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อิทธิพลของการอบแห้งโดยวิธีการแผ่รังสีอินฟราเรดคลื่นยาวร่วมกับการพาอากาศร้อนต่อลักษณะการอบแห้งและคุณภาพทางกายภาพของกล้วยส้ม

Effect of combined FIR and hot-air convective drying on drying characteristics and physical properties of banana(*Musa* (ABB group))

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Abstract

Effects of combined far-infrared radiative and hot-air convective drying on drying characteristics and physical properties of banana was investigated. Drying factors studied included; far-infrared radiative intensities ranged from 3-5 kW/m^2, hot-air temperatures at 40 °C, and hot-air velocities ranged from 1-2 m/s. Banana (*Musa* (ABB group), "Kluai Som" was used in this study. The ripened bananas were pre-treated with 1% KMS and dried under drying conditions. Physical properties including moisture content, product temperature, color, texture (shear force) and shrinkage, of dried bananas were determined. The optimum conditions in combined far-infrared radiative and hot-air convective drying of banana was that far-infrared radiative intensity of 5 kW/m^2 combined with hot-air temperature at 40°C and hot-air velocity of 1 m/s. Under these conditions, the quality of dried banana was satisfactory.

Keywords: Far-infrared radiation, Hot-air convection, Banana

บทคัดย่อ

การศึกษาอิทธิพลของการอบแห้งโดยวิธีการแผ่รังสีอินฟราเรดคลื่นยาว(FIR)ร่วมกับการพาอากาศร้อนต่อลักษณะการอบแห้งและคุณภาพทางกายภาพของกล้วย ปัจจัยของการอบแห้งที่ศึกษาได้แก่ ความเข้มของการแผ่รังสีอินฟราเรด 2-6 kW/m^2 อุณหภูมิของอากาศร้อน 40°C และ ความเร็วของอากาศร้อน 1-2 m/s กล้วยส้ม (*Musa* (ABB group) ที่ใช้ในการศึกษาจะผ่านกระบวนการพรีทรีทเมนท์โดยการแช่สารละลายโปแตสเซียมเมตาไบซัลไฟต์ (KMS) 1% และนำไปอบแห้งภายใต้เงื่อนไขที่กำหนด คุณภาพของกล้วยที่ศึกษาประกอบด้วย ความชื้น อุณหภูมิของผลิตภัณฑ์ สี เนื้อสัมผัส (แรงเฉือน) และการหดตัว จากผลการทดลองพบว่าเงื่อนไขการอบแห้งที่เหมาะสม คือ การอบแห้งที่ความเข้มของการแผ่รังสีอินฟราเรด 5 kW/m^2 อุณหภูมิของอากาศร้อน 40°C และความเร็วของอากาศร้อน 1 m/s โดยพิจารณาจากคุณภาพด้าน สี เนื้อสัมผัสและการหดตัว การอบภายใต้สภาวะนี้จะได้กล้วยที่มีคุณภาพด้านกายภาพที่น่าพึงพอใจ

คำสำคัญ: การพาอากาศร้อน รังสีอินฟราเรดคลื่นยาว กล้วย

Introduction

Banana (*Musa* (ABB group), "Kluai Som" is one of among numerous species of banana cultivars widely grown in the north-eastern of Thailand (Ruangsuttapha *et al*., 2007). It has long been consumed as ancient food especially by adding in traditional baby food in north-eastern food since it has unique sweet and sour taste, but it deteriorates rapidly after harvest. As a result, the preservation methods of banana products are applied to prolong the product storage, such as drying methods. The drying method by using the combination of far-infrared radiation (FIR) and hot-air convection is one of the fruit preservations since the main components of the agricultural products (i.e. proteins, starches and water) have the principal bands of infrared radiation absorption at wavelengths greater than 2.5 μm (Sandu, 1986; Sakai and Hanzawa, 1994). Infrared radiation induces the changes in the molecular vibration state of products, which converts to heating inside the products. This result in

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the moisture diffused from the interior to the product surface, and moisture at the product surface loses into the environment via air convection. From this feature of combined FIR and hot-air convective drying, it is believed that the combined drying method should be appropriate for applying in the fruit drying method. Therefore, the main attention of this research is to study the effect of combined FIR and hot-air convective drying on banana drying characteristics and physical properties.

