การออกแบบและสร้างเครื่องอบแห้งแบบสูบความร้อนขนาดเล็กสำหรับผลิตภัณฑ์เกษตร

Design and construction of a small heat pump dryer for agricultural products

นัฐราช แสนมีมา[1] ณัฐพล ภูมิสะอาด[1] และ ละมุล วิเศษ[1]

Nattarat Sanmeema[1], Nattapol Poomsa-ad[1] and Lamul Wiset[1]

Abstract

The experimental drying of agricultural products generally needs a lot of samples to operate each batch. Use of small dryer is advantageous for testing various products, especially products with high values such as herbs. This research was aimed to design, construct and test a small heat pump dryer for agricultural products. The air condition system of vehicle with R12 refrigerant as working fluid was used for the dryer. A reciprocated compressor (Sanden 507) and a 2.3 kW electrical motor were used. The size of a compressor and an evaporator was 0.30 x 0.24 m2 and 0.46 x 0.31 m2. The dimension of the drying chamber was 0.6 x 0.6 x 0.8 m3 which contained 3 trays of products. From the preliminary test, the air temperature inside the drying chamber could be heated up to 65 °C at the constant air velocity of 0.5 m/s and compressor speed of 1450 rpm. For 200 g of the oyster mushroom drying at 60 °C with initial moisture content of 1012% dry basis could be reduced down to 22% dry basis within 140 min consuming 4.7 kWh of electrical energy. For the drying of 100 g moringa leaves at 60 °C with initial moisture content of 265% dry basis could be dried down to 9.1% dry basis within 80 min using 1.2 kWh of electrical energy.

Keywords: Air condition system, moringa leaves, oyster mushroom

บทคัดย่อ

การทดลองอบแห้งผลิตผลทางการเกษตรโดยทั่วไปต้องใช้ตัวอย่างจำนวนมากในการอบแห้งแต่ละครั้ง การใช้เครื่องอบแห้งขนาดเล็กจึงเป็นข้อได้เปรียบในการทดสอบผลิตภัณฑ์หลากหลายชนิด โดยเฉพาะผลิตภัณฑ์ที่มีราคาแพง เช่น สมุนไพร งานวิจัยนี้มีวัตถุประสงค์เพื่อออกแบบ สร้างและทดสอบเครื่องอบแห้งแบบสูบความร้อนขนาดเล็กสำหรับใช้อบแห้งผลิตภัณฑ์เกษตร เครื่องอบแห้งนี้ได้นำระบบปรับอากาศของรถยนต์มาประยุกต์ ใช้สารทำความเย็นคือ R12 เครื่องอัดไอแบบลูกสูบ (รุ่น Sanden 507) ใช้ต้นกำลังจากมอเตอร์ไฟฟ้าขนาด 2.3 kW เครื่องทำระเหยมีขนาด 0.30 x 0.24 ตารางเมตร และเครื่องควบแน่นมีขนาด 0.46 x 0.31 ตารางเมตร ห้องอบแห้งมีขนาด 0.6 x 0.6 x 0.8 ลูกบาศก์เมตร ซึ่งบรรจุถาดใส่ผลิตภัณฑ์ได้ 3 ถาด จากการทดสอบเบื้องต้นพบว่า ที่ความเร็วของอากาศในห้องอบแห้ง 0.5 เมตรต่อวินาที และความเร็วรอบของเครื่องอัดไอ 1450 รอบต่อนาที สามารถทำอุณหภูมิภายในห้องอบแห้งได้ถึง 65 องศาเซลเซียส และในการทดสอบอบแห้งเห็ดนางฟ้าน้ำหนัก 200 กรัม ที่อุณหภูมิ 60 องศาเซลเซียส สามารถอบแห้งจากความชื้นร้อยละ 1012 มาตรฐานแห้ง ให้เหลือความชื้นร้อยละ 22 มาตรฐานแห้ง ได้ในระยะเวลา 140 นาที ใช้พลังงานไฟฟ้าในการอบแห้ง 4.7 กิโลวัตต์ชั่วโมง สำหรับการทดสอบอบแห้งใบมะรุม 100 กรัมที่อุณหภูมิอบแห้ง 60 องศาเซลเซียส สามารถอบแห้งจากความชื้นร้อยละ 265 มาตรฐานแห้ง ให้เหลือความชื้นร้อยละ 9.1 มาตรฐานแห้ง ได้ในระยะเวลา 80 นาที ใช้พลังงานไฟฟ้าในการอบแห้ง 1.2 กิโลวัตต์ชั่วโมง

