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Kundan
M.Tech. Student, Department of Processing and Food Engineering, College of Technology and Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Sanjay Kumar Jain
Head, Department of Processing and Food Engineering, College of Technology and Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Narendra Kumar Jain
Dean, College of Dairy and Food Technology, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Corresponding Author:
Kundan
M.Tech. Student, Department of Processing and Food Engineering, College of Technology and Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Comparison of drying characteristics of green chilli in tray and heat pump dryer

Kundan, Sanjay Kumar Jain and Narendra Kumar Jain

Abstract
Chilli is an abundantly consumed spice and green chilli is an important essential food ingredient in many parts of the world. Green chilli samples were dipped in a hot water at 90 °C for 3 min and other samples were pre-treated with the chemical solution of 0.7 per cent concentration of potassium meta-bisulphite at 90 °C for 1.5 min. The drying characteristics of green chilli were studied in tray and heat pump dryers at 40, 45, 50 and 55 °C. The optimum process parameters for drying green chilli samples were found to be 55 °C in a tray and 45 °C in a heat pump dryer with a chemically treated sample. The variation of effective moisture diffusivity was in the range of 3.10×10^{-9} to 1.70×10^{-8} m^2/s in tray dryer and 1.23×10^{-9} to 6.55×10^{-8} m^2/s in heat pump dryer.

Keywords: Green chilli, moisture diffusivity, tray dryer, heat pump dryer

1. Introduction
Spices are an important agricultural commodity since ancient times and also contain antioxidants and bioactive components (Dubey *et al*. 2015) [5]. These are aromatic substances generally used in seasoning and flavouring foods. India is the land of spices as a variety of spices are grown due to the availability of different agro-climatic conditions. It is the largest producer, consumer and exporter of spices. The speciality of Indian food is its spices and chillies gave that special flavour. There are two types of chillies; green and red, green chillies contain a bunch of nutrients. India has produced around 1014.60 million tonnes of chilli with an area of 654 million hectares and a productivity of 1551 kg/ha during 2005-06 (Jagpat *et al*. 2012). Fresh green chilli contains calcium 29 mg, phosphorus 78 mg, iron 1.2 mg, potassium 3.74 mg, thiamine 0.22 mg, riboflavin 0.36 mg and niacin 4.4 mg per 100g (Take *et al*. 2012) [15]. Chillies also contain vitamin B-6, pyridoxine and thiamine (Dubey *et al*. 2015) [5]. Ascorbic acid is also one of the most abundant constituents of its flesh along with flavonoids, carotenoids, phenols, vitamins, saponins, nitrogenous compounds and minerals (Sarker *et al*. 2012) [13]. Chilli extracts act as biochemical pest repellents and pesticides (Chinn *et al*. 2011). Volatile alkaloid capsaicin makes it pungent (Dubey *et al*. 2015) [5]. However, despite its nutritional and economic importance, chilli is a non-climacteric, perishable fruit that generally suffers postharvest complications such as deteriorating quality, rapid weight loss and colour changes (Edusei *et al*. 2012) [6]. Chilli has more than 80 per cent (%) wet basis (Wb) moisture at the harvest and is susceptible to insect and fungal assaults. Most consumption of chilli is in the form of powder and its processing includes cleaning, drying, powder making and packaging. Conventional drying of chilli has been reported by many researchers. Most of them dried in the ripened state in the open sun (Sarker *et al*. 2012) [13]. Singh, 2018 optimized the process parameters of drying green chilli to develop an efficient process for a quality product.

