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Effect of Different Pretreatments and Air Temperatures on Drying Characteristics of Kachri (*Cucumis callosus*) Dried in Heat Pump Dryer

Ramyashree S., Sanjay Kumar Jain, Narendra Kumar Jain, Shreedhar Singh Lakhawat, Arun Kumar, Pradeep Kumar Singh

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ABSTRACT

Kachri (*Cucumis callosus*) is an underutilized fruit of India widely found in the western part of Rajasthan during the rainy season. In this study kachri fruit slices were pretreated with different pretreatments such as hot water blanching, 0.1% w/v potassium metabisulfite (KMS) and 0.1% w/v magnesium oxide (MgO) at 80ºC for 3 min. Pretreated samples were dried in a heat pump dryer at 40, 50 and 60ºC and their drying characteristics such as moisture content, drying rate, moisture diffusivity and rehydration ratio were studied. The initial moisture content of control kachri was 893.04% (db) and for the pretreated sample, it was 906.75% (db) and the final moisture content was found 4 to 6% (db) for all the treatments. The KMS treated sample took less drying time and a higher drying rate followed by MgO, hot water blanching and control. Moisture diffusivity ranged from 1.90×10^{-07} to 8.28×10^{-07} m^2/s as the temperature increased from 40 to 60ºC. The value of the rehydration ratio ranged from 2.1 to 5.03. It was found that both rehydration ratio and moisture diffusivity values increased with an increase in drying air temperature.

Keywords *Cucumis callosus*, Heat pump drying, Kachri, Pretreatments, Rehydration ratio.

INTRODUCTION

Kachri is a green fast growing climber plant belongs to family Cucurbitaceae (Nathawat *et al.* 2013). It is harsh, drought tolerant crop grown in arid and semiarid regions of Rajasthan particularly in Nagaur, Churu, Jaisalmer, Jodhpur and Barmer districts. It grown naturally as wild crop or cultivated has intercrop/main crop particularly during rainy season. Fruits are small, ovoid and ellipsoid in shape of 60-550 g in weight, light green, yellow and brown in color with uniformly spaced white strips over surfaces.

Ramyashree S.[1]*, Sanjay Kumar Jain[2], Narendra Kumar Jain[3], Shreedhar Singh Lakhawat[4], Arun Kumar[5], Pradeep Kumar Singh[6]

[1]PhD Research Scholar, [2]Professor and Head, [3]Former Dean, [4]Professor, [5]Associate Professor, [6]Dean

[1, 2]Department of Processing and Food Engineering, College of Technology and Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan 313001, India
[3]College of Dairy and Food Technology, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan 313001, India

[4]Department of Horticulture, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan 313001, India

[5]Department of Dairy and Food Chemistry, College of Dairy and Food Technology, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan 313001, India

[6]College of Technology and Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan 313001, India

Email : 46ramyas@gmail.com
*Corresponding author

The availability of arid vegetables is limited to a period of short duration only. During this period, a little part of the total produce is used in the form of vegetables. The remaining produce spoils either through over ripening or from unawareness of various processing and value addition methods. Due to its perishable nature and overproduction during harvest, kachri has post-harvest losses that range from 30 to 40% and lower the market value of the fruits (Nathawat *et al.* 2013).

Drying is one of the most commonly used preservation method to extend the shelf life of foods by lowering the moisture content (Deng *et al.* 2019). It is a complex process involves transient heat and mass transfer process. The problem of post-harvest losses can be solved by dehydrating the produce, which can also offer significant economic returns to the growers and the availability of fruits throughout the year.

It is possible to dry fruits and vegetables either naturally as they are or after giving pretreatments before drying to inactivate the enzymes that cause unfavorable alterations, it also helps in reducing the drying time, energy consumption and preserve the quality of dried products (Deng *et al.* 2019). The most commonly used pretreatments for fresh produce are blanching, freezing, chemicals, high pressure and ultrasound. Blanching is hydrothermal treatment that inactivates the enzyme, aids in softening the tissues and extend the shelf life by minimizing microbial attack.

