การเปลี่ยนแปลงคุณภาพทางกายภาพของถั่วเหลืองภายใต้การอบแห้งแบบฟลูอิไดซ์เบดโดยใช้ NIR ร่วมกับอากาศร้อน

Changes in soybean physical quality under combined NIR and hot-air fluidized-bed drying

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Abstract

The changes in physical quality of soybean (e.g. breakage and cracking percentages and color) under combined near-infrared radiation (NIR) and hot-air fluidized-bed drying were studied. The drying conditions are as follows: the combination of NIR power of between 2-8 kW and hot-air temperature at 40 °C, hot-air velocity of between 3.67-6.80 m/s, soybean bed depth of 9 cm and initial moisture content of soybean of 37 % dry basis. The experimental results found that the changes in the breakage and cracking percentages of soybean under all conditions of combined near-infrared radiation and hot-air fluidized-bed drying investigated in this present study were less than 3 %; moreover, the total color differences (ΔE) of soybean did not exceed 3 %. Besides, overall quality changes slightly changed as compared with the individual hot-air fluidized-bed drying from previous studies by others. This study also found that overall physical quality of soy bean was in a good criterion for the animal feed industry in Thailand.

Keywords: Fluidized-bed, Near-infrared radiation, Physical quality, Soybean

บทคัดย่อ

วัตถุประสงค์ของงานนี้คือ การศึกษาการเปลี่ยนแปลงคุณภาพทางกายภาพของถั่วเหลือง (เช่น เปอร์เซ็นต์การแตก เปอร์เซ็นต์การร้าว และสี) ภายใต้การอบแห้งแบบฟลูอิไดซ์เบดโดยใช้รังสีอินฟราเรดคลื่นสั้น (NIR) ร่วมกับอากาศร้อน สำหรับเงื่อนไขของการอบแห้งที่ศึกษาประกอบด้วย กำลังของการแผ่รังสีอินฟราเรดคลื่นสั้นระหว่าง 2-8 kW ร่วมกับอุณหภูมิของอากาศร้อนที่ 40 °C ความเร็วของอากาศร้อนระหว่าง 3.67-6.80 m/s ความสูงเบดของถั่วเหลือง 9 cm และความชื้นเริ่มต้นของถั่วเหลือง 37 % มาตรฐานแห้ง ผลการทดลองพบว่า การเปลี่ยนแปลงของเปอร์เซ็นต์การแตกและการร้าวของถั่วเหลืองภายใต้เงื่อนไขทั้งหมดของการอบแห้งแบบฟลูอิไดซ์เบดโดยใช้รังสีอินฟราเรดคลื่นสั้นร่วมกับอากาศร้อนมีน้อยกว่า 3 % รวมทั้งการเปลี่ยนแปลงสีโดยรวม (ΔE) ของถั่วเหลืองไม่เกิน 3 % นอกจากนี้คุณภาพทางกายภาพของถั่วเหลืองโดยรวมภายใต้การอบแห้งแบบฟลูอิไดซ์เบดโดยใช้รังสีอินฟราเรดคลื่นสั้นร่วมกับอากาศร้อนมีการเปลี่ยนแปลงน้อยมากเมื่อเปรียบเทียบกับการอบแห้งแบบฟลูอิไดซ์เบดโดยใช้อากาศร้อนอย่างเดียวจากงานวิจัยที่ผ่านมาในอดีต ซึ่งคุณภาพทางกายภาพของถั่วเหลืองที่ผ่านการอบแห้งโดยวิธีภายใต้การอบแห้งแบบฟลูอิไดซ์เบดโดยใช้รังสีอินฟราเรดคลื่นสั้นร่วมกับอากาศร้อนนี้พบว่าอยู่ในเกณฑ์ที่ดีสำหรับอุตสาหกรรมสัตว์ในประเทศไทย