2. Materials and Methods
Fresh green chilli of shakti-51 variety of similar ripeness, having uniform visual quality, maturity and size were procured from local vegetable Mandi of Udaipur, Rajasthan, India. The samples were washed thoroughly with water to remove dust, contaminants and adhering impurities. The pedicel and calyx were separated. Fresh green chilli samples were cut into 2 cm lengths with help of a stainless-steel knife. Samples were blanched in (i) hot water at 90 ºC for 3 min and (ii) pre-treated with a 0.7 per cent concentration of potassium meta bi-sulphite as suggested by Bodra and Ansari, 2018. Control, blanched and chemically treated samples were dried at 40, 45, 50 and 55 °C in a convective tray and heat pump dryers at an air velocity of 2 m/s. The initial moisture content of the green chilli sample was determined as per AOAC

(2005) [1]. The mass of samples was measured after a regular interval of time and moisture contents of the samples were determined by mass balance equations.

3. Results and Discussion

The drying time required to obtain the desired moisture content for green chilli samples in a tray and heat pump dryer at 55, 50, 45 and 40°C was 960-1620, 720-1170, 540-1110 and 930-1590, 690-1120, 480-1020 minutes for control, blanched and chemically treated samples respectively. The drying rate curves and diffusivities were determined by drying characteristics data analysis. There was a significant difference in drying time to attain the final moisture content (FMC) in the range of 7.30 to 9.42 per cent (wet basis) from the initial moisture content of 83.26 to 85.18 per cent (wet basis). The minimum time required for drying was 480 min for 55 ºC temperature for chemically treated samples in a heat pump dryer and the maximum time required was for drying of control samples at 40 °C in a tray dryer which was 1620 min (Table 1). It was also observed that an increase in temperature for the treatments including control resulted in a reduction in drying time for both the dryers. However, it was found that the drying time required in a heat pump dryer was less when compared with the tray dryer for all the temperatures to achieve the same final moisture content, the observations are in line with the findings reported by Costa *et al.* (2015) [4]. Many researchers have also observed that the heat pump dryer can reduce the drying time (Phoungchandang *et al*. 2009; Phoungchandang and Saentaweesuk, 2011) [12, 11].

For the temperature varied from 40-55 °C, the percentage reduction of time in a tray dryer and heat pump dryer for control, blanched and chemically treated samples were 40.74, 38.46, 51.35 and 41.50, 38.39, 52.29% respectively.

The dehydration ratio (D_r) increased with drying temperature. Chemically treated samples had a higher dehydration ratio than control and blanched samples (Table 1). The dehydration ratio of samples varied slightly between tray dried and heat pump dried samples. In a tray dryer, the lowest and highest values of dehydration ratio were found as 6.46 and 7.27 respectively, whereas in a heat pump dryer, the lowest and highest values of dehydration were found as 6.47 and 7.33 respectively (Table 1). The value of statistical parameter P-value was found less than 0.05 indicating that the model is significant.

The water activity (a_w) values ranged from 0.146 to 0.236. The values for water activity were relatively lesser for chemically treated samples and decreases with drying temperatures (Table 1). The water activity of dried green chilli powder was observed to decrease with an increase in air temperature from 40-55°C for all treatments. The lowest water activity at the highest air temperature may be due to a higher evaporation rate influencing the moisture content and consequently water activity of the product (Kaur and Singh, 2014) [9]. The lowest and highest values of water activity in a tray dryer were found as 0.146 and 0.187 respectively, whereas in a heat pump dryer lowest and highest values of water activity were found as 0.148 and 0.236 respectively.

