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Effect of infrared radiation on the drying kinetics of osmosed papaya cubes

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Abstract
In osmotic dehydration, papaya cubes were immersed in the sugar syrup having concentration 60%, constant temperature 37ºC and immersion time 4.25 h. A laboratory scale infrared- convective dryer was used for drying osmosed papaya cubes. The drying was carried out at infrared power levels of 300, 400 and 500 W, drying air temperature of 40, 50 and 60ºC and air velocities of 1.0, 1.5 and 2.0 m/s. The infrared convective drying of osmosed papaya cubes exhibited drying having taken place in falling drying rate period. The drying rate was significantly influenced by infrared power, air temperature and air velocity. The drying time increased with increased in air velocity at all infrared power and air temperature.

Keywords: Infrared; convective; drying rate; osmosis

1. Introduction
Papaya (*Carica papaya*) is an important fruit of tropical and subtropical regions. Papaya is one of the most popular tropical fruits. The fruit is known for its nutritive and health promoting properties. The minimally processed papaya cubes were reported to have shelf life of 1–2 days at ambient temperature and 5–8 days at 8–10°C (Alam *et al*. 2013) [1]. This is too short a period to make the process commercially viable. Processing into intermediate and low moisture value added products are viable options. Therefore, many alternative approaches were followed for papaya preservation to reduce the post-harvest losses.

Therefore, many alternative approaches were followed for papaya preservation. One of the techniques being widely studied is osmotic dehydration. It has been proven to improve the texture characteristics of thawed fruits and vegetables, decreases structural collapse and retain natural colour as well as volatile compounds during subsequent drying. The two most important advantages for its use as pre-treatment in a complementary process are: quality improvement and energy saving. Osmo-air dehydration treatments are widely applied to fruits in order to prolong shelf –life, reduce packing and logistic costs and improve both sensory and nutritional quality of the end products.

Infrared technology is a new word in the world of drying science and is based on the property of water to absorb infrared radiations. 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. Hence, the material is heated rapidly and more uniformly. The infrared drying offers many advantages over conventional drying as the energy transferring to the product directly and allowing to reach the rapidly suitable temperature levels, which activates the fundamental drying mechanisms of the operation, high energy efficiency, high quality finished products, uniform temperature in the product while drying, and a reduced necessity for air flow across the product (G.P. Sharma, R.C. Verma, P.B. Pathare, 2005) [9].

The objective of this research was to study the drying kinetics of osmosed papaya cubes using infrared-convective dryer, and to study the effects of operational variables such as infrared power, air temperature and air velocity on drying rate and quality of dried osmosed papaya cubes.

2. Materials and methods
2.1 Experimental dryer
A laboratory scale infrared-convective dryer was developed for the present study where in infrared power, air temperature and air velocity could be varied within the range of 0–500 W,

30–50ºC and 1–2 m/s. Constructional details of the dryer are given elsewhere (Sharma, Verma, & Pathare, 2005) [9]. The infrared-convective dryer is comprised of two components i.e. a drying chamber having a tube type infrared heater and a hot air supply unit. Provision was made in the dryer so that the infrared radiation intensity as well as air temperature could be varied by regulating the voltage through a variac. The air velocity was regulated with the help of a damper placed in the air supply line to the drying chamber.

2.2. Osmosis of papaya cubes

40 g papaya cubes were weighed and suspended in the vessel containing the sugar solution at the concentration of 60%, temperature 37ºC and 4.25 hours immersion time (Jain, 2011) [2].

2.3 Experimental procedure

Locally available papayas were used in the present study. The papayas were cleaned, supporting fibres were scraped off and cut with a stainless steel knife into slices of thickness up to 10±0.12 mm. Three measurements were made on each slice for its thickness, using a Vernier calliper and their average values were reported. The moisture content of the papaya cubes was measured by oven dry method and was expressed as g water/g dry matter. Sugar syrup of desired concentration was prepared by dissolving required amount of sugar in water. The initial moisture content in the raw papaya was found to be 6.77 g water/g dry matter approximately. After osmotic dehydration, initial moisture content of papaya cubes was 2.33 g water/ g dry matter approximately. The dryer was run idle for about 0.5 h to achieve a steady state in respect of pre-set experimental drying conditions before each drying run.

Osmosed papaya cubes after weighing were uniformly spread on the tray. Preliminary trial of drying the osmosed pineapple slices, at infrared power of 600 W at 2.0 m/s air velocity browning the product. The drying experiments were, therefore carried out at infrared power 300, 400 and 500 W; drying air temperature 30, 40 and 50 ºC and lower air velocities of 1.0, 1.5 and 2.0 m/s. The mass of the osmosed papaya cubes was measured by a digital electronic balance throughout the drying experiment at an interval of 5 min for first one hour and 15 min subsequently thereafter. For measuring the mass of the sample at any time during experimentation, sample along with tray was taken out of the drying chamber and weighed on the digital top pan balance and placed back into the chamber.

3. Result and Discussion

The data collected on loss in the moisture content with elapsed time were analyzed to study the drying behavior of the product and also the effect of operational parameters on the drying characteristics was analyzed.

3.1 Effect of air temperature

The drying curves of papaya cubes at air velocity of 2.0 m/s and infrared power 300 W, total drying time for papaya cubes at 40, 50, 60ºC are shown Fig.1 and Table 1. The drying curves are typical to ones for food stuffs, i.e. moisture content of osmosed papaya cubes decreased exponentially with elapsed drying time. As the drying air temperature increased at any IR power (P), the drying curves exhibited a steeper slope indicating that drying become faster with increase in drying air temperature and this resulted into substantial decreased in drying time (t), when higher air temperature where used. Kumar *et al*. (2005) [1] had also reported similar findings while drying onion under infrared and hot air drying conditions. The drying curves of papaya cubes at air velocity of 2.0 m/s and infrared power 300 W, total drying time for papaya cubes at 40, 50, 60ºC were about 7, 6.5, 6 h. respectively.