Limited work has been done on the drying characteristics of kachri, most of the researchers focused on the value addition and development of a new product from the kachri fruit. This is important in order to understand the effect of different drying conditions on the quality of the final product because the final quality of the developed product depends on the processing parameters. Based on these requirements, it was therefore this work was taken up to investigate the effect of different drying conditions on the drying characteristics of kachri.

MATERIALS AND METHODS

Sample preparation

Fresh, matured kachri fruits of cultivar AHK 200 were procured from Central Arid Zone Research Institute, Jodhpur, Rajasthan were thoroughly cleaned before processing. The adhered foreign material such as soil and dust particle were removed by washing in tap water.

Pre-treatment process

The kachri slices were pre-treated with different pretreatments such as hot water blanching, 0.1% potassium metabisulphite (KMS), 0.1% magnesium oxide (MgO) at 80^{o}C for 3 min (Prajapati *et al.* 2011) and unblanched sample as a control.

Experimental procedure for heat pump drying of kachri fruit slices

To determine the drying kinetics of kachri fruits were dried in convective heat pump dryer at 40, 50, and 60^{o}C. The kachri slices were spread uniformly over the trays and placed in the drying chamber. The experiments were conducted in three replications. The drying process starts when the required drying conditions were achieved. Weight of the samples were recorded constantly with an interval of one hour for both tray and heat pump dryer to determine the drying characteristics at different time interval. The drying was carried until two to three consecutive constant weights were recorded. The data were used to analyse the drying characteristics such as moisture content, drying rate, moisture ratio and rehydration ratio of sample.

Moisture content

The moisture content of kachri samples were determined using hot air oven method on the basis of dry matter of sample. The moisture content (% db) was calculated by using the following equation.

$$\textit{Moisture content \% db} = \frac{W_1 - W_2}{W_2} \times 100 \qquad \ldots(1)$$

Where,

W_1 = Initial weight of the sample (g)

W_2 = Final weight of the sample (g)

Moisture ratio

To study the drying characteristics of kachri and to represents drying behavior graphically it is need to calculate the moisture ratio at different time interval. The moisture ratio curves at different drying conditions can better describe the drying behavior as compared to moisture content curve, as the initial value for all the experiment is one. The moisture ratio (MR) was calculated by using the following Eq. 2 (Gomez-Daza and Ochoa-Martinez 2015).

$$MR = \frac{M - M_e}{M_0 - M_e} \qquad \ldots(2)$$

Where,

M = Moisture content at time t (min) during drying (% db)

M_e = Equilibrium moisture content (% db)

M_o = Initial moisture content ((% db)

The values of M_e were neglected because when compared to M_o and M the values of M_e (equilibrium moisture content) were very small for long drying time. Therefore the following Eq. 3 was used to calculate the MR.

$$MR = \frac{M}{M_0} \qquad \ldots(3)$$

Drying rate

The moisture content data recorded during experiments will be analyzed to determine the moisture lost from the sample of kachri in particular time interval. The drying rate of sample will be calculated by using the following Eq. 4 (Erol 2022).

$$Drying\ rate = \frac{M_{(t+dt)} - M_t}{dt} \qquad \ldots(4)$$

Where,

M_{t+dt} = Moisture content at t + dt (g water/g dry matter)
dt = Time between two sample weighing (min)

Rehydration ratio

The rehydration characteristics of dried sample indicate the quality of the dried product. According to Ranganna (2000) there is no standard time for rehydration. It depends on the product to product. About 2 g of dried kachri slices were taken in a 250 ml beaker filled with 150 ml distilled water and boiled for about 10 min in water bath at 70ºC. The samples were taken out and adhered surface moisture was removed by tapping tissue paper and weight was noted (Velic *et al.* 2004). The measurements were taken in triplicate and the values were used for further parameter calculation i.e. rehydration ratio (RR). These rehydration characteristics were calculated as follows (Al-Amin *et al.* 2015).