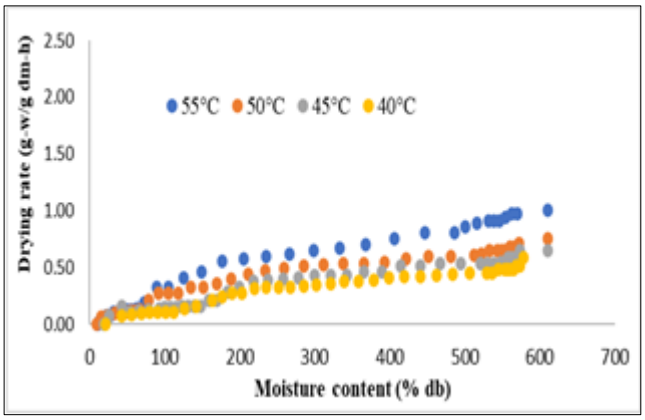
The range of moisture diffusivity (D_w) values in a tray dryer were 3.10×10^{-9} to 7.77×10^{-9} m^2/s, 4.20×10^{-9} to 1.07×10^{-8} m^2/s and 4.26×10^{-9} to 1.70×10^{-8} m^2/s for control, blanched and chemically treated sample respectively, whereas in heat pump dryer its values were 1.23×10^{-9} to 3.26×10^{-9} m^2/s, 6.21×10^{-9} to 1.23×10^{-8} m^2/s and 7.77×10^{-9} to 6.55×10^{-8} m^2/s for control, blanched and chemically treated sample respectively for the temperature range of 40-55°C (Table 1). For both dryers, drying temperature and pre-treatments affected moisture diffusivity values. Moisture diffusivity values increased as drying air temperature increased (Mohanty *et al.* 2021) [10]. Treatment was carried out as per suggested by Jain *et al.* (2011) [8] for papaya cubes immersed in sugar syrup at a constant temperature water bath. The moisture diffusivity of chemically treated samples was higher than that of control samples. This could be observed that at higher temperatures moisture diffuses more quickly due to increased drying potential and sub-surface moisture evaporation.

Table 1: Comparison of drying parameters of green chilli in tray and heat pump dryer

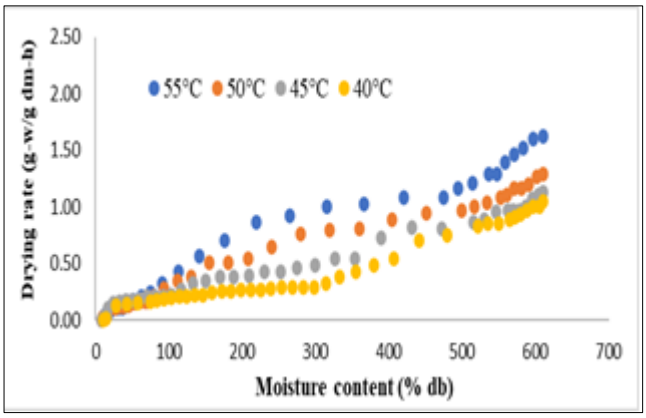
Temp (°C)	Types Of samples	Tray dryer						Heat pump dryer					
		Time (min)	FMC, Wb (%)	D_w (m^2/s)	R^2	D_r	a_w	Time (min)	FMC, Wb (%)	D_w (m^2/s)	R^2	D_r	a_w
40	a) Control	1620	9.42	3.10×10^{-9}	0.92	6.46	0.186	1590	9.36	1.23×10^{-9}	0.90	6.47	0.213
	b) Blanched	1170	9.37	4.20×10^{-9}	0.89	6.78	0.187	1120	9.25	6.21×10^{-9}	0.88	6.80	0.236
	c) Chemically treated	1110	9.15	4.26×10^{-9}	0.94	6.85	0.185	1020	9.10	7.77×10^{-9}	0.92	6.88	0.187
45	a) Control	1290	9.23	4.66×10^{-9}	0.92	6.46	0.172	1260	9.18	1.25×10^{-9}	0.91	6.51	0.193
	b) Blanched	1080	9.16	7.77×10^{-9}	0.94	6.80	0.173	1030	9.10	7.20×10^{-9}	0.88	6.85	0.176
	c) Chemically treated	900	8.83	8.20×10^{-9}	0.93	6.98	0.170	780	8.46	8.16×10^{-9}	0.91	6.98	0.174
50	a) Control	1140	8.68	6.22×10^{-9}	0.93	6.51	0.170	1080	8.57	1.54×10^{-9}	0.86	6.57	0.171
	b) Blanched	970	8.49	8.37×10^{-9}	0.91	6.82	0.172	900	8.16	7.77×10^{-9}	0.91	6.93	0.173
	c) Chemically treated	660	7.72	9.33×10^{-9}	0.95	7.16	0.148	600	7.48	9.21×10^{-9}	0.94	7.16	0.168
55	a) Control	960	7.90	7.77×10^{-9}	0.92	6.59	0.152	930	7.88	3.26×10^{-9}	0.89	6.62	0.153
	b) Blanched	720	7.75	1.07×10^{-8}	0.96	6.91	0.171	690	7.64	1.23×10^{-8}	0.92	6.95	0.171
	c) Chemically treated	540	7.38	1.70×10^{-8}	0.90	7.27	0.146	480	7.30	6.55×10^{-8}	0.86	7.33	0.148