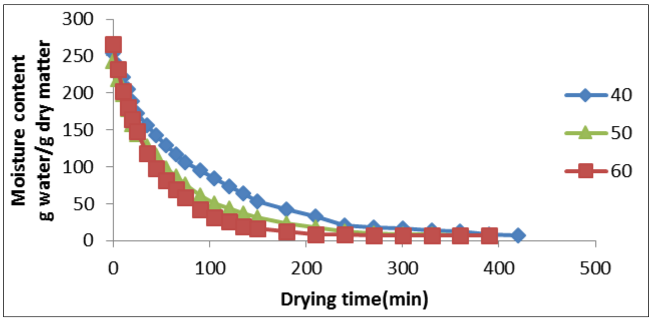

Fig 1: Drying curves for osmosed papaya cubes at various air temperatures (ºC) at air velocity 2.0 m/s, infrared power of 300 W.

3.2 Effect of infrared power

Drying curves at air velocity of 1.0 m/s, air temperature of 50 ºC as a function of infrared power are shown in Fig 2 and Table 1. The drying time to reduce the moisture content of osmosed papaya cubes to about 0.06 g water/g dry matter at infrared power of 300, 400 and 500 W was about, 4.5 and 3.5 h. respectively. The drying time reduced with increase in infrared power. The increase in infrared power caused a rapid increase in the product temperature of the product, which increases the vapours pressure inside the product resulting in faster drying. A similar trend was observed at other air velocity of 1.5 m/s and 2 m/s and at air temperature of 55ºC and 60ºC when IR power was increase from 400 W to 500 W.

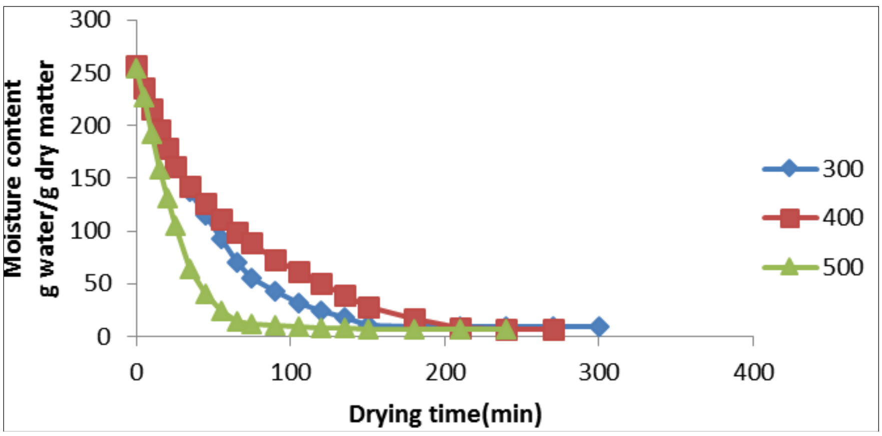

Fig 2: Drying curve for osmosed papaya cubes at various Infrared powers (watt) at air velocity 1 m/s, air temperature 50°C.

3.3 Effect of air velocity
The air velocity also influenced the drying time of the osmosed papaya cubes as shown in Fig.3 and Table 1. At a given air temperature and infrared power, an increase in air velocity increased the drying time i.e. decreased the moisture removal rate. The drying time for the papaya cubes at air velocity 1.0 m/s was about 5 hours at infrared power 300W and air temperature of 50ºC, which increased to about 6.5 hours when air velocity was 2.0 m/s, the other parameters being unchanged. They observed that in increased drying time of papaya cubes at all infrared convective drying conditions when air velocity was increased. The increase in air velocity accelerated the cooling effect, reducing the temperature at the surface of product thus the water vapor pressure or the moisture driving force.

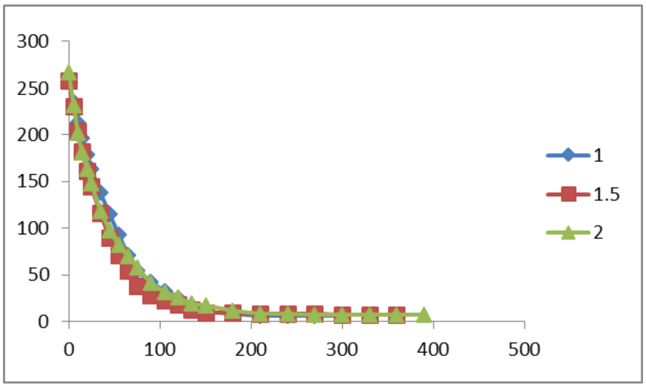

Fig 3: Drying curves for osmosed papaya cubes at various air velocities (m/s) at temperature of 50ºC infrared power of 300 W.

Table 1: Effect of process variables on drying time**.**

Drying air conditions		300 W	400 W	500 W
Air velocity (m/s)	**Air temperature (°C)**	**Drying Time (min)**		
1	40	330	300	270
	50	300	270	240
	60	270	210	150
1.5	40	390	360	300
	50	360	300	270
	60	330	240	210
2	40	420	390	330
	50	390	360	300
	60	360	300	240

4. Conclusion
The infrared convective drying of papaya cubes exhibited drying to have taken place in falling drying rate period. The drying rate was significantly influenced by infrared power, air temperature and air velocity. The drying time increased with the increase in air velocity at all infrared powers applied, however it reduced with increase in infrared power. The effective moisture diffusivity increased with decrease in moisture content of osmosed papaya cubes. There is good scope of producing a good quality dried cubes using infrared radiations.

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