$$Rehydration\ ratio = \frac{Weight\ of\ rehydrated\ sample}{Weight\ of\ dehydrated\ sample} \qquad \ldots(5)$$

RESULTS AND DISCUSSION

Effect of air temperature on moisture content of kachri fruit samples

The variation in moisture content, per cent (db) with drying time is presented in (Fig.1). The moisture content of kachri fruit slices decreased exponentially with time for entire drying experiment. The loss in moisture content with of drying time followed almost similar pattern for all pretreatments and drying air temperatures. Initial moisture removal rate was higher due to high moisture content, and then decreased with drying time. Falling rate period was observed during the whole drying process and constant rate period was completely absent for all the experiments, it showed that there was no surface moisture present on the kachri fruit slices. The increasing drying temperatures also fasten the drying process within temperature range (40 – 60ºC). Similar results were also obtained by Kohli *et al.* (2022), Kannan *et al.* (2021).

For the different pretreatments the moisture content versus drying time dried in different dryers is shown in (Fig. 1). The samples were pre-treated with hot water, 0.1% KMS and 0.1% MgO. From the (Table 1) shows that the pre-treated samples took less drying time with comparison to control sample. The initial moisture content of control sample was

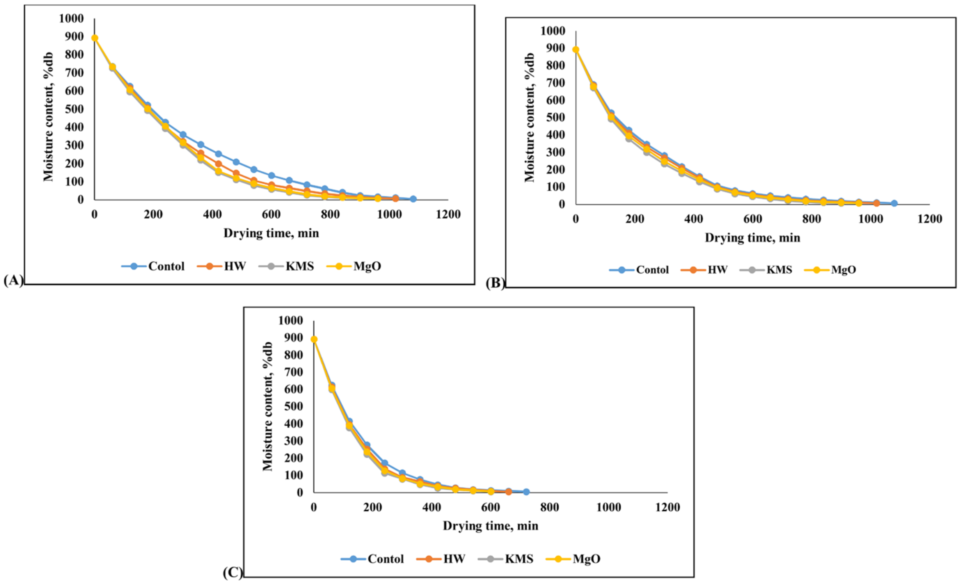

Fig. 1. Variation in moisture content of kachri fruit slices pre-treated with various pretreatments dried in heat pump dryer at (A): 40 ºC, (B): 50ºC, (C): 60ºC.

893.04% (db) for all the treatments and final moisture content varied from 6–8% (db) irrespective of treatments. For the pre-treated sample the initial moisture content increases to 906.75% (db) (at 40ºC for 0.1% KMS blanched samples).