คำสำคัญ: ระบบปรับอากาศ ใบมะรุม เห็ดนางฟ้า

Introduction

Conventionally, materials are dried either in the field (sun drying) or using high temperature dryers (electrical heater, gas fire, etc.). Successful outdoor drying depends upon good weather and bad weather can render a product worthless. High temperature drying can damage the nutrient content and impart an unpleasant smell to the dried product. Specialty crops such as mushroom, herbs, etc., need to be dried at low temperatures (30 - 45°C) for product quality optimization. This is an important consideration as they have relatively high

[1] คณะวิศวกรรมศาสตร์ มหาวิทยาลัยมหาสารคาม ตำบลขามเรียง อำเภอกันทรวิชัย จังหวัดมหาสารคาม 44150

[1] Faculty of Engineering, Mahasarakham University, Kamriang District, Kantarawichai, Mahasarakham, 44150

commercial value. Heat pump dryers (HPD) have the potential to operate more efficiently, and at lower temperatures than conventional dryers (Vázquez et al., 1997). The heat pumps are used to transfer heat from a relatively low-temperature source and upgrade it to a higher temperature, and to recover latent heat from high humidity streams. The color and aroma qualities of dried agricultural products using heat pumps were better than those products using conventional hot air dryers, but the HPD was more economical than other systems although the initial cost was higher (Prasertsan and Saen-saby, 1998 and Teeboonma et al., 2003)

The experimental drying of agricultural products generally needs a large samples size for each batch. Use of smaller dryer is advantageous for testing various products, especially products with high values such as herbs. This research was aimed to design, construct and test a small heat pump dryer for agricultural products by applying the air condition system of vehicle.

Materials and Experimental Methods

A schematic diagram of the closed loop heat pump dryer is shown in Fig. 1. The apparatus has two circuits; one for the drying air and the other one for the refrigeration. The air condition system of a vehicle with R12 refrigerant was applied for the dryer. A reciprocated compressor (Sanden 507) and a 2.3 kW electrical motor were used. The size of a condenser and an evaporator are 0.30 x 0.24 m^2 and 0.46 x 0.31 m^2. The dimension of the drying chamber is 0.6 x 0.6 x 0.8 m^3 which contained 3 trays of products. An external condenser is combined with an internal condenser. Practically, the solenoid valve is opened to bypass the refrigerant to reject the excess heat at an external condenser when the drying air temperature is higher than a setting temperature. The evaporator is constantly bypass 60% air.

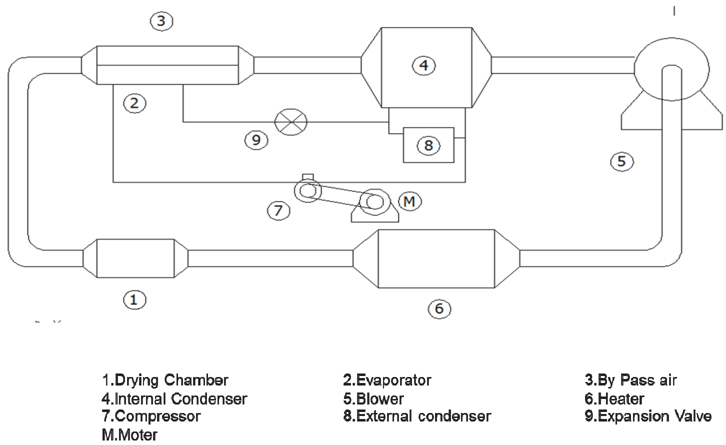
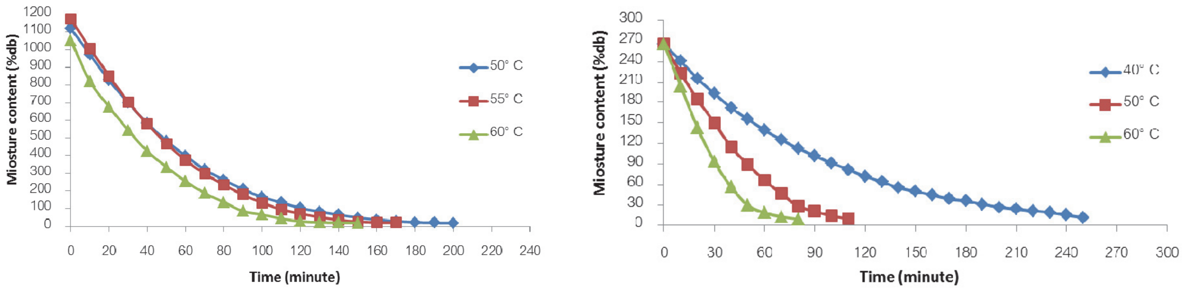