Materials and Methods

Bananas (*Musa* (ABB group), also called "Kluai Som", in the ripeness level of green tip (color index no.5) from a farm in Mahasarakham province, Thailand were divided into three parts along its length. They were pre-treated by immersing with 1% KMS for 2 minutes followed by dipping in water for 0.5 minute, then drained and dried under drying conditions.

In the drying operations, the banana samples were placed into the mesh tray and irradiated in a combined FIR and hot-air tray dryer at FIR intensities between 3 -5 kW/m^2, hot-air temperature of 40°C and hot-air velocities between 1-2 m/s. Banana samples were dried until reaching their final moisture content between around 17.0-18.0% dry basis (d.b.). The physical properties of banana are as follows: banana color was measured using a colorimeter, reporting as the difference in three hunter color parameters (ΔL (lightness), Δa (redness/greenness), Δb (yellowness/blueness)) and color difference (ΔE), shear force (N) was measured using texture analyzer, and shrinkage was measured in terms of the percentage change of the volume of the sample.

Results

This present study reports the assessments of drying characteristic and physical qualities of banana under combined FIR and hot-air convective drying. Preliminary studies were performed to investigate the sample preparation before drying. The result showed that bananas pre-treated with 1%KMS gave better uniform color after drying than those without treatment (data not shown), it hence was selected for further studies.

The effects of FIR intensity on drying and temperature curves and physical properties are shown in figures 1. It can be seen that the drying time decreased while the temperatures of banana samples increased, with an increase in the FIR intensity. Since drying at 5 kW/m^2 took shorter drying time, therefore it was selected for further studies of effect of hot-air velocity on drying characteristics of banana . It was found that the drying time also decreased with a decrease in the hot-air velocity (Figure 2).

Color, shrinkage, and texture (shear force) of dried banana at different FIR intensities are shown in Table 1. Higher FIR intensity resulted in greater change of brightness, redness and yellowness of dried bananas than did lower FIR intensity. Whilst, reduction of shrinkage was lower when higher intensity was applied. However, there was no significantly different between 3 and 4 kW/m^2,and 4 and 5kW/m^2 but significantly different between 3 and 5 kW/m^2. Similar results were found in shear force. Additionally, three levels of hot-air velocities of 1, 1.5 and 2 m/s at 5 kW/m^2 were compared to investigate the effects of drying air velocity on physical properties of banana, as shown in Table 2. The results showed that the color of banana was significantly affected by hot-air velocity, higher hot-air velocity resulted in smaller color changes. However, shrinkage and shear force were found not significantly affected by this parameter tested in this present study.

Discussion

The moisture reduction and the temperature increase of banana samples significantly resulted from an increase of FIR intensity. High FIR intensity resulted in converting to heating inside the products highly and then the moisture was diffussed from the interior to the product surface rapidly. In the case of texture it was found that banana slices dried under higher FIR intensity were significantly harder than those dried under lower intensity, as

indicated by the higher value of the shear force. This due to the fact that drying at higher FIR intensity led to faster water removal from the interior of banana tissues to the product surface, causing more dense structure (Nimmol *et al.*, 2007).

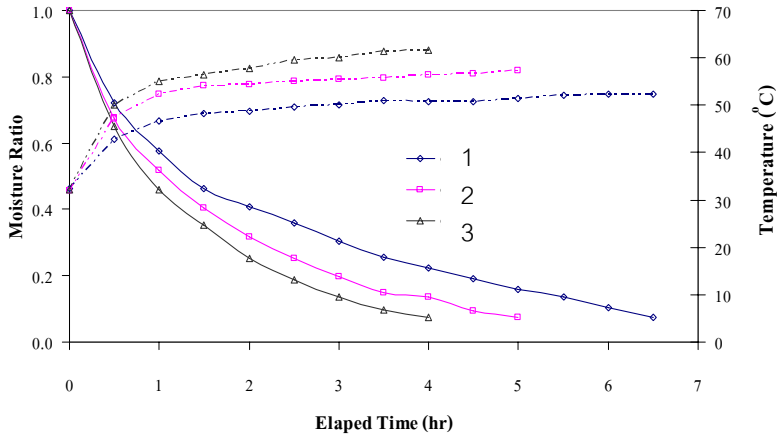

Figure 1 Effects of FIR intensity on drying characteristics of banana (conditions as shown in Table 1).