Effect of air temperature on drying rate of kachri fruit samples

The variation in drying rate versus time of control and pretreated dried at different temperatures in heat pump dryer were illustrated in (Fig. 2). The effect of pretreatment, and temperature can also be observed in Fig. 2. It was found that as the drying air temperature increases the drying rate increases for all the experiments. Further, the method of pretreatment increased the drying rate, the drying rate of the KMS and MgO treated sample more followed by the hot water blanched sample compared to the control. The increase in drying rate with an increase in temperature might be due to high moisture diffusivity at higher temperatures.

Table 1. Drying time of kachri samples drying in heat pump dryer under different temperatures and pretreatments.

Temperature	Pretreatments	IMC % (db)	FMC % (db)	Drying time, min	Percent reduction in drying time
40	Control	893.04	7.66	1080	-
40	HW	898.47	6.33	1020	5.56
40	KMS	906.34	6.73	960	11.11
40	MgO	900.75	6.69	960	11.11
50	Control	893.04	7.21	1020	-
50	HW	897.32	7.20	960	5.88
50	KMS	906.75	6.07	900	11.76
50	MgO	902.45	6.55	960	11.76
60	Control	893.04	6.53	720	-
60	HW	894.25	6.93	660	8.33
60	KMS	903.42	6.49	600	16.67
60	MgO	901.14	6.85	600	16.67

The maximum drying rate of 0.05 g-w/g-dm-min was observed initially for a 0.1% KMS treated sample dried at 60ºC. It was observed from the figures that the drying rate was found maximum during the initial inception of drying and it was reduced with time as the moisture content was reduced towards the end of drying. It can also be seen that in the initial period of 120–180 min, the drying rate of various samples for different air temperatures varied but later as drying continues it was found to be the same for all the temperatures. It can be evident from the (Fig. 2) constant rate period was absent and complete drying of kachri slices takes place in a falling rate period for all the experiments. These results are in line with the

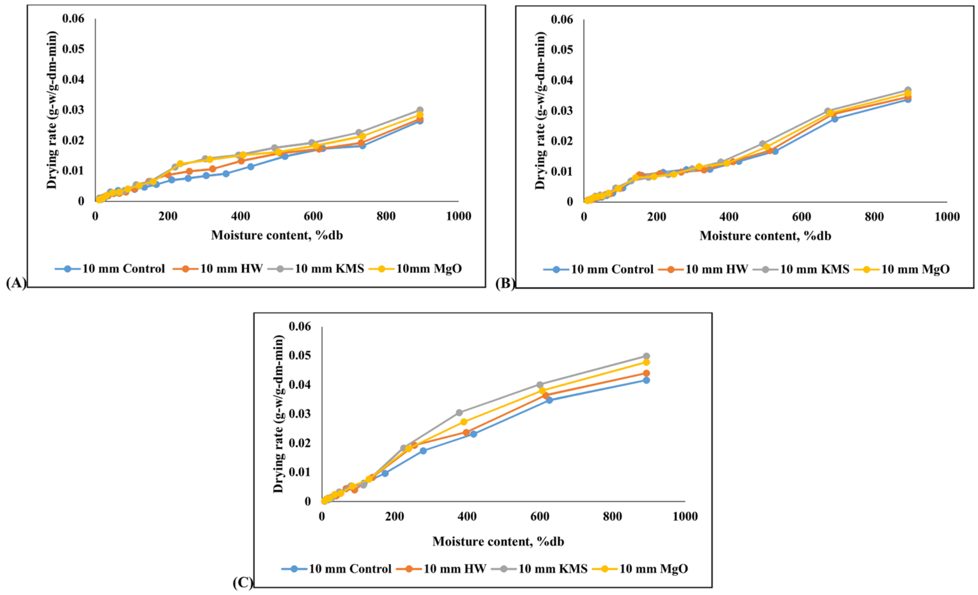

Fig. 2. Variation in drying rate with moisture content of kachri fruit slices pre-treated with various pretreatments dried in heat pump dryer at (A) : 40°C, (B) : 50°C, (C) : 60°C.

findings of several researchers works on the drying characteristics of fruits and vegetables viz., Kohli *et al.* (2022) for asparagus roots, Akpinar (2010) for the drying of mint leaves, Al-Amin *et al.* (2015) for the drying of carrots.