3.1 The drying rate in tray and heat pump dryer

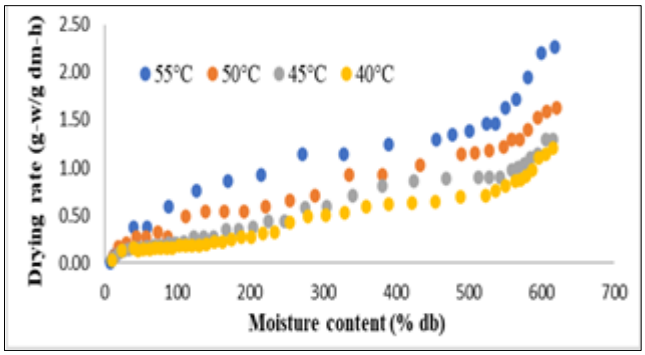
The drying rates were calculated in a gram of moisture evaporated per gram of dry matter per hour. The variation in drying rate and moisture content for the control, blanched and chemically treated green chilli samples are shown in Fig. 1 (a, b and c) and Fig. 2 (a, b and c). The drying rate was higher at the initial phases of drying and afterwards, it slowed down with time. The drying rate graphs followed a similar pattern for all treatments. The constant drying rate period was absent and a complete falling rate period was noted throughout the period.