คำสำคัญ: ฟลูอิไดซ์เบด รังสีอินฟราเรดคลื่นสั้น คุณภาพทางกายภาพ ถั่วเหลือง

Introduction

Soybean [*Glycine max.* (L.) Merril] has been known as a good protein for human diet and animal feed. However, the nutritive value and protein digestibility of raw soybean are very poor, due to the presence of anti-nutrients, the most important being protease (trypsin and chymotrypsin) inhibitors and haemaglutonins (ASA., 1990,;Lyman, *et al.*1974 and Jaffe, 1966). These anti-nutritional substances, however can be significantly eliminated by adequate heat processing. Therefore, methods which can effectively reduce the anti-nutrients but still remain good nutritive values of soybean are needed. Since soybeans are harvested in the level of high

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moisture contents between 25-38 %dry basis (d.b.), drying is one of prior alternatives to be considered. Fluidized bed drying, one of numerous heat treatments of soybean, is a rapid drying method due to the large air to product contact area achieved relative to a static bed caused by fluidization of the product, and the high air speed and high drying air temperature used (Soponronnarit *et al*., 2001). This fluidized bed drying, however, are not completely effective because the moisture gradient inside soybean kernels is highly increased, resulting in cracks and breakages (in the form of V-shaped fissures) of soybean. This is mainly due to the fast decrease in moisture content under fluidized bed drying process. Moreover, it was still found that breakage and cracking were increased with the drying air temperature and the initial moisture content of soybean.

According to the mechanism of near-infrared radiation (NIR) drying, heat is generated deep inside the grain and tends to be selectively absorbed in the regions with high moisture content. Thus the vapour pressure would be the largest in these regions, and the moisture diffusion will be in the direction toward the areas of lower vapour pressure such as the grain surface (Ginzburg, 1969, Sandu, 1986; Sakai & Hanzawa,). As mentioned above , it is believed that NIR should be help the improvement of the physical properties in terms of cracks and breakages of soybean under fluidized bed drying. Therefore, the purpose of this research was to experimentally investigate the changes in physical quality of soybean under combined NIR and hot-air fluidized bed drying.

Materials and Methods

Raw soybeans with initial moisture content of 14%d.b. from Loei province, Thailand were rewetted by adding the required amount of water to get the initial moisture contents 37.0 %d.b., kept in cold room at temperatures of 3-5°C (Prachayawarakorn *et al*., 2006). In the drying experiments, soybeans were dried by using combined NIR and hot-air fluidized bed dryer at NIR powers 2-8 kW, drying air temperature of 40 °C, drying air velocities of 3.76-6.80 m/s and soybean bed depth of 9 cm.. Soybean samples were taken before and after each experiment for determining moisture content (ASA, 1990), grain temperature and physical quality of soybean (Soponronnarit, S., et al., 2001. Wiriyaumpaiwong, S., et al., 2001), together with color changes (Hunter Lab Color Scale, 1996). The physical qualities of soybean were calculated from as follows:

% cracking = (Weight of cracking seed / weight of example seed) x (100) (1)

% breakage = (Weight of breakage seed / weight of example seed) x (100) (2)

$$\Delta E = ((\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2)^{1/2} \quad (3)$$

Results and discussion

The curves of drying and the grain temperature of soybeans during combined NIR and hot-air fluidized bed drying shown in Figure 1a, 1b and 1c depict the changes of the moisture contents and the grain temperatures with elapsed times. All drying conditions were similar, excepting four different NIR power levels. Under these conditions, the difference among all conditions was the drying curves. These results indicated that it can be seen from the figure that the grain temperatures were considerably increased with higher NIR power level.

