TURMERIC DRYING USING A COMBINED VACUUM AND FAR-INFRARED DRYER

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ABSTRACT

Turmeric (*Curcuma Longa Linn*.) is the herb that has been widely used in the modern and traditional medicine. However, the utilization of fresh turmeric is limited because it was easy deterioration. Since, the drying process was applied to preserve the turmeric. The aim of this research was to investigate the drying kinetics and qualities of turmeric using a combined vacuum and far-infrared drying. The experiments were carried out at the following conditions: absolute pressure of 2 and 5 kPa; controlled drying temperature at turmeric surface at 50, 60 and 70 ^oC. In drying process, the samples were dried until reaching the final moisture content of 5 %(d.b.) Based on this experiment the drying kinetics depends on the slice thickness, absolute pressure and drying temperature. For color change, the lightness and yellowness increased with an increase in drying temperature while the redness was quite constant. Furthermore, the curcumin content of the dried turmeric was higher than that of Thai industrial Standards Institute.

INTRODUCTION

Turmeric (*Curcuma Longa Linn*.) is one kind of herb that has been widely used in the modern and traditional medicine [1]. Its appearance is dark yellow and has a unique of smell. The important component in turmeric used in pharmaceutical industry is curcuminoids consisted of curcumin, demethoxy curcumin and bisdemethoxy curcumin[2]. However, the utilization of the turmeric in for producing drug and healthy food needed to apply an suitable post-harvest technology to prolong the shelf life [3]. Drying was a method for product preservation by transferring heat in accompany with moisture from the product. In the past, the traditional drying method was sun drying but this method took a long time about 10-15 days. Vacuum drying is an effective method to reduce the deterioration of heat sensitive product [4]. Reducing chamber pressure below the atmospheric pressure will cause the water boils and evaporate at low temperature. As the result, vacuum drying process is useful to maintain the quality of dried product such as color, shape, aroma and flavor, and nutritive values [5]. However, the limitation of vacuum drying process was to select heat source for heating up the product under low pressure condition which is difficult to exchange heat by convection [6].

Far infrared (FIR) has recently much attention as a heat source to augment other drying techniques to enhance the overall process efficiency. The energy from infrared radiation penetrates through the material and is converted into heat [7]. Hence, the material is heated rapidly and more uniformly. The infrared radiation has been applied in conjunction with several drying process because it has advantages of increased drying efficiency and space saving [8]. The most herbs are heat-sensitive in nature hence it is desirable to dry these herbs at low temperature. Drying under vacuum is generally performed because under vacuum water evaporate at lower temperature. Several researches have combined the advantages of FIR drying with those of vacuum drying to dry several products [9-11]

The aims of the present work were to investigate the drying kinetics and turmeric qualities undergoing combined vacuum and far-infrared drying. In addition, the qualities in terms of color and curcumin content were examined.

MATERIALS

The turmeric used in this experiment was 9-12 months, which was purchased from a local market in Bangkok. The samples were cleaned and peeled after that they were sliced with the thickness of 2 and 3 mm by the slicing machine. The initial moisture content was approximately 550-600 %(d.b.).

EXPERIMENTAL SET-UP

A schematic diagram of combined vacuum and far infrared dryer was shown in Fig. 1 The dryer consists of a vacuum chamber made from stainless steel with dimensions of (0.32 m × 0.26 m × 0.38 m). Two infrared heaters (400 watt) were installed at the top of the chamber. The distance between the FIR heater and the samples were approximately 15 cm. Vacuum pump used in this experiment was rotary vane with the pumping speed of 60 m^3/h. The pressure in the chamber was controlled by bleeding value and was measured by digital pressure gauge (Keyence, AP-C30W) with an accuracy ±0.1 kPa. The temperature above turmeric slices and inside a turmeric sample (at the middle of the slice) were measured continuously using type T thermocouples which were connected to a data logger(Yokogawa, Model DX230, Tokyo, Japan). A PID controller (Shinko, Model JCS-33 A-R/M) was used to control the FIR heater via the predetermined surface temperature of the turmeric slice. The change of the mass of the sample was measured continuously using a load cell (Vishay Tedea-Huntleigh, Model 1022-3kg) with accuracy of ± 0.1 g.

