0.2870, respectively.



Statistical results from the exponential modified

Regression coefficients	Near-infrared radiation powers 4 kW	6 kW	8 kW
a	83.73	67.07	73.07
b	2.734	52.97	17.51
d	26.74	171.4	79.83
R^2	0.9686	0.9950	0.9861
EF	0.9602	0.9952	0.9863
RMSE	0.4471	0.4451	0.4482
Chi-square	0.2856	0.2830	0.2870

Figure 1 Results of protein solubility as fitted by the exponential modified model affer drying under the combined near-infrared radiation and fluidized-bed drying.



Statistical results from the exponential 3 parameter

Regression coefficients	Near-infrared radiation powers 4 kW	6 kW	8 kW
C_0	60.79	52.84	39.03
a	38.35	48.06	65.31
b	0.033	0.137	0.188
R^2	0.9688	0.9720	0.9595
EF	0.9697	0.9728	0.9610
RMSE	2.3914	2.8419	4.4309
Chi-square	8.1700	11.538	28.047

Figure 2 Results of residual urease activity as fitted by the exponential 3 parameter model affer drying under the combined near-infrared radiation and fluidized-bed drying.

2. Residual urease activity

Results of the residual urease activity of soybean samples affer drying under the combined near-infrared radiation with fluidized-bed are as shown in Fig. 2. It could be seen that the residual urease activity was rapidly decreased in the early period of drying and then remains steadily at 70% (4 kW), 52% (6 kW) and 39% (8 kW). The residual urease activity could be successfully modelled using the exponential 3 parameter model, which could be used to estimate the residual urease activity changes during drying. The prediction line and statistical results from the exponential 3 parameter model at different drying condition are presented in Fig 2. Statistical analyses of the results found that the coefficient of correlation was more than 0.9595, efficiency model more than 0.9610, root mean square error less than 4.4309 and chi-square less than 28.047.

Summary

The protein solubility and residual urease activity were decreased with the increased of the near-infrared radiation power and drying time. The final value of protein solubility and residual urease activity were in the range of 79-84% and 33-60%, respectively, depending on near-infrared radiation power. The changes of protein solubility were satisfactorily described by exponential modified model, and exponential 3 parameter model described the change of residual urease activity.

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