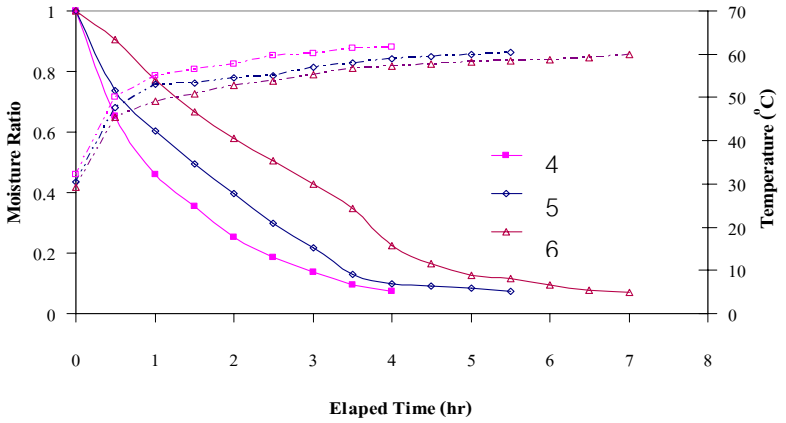

Figure 2 Effects of drying air velocity on drying characteristics of banana (conditions as shown in Table 2)

Table 1 Effects of FIR intensity on physical properties of banana

Conditional No.	ΔL	Δa	Δb	ΔE	%Shrinkage	shear force (N)
1 (I=3kW/m^2, T=40°C, V=1m/s)	-15.12±0.21^a	3.083±0.03^a	-1.69±0.08^b	16.10±0.20^c	2.11±0.16^a	21.75±1.42^b
2 (I=4kW/m^2, T=40°C, V=1m/s)	-16.12±0.21^a	4.08±0.03^a	-1.66±0.18^b	17.39±0.20^b	1.79±0.09^{ab}	26.44±0.25^a
3 (I=5kW/m^2, T=40°C, V=1m/s)	-17.57±0.13^b	5.15±0.13^b	-2.06±0.11^a	19.20±0.13^a	1.54±0.16^b	26.49±0.53^a

I = FIR intensity; T= hot-air temperature; V = hot-air velocity

Table 2 Effects of drying air velocity on physical properties of banana

Conditional No.	ΔL	Δa	Δb	ΔE	%Shrinkage	shear force (N)
4 (I=5kW/m, T=40°C, V=1m/s)	-17.57±0.13^b	5.15±0.13^a	-2.06±0.47^b	19.20±0.13^a	1.54±0.16	26.49±0.53
5 (I=5kW/m, T=40°C,V=1.5m/s)	-16.00±0.17^a	4.21±0.14^b	-2.06±0.47^b	17.39±0.20^b	1.60±0.24	25.89±0.12
6 (I=5kW/m, T=40°C, V=2m/s)	-15.79±0.23^a	5.13±0.13^b	-1.29±0.04^a	16.72±0.24^c	1.67±0.18	25.82±0.93

I = FIR intensity; T= hot-air temperature; V = hot-air velocity

The brightness, redness and redness were significantly affected by FIR intensity and drying air velocity. Drying at higher FIR intensity yielded a greater color change than drying at lower FIR intensity. However, a uniform color of banana dried by combined FIR and hot-air convective drying was observed. Greater color changes were found when higher FIR intensities were applied. This could be explained that high FIR intensity induces more heat conversion inside the products than lower intensity, resulting in increased formation of browning compound caused by non-enzymatic browning reaction. The higher temperatures led to higher levels of non-enzymatic browning reaction (Krokida *et al*., 2000; Krokida *et al*., 2001). Shrinkage corresponds to a continuous collapse of the solid matrix of plant tissue as a consequence of the contracting stresses produced by the removal of the water (Mayor and Sereno, 2004). It was observed that banana dried using the combination of FIR and hot-air convection provided a minor shrinkage compared with those dried by individual hot air drying.

Summary

This present study has shown that combined FIR and hot-air convective drying was a potential method for banana drying, providing shorter drying time, uniform color and less shrinkage. The optimum conditions in combined FIR and hot-air convective drying of banana was that infrared radiative intensity of 5 kW/m^2 combined with hot-air temperature at 40 °C and hot-air velocity of 1 m/s. Under these conditions, the quality of dried banana was satisfactory.

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