Figure 1 Diagram of Heat Pump dryer

The oyster mushroom and moringa leaves were used in this study. Samples for each batch about 200 g mushroom and 100 g moringa leaves were dried by heat pump dryer at the drying temperature of 50, 55 and 60 °C for oyster mushroom and 40, 50 and 60 °C for moringa leaves. A constant air velocity of 0.5 m/s in a drying chamber was controlled. The drying stopped when the final moisture content of sample reached about 15% dry basis by determining the weight every 10 min and calculate moisture content. Hot wire anemometer was used to measure air velocity distribution in the duct. A digital balance was used to weigh the material during the drying process. The electrical power supplied to the electric heaters, blower and compressor were measured by a digital clamp meter.

Result and discussion

A preliminary test run of the heat pump dryer was using 200 g of oyster mushroom. The results showed the air temperature inside the drying chamber could be heated up to 65 °C at constant air velocity of 0.5 m/s. The electrical consumption for compressor and blower were 2.6 and 2.8 A, respectively.



a) Oyster mushroom

b) Moringa leaves

Figure 2 Drying characteristic of oyster mushroom and moringa leaves at various drying temperature

The drying characteristic of each product is as shown in Figure 1. Drying rate of oyster mushroom is faster than that of moringa leaves due to structure and composition which effect to the moisture movement during drying. Plant with high moisture content and loosely packed cell leads to the water migrate easily to the surrounding. For the drying temperature, the higher temperature of drying air causes higher water vapor inside the product, then more water can escape resulting in the fast drying rate.

Table 1 Electrical Energy Consumption of heat pump dryer of oyster mushroom and moringa leaves at various drying temperatures

Product	Drying Temperature (°C)	Electrical Energy Consumption (kWh)	
		Compressor	Total
Oyster mushroom	50	4.5	5.5
	55	4.3	5.1
	60	3.5	4.7
Moringa leaves	40	1.4	1.7
	50	1.2	1.5
	60	0.9	1.2

The electrical energy consumption of heat pump dryer for both products under different drying temperatures is presented in Table 1. The results found that drying temperature affects total energy consumption. At high drying temperature resulted in the decreasing of energy consumption. However, the energy consumption is more affected by the drying time than drying temperature used in removing the moisture content of the products to safe level.

Conclusion

Based on the experimental results of the present work, the following conclusions could be drawn

- From the preliminary test, the air condition system of vehicle with R12 could be applied for the heat pump dryer. The air temperature inside the drying chamber could be heated up to 65 °C at the constant air velocity of 0.5 m/s.
- For the drying of 200 g oyster mushroom at 60 °C, sample with initial moisture content of 1012% dry basis could be reduced down to 22% dry basis within 140 min consuming 4.7 kWh of electrical energy.
- For the drying of 100 g moringa leaves at 60 °C, sample with initial moisture content of 265% dry basis could be dried down to 9.1% drying basis within 80 min using 1.2 kWh of electrical energy.

Acknowledgement

The authors wish to thank Faculty of Engineering, Mahasarakham University for financial support for the research. Thanks to student team work to Miss Jiraporn Raksutthee, Mr. Teerawat Namchaisong, Mr. Pongsakon Promviriyakun and Mr. Arkom Onnkhao for their good team work.

Reference

Prasertsan, S. and P. Saen-saby. 1998. Heat pump drying of agricultural materials. Drying Technology–An International Journal 16(1&2): 235–250.

Teeboonma, U., J. Tiansuwan and S. Soponronnarit. 2003. Optimization of heat pump fruit dryers, Journal of Food Engineering 59(4): 369–377.

Vázquez, G., F. Chemo, R. Moreria and E. Cruz. 1997. Grape Drying in a Pilot Plant with a Heat Pump, Drying Technology-An International Journal 15(3&4): 899-920.