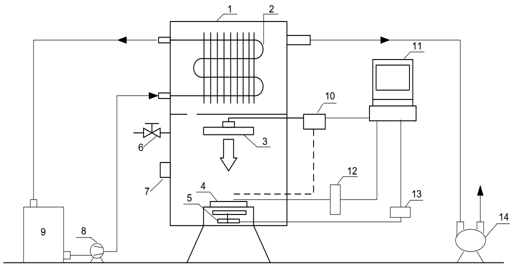

Fig. 1 A schematic diagram of combined vacuum and far-infrared dryer (1) Drying Chamber (2) Condenser (3) Far infrared heater (4) Sample tray (5) Load Cell (6) Bleeding Valve (7) Pressure gauge (8) Water pump (9) Cooling unit (10) PID Controller (11) Personal computer; (12) Data Logger (13) Weighing indicator (14) Vacuum pump

METHODS

The sliced sample about 64 pieces, each with diameter of 18 mm were placed on a tray. The experiments were carried out at the following conditions: absolute pressure of 2 and 5 kPa; controlled (predetermined) temperature at surface of turmeric slices at 50, 60 and 70 ^{o}C and thickness of turmeric slice 2 and 3 mm. In drying process, the samples were dried until reaching a final moisture content of 5 % (d.b.). All experiments were performed in triplicates and the mean values with standard deviations were reported. The moisture content of the samples was determined by AOAC (1990) [12]. In this method, the 5 g of fresh turmeric sample was put in the moisture can and then it was dried by electrical oven at 105 ^{o}C until the sample mass did not change.

EVALUATION OF COLOR

The color of dried turmeric was measured by using spectrophotometer (HumterLab Reston, model ColorFlex, USA) with a D65 light source and observer at angle of 10^{o}. Before measuring the color the spectrophotometer was calibrated with a colored reference (L* = 93.55,a* = -1.08, b* = 1.38). The color values of sample were expressed in terms of L*(Lightness), a*(redness/greenness), and b* (yellowness/blueness) value.

EVALUATION OF CURCUMIN CONTENT

The curcumin content in the sample was analyzed by the modified method of Jayaprakasha et al.[13]. It was determined by using HPLC equipped with C18 column (sunfire 150×4.6 mm), controlled temperature at 40 ^{o}C, mobile phase of 1% acetic acid : acetonitril (45:55, v/v), flow rate of 1 ml/min, inject volume equal to 10 µl. The wavelength at 425 nm was investigated by using UV-visible detector and the average value from triplicates of each experiment was reported.

RESULTS AND DISCUSSION

Drying kinetics of turmeric slices

Fig. 2 shows the drying curves of turmeric slices with thickness of 2 mm and absolute pressure of 2 kPa undergoing at various temperatures. At the same vacuum level, it was found that the rate of moisture reduction increased with an increase in drying temperature due to the increased temperature difference between the drying product and the surrounding led to the increased moisture diffusivity. In addition, the drying time decreased rapidly with an increase in drying temperature at absolute pressure of 2 kPa.

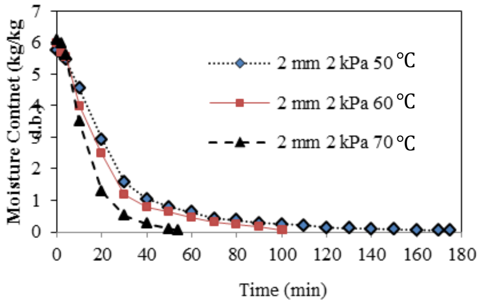

Fig. 2 Drying curve of turmeric slice witvarious temperatures (50, 60 and 70 oC) at absolute pressure 2 kPa and thickness 2 mm

Fig. 3. illustrates the effect of vacuum level on drying kinetics of turmeric slices. It is seen that the rate of moisture reduction increased with a decrease in the absolute pressure because at lower pressure water boils and evaporates at lower temperature. As expected, the drying time decreased with a decrease in absolute pressure. It should be noted that the water boils and evaporates at 17.33 and 32.73 ^{o}C when the absolute pressures in drying chamber are 2 and 5 kPa, respectively [14].