The relationship between the percentages of cracking and breakage and final moisture content under drying condition at three different air velocities (3.76-6.80 m/s) and a NIR power level of 6 kW were plotted and shown in Figure 2a, 2b and 2c. It can be seen that the values of cracking and breakage percentages were reduced with lower final moisture content. These values were in a good criterion for the animal feed industry in Thailand, approximately 3 %weight for cracking of soybeans (Soponronnarit *et al*., 2001). An improvement in the cracking and breakage of soybean in the drying process was mainly due to the NIR energy absorbed by moisture inside a soybean kernel aided migration moisture from inside to outside the soybean kernel. Thus, moisture removal and moisture leveling were occurring simultaneously. The latter resulted in decreasing moisture gradient as well as the stresses development within the kernel, hence the cracking and breakage of soybean were maintained.

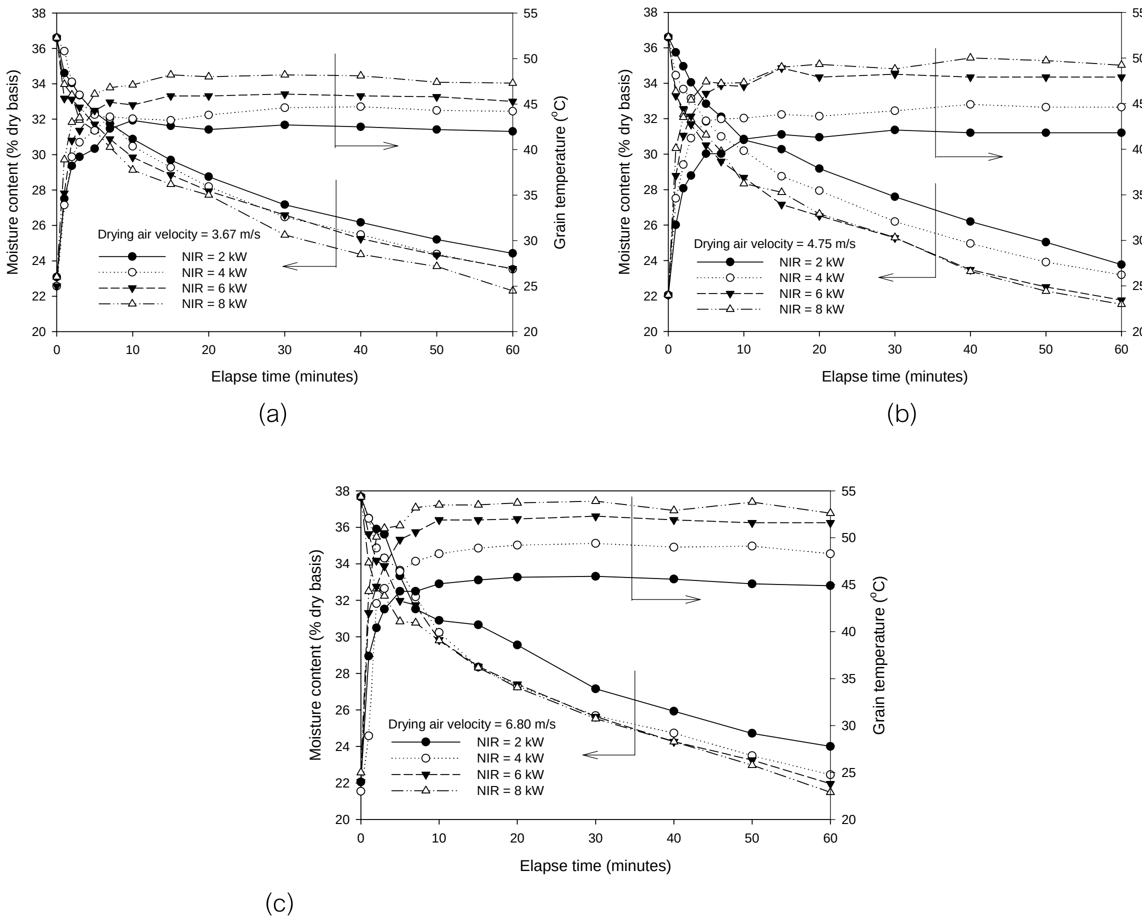

Figure 1 Curves of drying and grain temperature of soybeans during combined NIR and hot-air fluidized bed drying