(a) Control green chilli sample

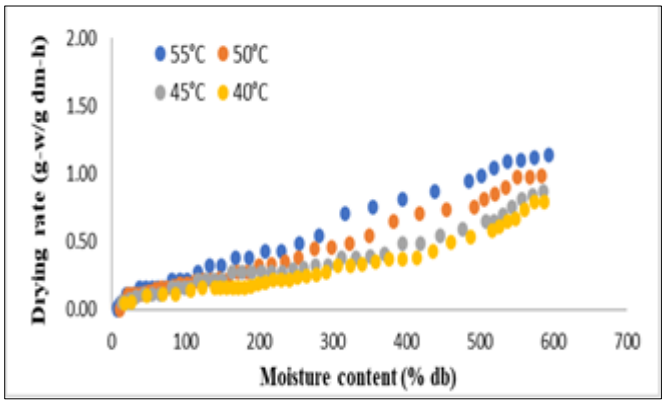


(b) Blanched green chilli sample

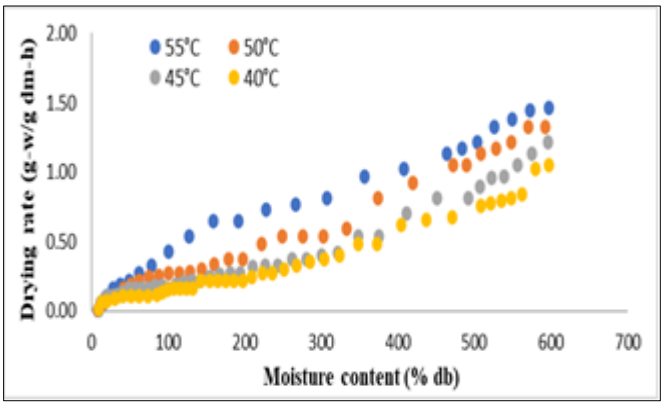


(c) Chemically treated green chilli sample

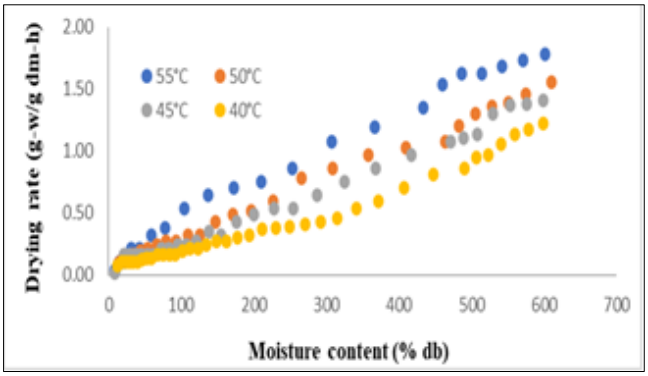
Fig 1: Variation in drying rate with moisture content for (a) control green chilli sample (b) blanched green chilli sample and (c) chemically treated green chilli sample in tray dryer for different drying temperatures



(a) Control green chilli sample



(b) Blanched green chilli sample



(c) Chemically treated green chilli sample

Fig 2: Variation in drying rate with moisture content for (a) control green chilli sample (b) blanched green chilli sample and (c) chemically treated green chilli sample in heat pump dryer for different drying temperatures

In case of tray dryer, the maximum drying rates were found for control samples as 1.01, 0.76, 0.65 and 0.58 g-water/ g-dm-h, whereas for blanched samples it was found as 1.62, 1.29, 1.13 and 1.09 g-water/ g-dm-h and for chemically treated samples 2.27, 1.62, 1.30 and 1.20 g-water / g-dm-h for 55, 50, 45 and 40 °C respectively. It can be observed that drying rates were higher in chemically treated samples, followed by blanched and control samples Fig. 1 (a, b and c). While in heat pump dryer maximum drying rates for control samples was 1.14, 0.99, 0.87 and 0.79 g-water/ g-dm-h, for blanched samples 1.46, 1.33, 1.22 and 1.05 g-water/ g-dm-h and for chemically treated samples 1.78, 1.56, 1.41 and 1.22 g-water/ g-dm-hat 55, 50, 45 and 40 °C respectively Fig. 2 (a, b and c). Heat pump dryer also showed a similar trend of drying rate and higher drying rates were observed for chemically treated samples followed by blanched and control samples.

4. Conclusion

This effect of drying methods on the drying characteristics of green chilli was studied. The increase in temperature reduced drying time. The shortest and longest drying time required in tray dryer for drying green chilli at 55°C for a chemically treated sample and at 40°C for a control sample was 540 and 1620 minutes respectively, whereas in a heat pump dryer shortest and longest drying time required at 55°C for a chemically treated sample and at 40°C for a control sample was 480 and 1590 minutes respectively. The values of the total time of heat pump drying were lower than those for the convective tray drying at all temperatures. The value of dehydration ratio, in a tray drying lowest and highest values were found as 6.46 and 7.27 respectively, whereas in a heat pump drying lowest and highest values were found as 6.47 and 7.33 respectively. The water activity of dried green chilli powder was observed to decrease with an increase in drying air temperature from 40-55°C for both tray and heat pump drying methods. The lowest water activity at the highest drying air temperature may be due to a higher evaporation rate influencing the moisture content and consequently water activity of the product. The water activity values ranged from 0.146 to 0.236. The lowest and highest values of water activity in a tray dryer were found as 0.146 and 0.187 respectively, whereas in a heat pump dryer lowest and highest values of water activity were found as 0.148 and 0.236 respectively. The green chilli was examined chemically as well as directly for its suitability for dried powder processing. It can be stated that tray and heat pump drying of green chilli, added valuable information to the current knowledge of the nutritional properties in green chilli powder, which could help the scope of commercial production of green chilli powder. The temperature and chemical treatment showed affected the drying time and characteristics including diffusivity in both tray and heat pump dryers.

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