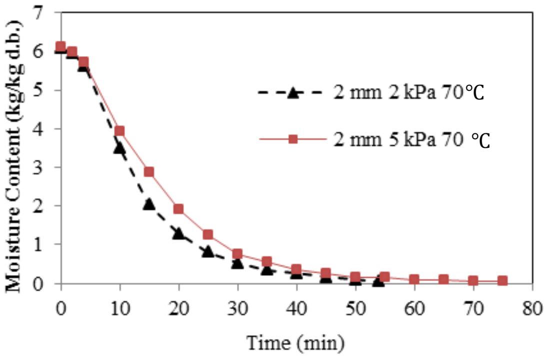

Fig. 3 Drying curve of turmeric slice with various absolute pressures (2 and 5 kPa) at temperature 70^{o}C and thickness 2 mm

Fig. 4. reveals the effect of the slice thickness on the drying curves of turmeric at 70^{o}C and 2 kPa. The rate of moisture reduction decreased with an increase in the thickness because the penetrated FIR to the sliced turmeric decreased with increasing thickness. When the penetrated FIR to the slice decreased, the energy converted into heat was also decreased. Consequently, the drying time increased with an increase in the thickness (see Fig. 4)

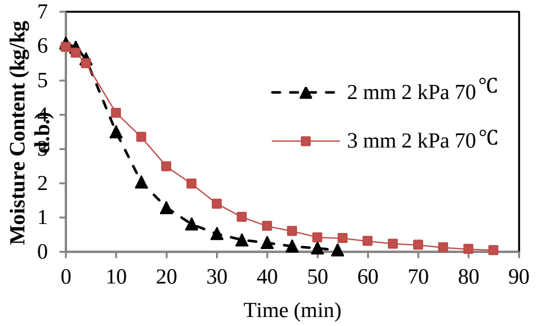

Fig. 4 Drying curve of turmeric slice with various thicknesses (2 and 3 mm) at absolute pressure 2 kPa and temperature 70 oC

Fig. 5 shows the temperature evolution within a turmeric slice. It is seen that the temperature decreased suddenly at the beginning of drying period because the water immediately evaporated from the turmeric slice due to abrupt pressure drop. As water evaporated it removed heat in terms of heat of vaporization from the turmeric slice led to the temperature drop. After this period the temperature increased gradually and approached to the controlled temperature at surface of turmeric slices.

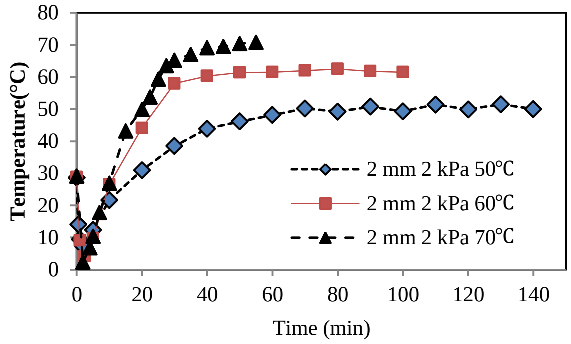

Fig. 5 Temperature distribution inside a turmeric slice with various temperatures (50, 60 and 70°C) at absolutepressure 2 kPa and thickness 2 mm

Qualities of dried turmeric slice

Table 1 shows the color changes of the turmeric slices at various temperatures, pressures and thicknesses. It was found that the lightness increased with an increase in drying temperature. This might be due to an increase in drying temperature led to a decrease in drying time or the time to contact heat of the turmeric slice. The lightness also increased with a decrease in absolute pressure. In addition, the lightness decreased with an increase with the slice thickness at 5 kPa. It might be due to an increase in the drying time with the increasing of the slice thickness. The yellowness increased with an increase in drying temperature due to the browning reaction occurring during drying process while the redness was quite constant.