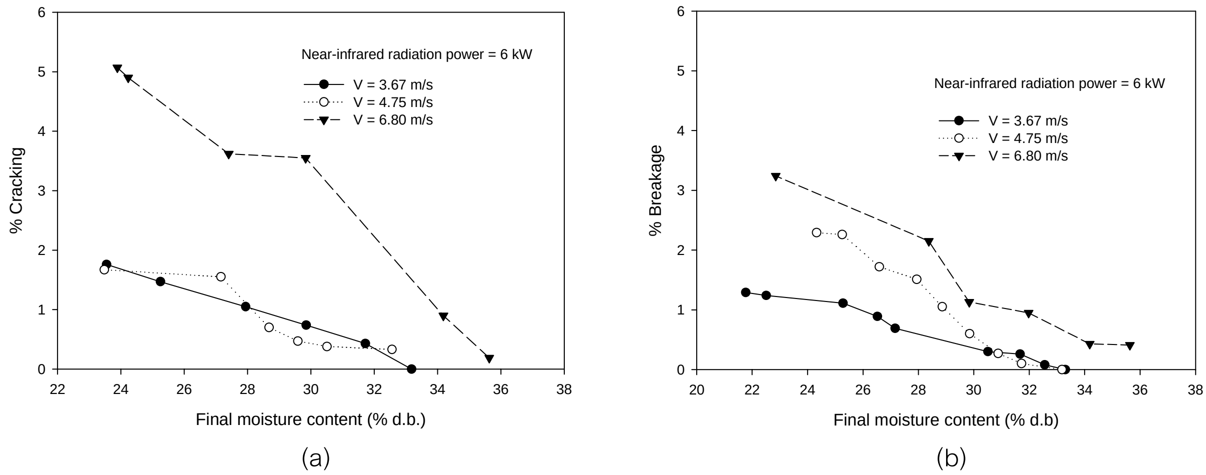

Figure 2 Relationship between cracking and breakage percentages and final moisture content of soybeans.

Changes in color of soybean after drying at different drying velocities and NIR powers are shown in Table 1. The results showed that ΔE was significantly increased when higher drying air velocity were applied at NIR power of 4, 6 and 8 kW but not at 2 kW. The results are similar to those when higher NIR powers were used. Increased NIR power resulted in a stepwise raise of ΔE, as indicated by average values of ΔE, from 2 to 4, 6 and to 8 kW respectively.

Table 1 Color change (ΔE) of soybean

Drying air velocity (m/s)	total color differences (ΔE)			
	2 kW	4 kW	6 kW	8 kW
3.67	1.58±0.15	1.51±0.09	1.56±0.14	1.83±0.01
4.75	1.59±0.21	1.82±0.19	2.04±0.17	2.11±0.34
6.80	1.66±0.22	1.98±0.05	2.12±0.07	2.12±0.54
Average (ΔE)	1.61±0.19	1.77±0.11	1.90±0.13	2.02±0.29

This may be because an increase of drying air velocity led to a dilution of soybean bed, resulting in increased surface area of soybean grains which were capably exposed to NIR irradiation more than those at lower drying air velocity. Under this NIR irradiation, more heat is generated deep inside the soybean grain, it therefore caused a greater change in color as a result of non-enzymatic browning reaction, mainly Maillard reaction that occurs between sugar aldehyde groups and free amino acid groups Krokida *et al*., 2001).

Summary

An improvement in the cracking and breakage of soybean in the drying process by using combined NIR and hot-air fluidized-bed drying was achieved in this present study. Under all conditions of combined NIR and hot-air fluidized-bed drying investigated in this present study were less than 3 %; moreover, the total color differences (ΔE) of soybean did not exceed 3 %. This study also demonstrated that overall physical quality of soy bean was in a good criterion for the animal feed industry in Thailand.

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