Table 1 Color of the dried turmeric slice

Drying conditions	L*	a*	b*
2 mm, 2 kPa, 50 °C	51.21 ±0.77 b	30.37 ±0.67 d	51.70 ±0.80 bc
2 mm, 2 kPa, 60 °C	54.36 ±1.11 de	27.19 ±0.77 b	58.14 ±1.21 def
2 mm, 2 kPa, 70 °C	56.14 ±0.83 e	27.11 ±0.83 b	59.65 ±1.18 efg
2 mm, 5 kPa, 50 °C	50.09 ±0.67 b	32.52 ±0.53 e	53.80 ±0.91 c
2 mm, 5 kPa, 60 °C	53.36 ±1.27 b	27.37 ±0.85 b	59.81 ±1.02 d
2 mm, 5 kPa, 70 °C	54.61 ±1.14 cd	26.18 ±1.05 b	61.16 ±1.19 g
3 mm, 2 kPa, 50 °C	52.14 ±0.70 bcd	30.45 ±0.74 d	53.94 ±0.71 c
3 mm, 2 kPa, 60 °C	55.85 ±1.21 be	29.62 ±1.03 cd	58.23 ±1.14 fg
3 mm, 2 kPa, 70 °C	57.45 ±1.26 e	27.49 ±0.98 b	60.61 ±0.78 def
3 mm, 5 kPa, 50 °C	50.28 ±0.96 b	30.50 ±0.68 d	51.16 ±1.09 b
3 mm, 5 kPa, 60 °C	53.30 ±1.06 cd	27.94 ±0.50 bc	57.78 ±1.04 de
3 mm, 5 kPa, 70 °C	54.11 ±0.98 de	27.65 ±0.62 b	59.49 ±1.21 efg
Fresh turmeric slice	37.80 ±1.27 a	22.77 ±1.44 a	29.91 ±1.50 a

[1]Different superscripts in the same column mean that values are significantly different ($p < 0.05$)

Table 2 Curcumin content of the dried turmeric slice

Drying conditions	Curcumin Content (mg/g)	Drying time (min)
2 mm, 2 kPa, 50 °C	48.11±0.35	175
2 mm, 2 kPa, 60 °C	n/a	110
2 mm, 2 kPa, 70 °C	45.25±0.92	55
2 mm, 5 kPa, 70 °C	40.10±0.82	75
3 mm, 2 kPa, 70 °C	36.11±0.35	85

Table 2 illustrates the curcumin content in the dried turmeric slice and drying time. At the same vacuum level, the curcumin content decreased with an increase in drying temperature. This might be due to the deterioration of the curcumin content at a higher temperature and a longer drying time. At the same temperature, it was found that the curcumin content decreased with an increase in absolute pressure due to a longer drying time. For the effect of the slice thickness on curcumin content, it was found that the curcumin content decreased with an increase in the slice thickness. Based on these experiments, the curcumin content of the dried turmeric slices at thickness of 2 mm was higher than that value of Thailand Industrial Standard (TISI). It is noted that the curcumin content of TSIS was 40 mg/g.

CONCLUSION

Drying of turmeric slice using a combined vacuum and far-infrared drying was investigated in this work. Based on these experiments, the drying temperature, vacuum level and the thickness of turmeric slices had significant effects on the drying kinetics and qualities of the turmeric slice. For color change, it is found that the lightness and yellowness increased with an increase in drying temperature while the redness was quite constant. The curcumin content of the dried turmeric decreased with an increase in drying temperature, absolute pressure and turmeric slice thickness. However, the curcumin content of the dried turmeric at thickness of 2 mm was higher than the value of TISI.

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