Effect of air temperature and pretreatments on moisture ratio of kachri fruit samples

The drying rate data was further analyzed to find out the effective moisture diffusivity. For the estimation

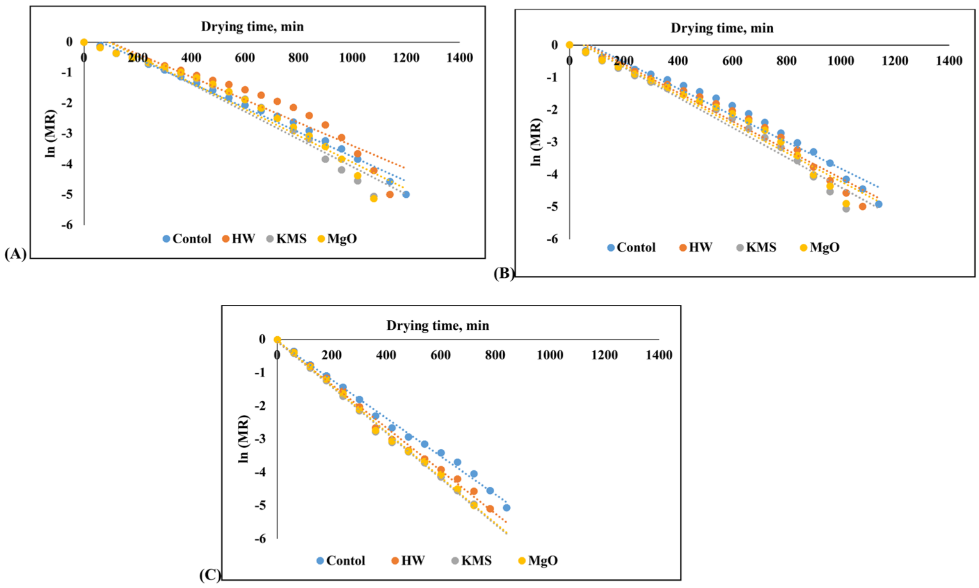

Fig. 3. Variation in ln (MR) with time of kachri fruit slices pre-treated with various pretreatments dried in heat pump dryer at (A): 40°C, (B): 50°C, (C): 60°C.

Table 2. Effective moisture diffusivity values at different conditions.

Temperature	Pretreatments	Effective diffusivity, m^2/s
40	Control	2.74×10^{-07}
40	HW	1.90×10^{-07}
40	KMS	2.14×10^{-07}
40	MgO	2.10×10^{-07}
50	Control	3.94×10^{-07}
50	HW	4.82×10^{-07}
50	KMS	5.23×10^{-07}
50	MgO	5.03×10^{-07}
60	Control	7.07×10^{-07}
60	HW	7.83×10^{-07}
60	KMS	8.09×10^{-07}
60	MgO	8.28×10^{-07}

of diffusion coefficients (D_{eff}) slope of ln (MR) versus time was used (Fig. 3). The values of effective moisture diffusivity are shown in Table 2. From Fig. 3 it can be observed that a linear relationship existed between the ln (MR) versus time for all the drying temperatures and pretreatments. As the time increases the moisture ratio of the sample decreased. Due to this for different air temperatures with drying time the values of ln (MR) decreased (Srinivas *et al.* 2018).

The values of effective moisture diffusivity for different temperatures and pretreatments ranged from 1.90×10^{-07} to 8.28×10^{-07} m^2/s. From Table 2 it is shown that the values of effective moisture diffusivity increase with the increase in the temperature and pretreatment (Jiang *et al.* 2021). As the temperature increases from 50 to 60°C the value of moisture diffusivity increased from 3.94×10^{-07} to 7.07×10^{-07} m^2/s.

Table 3. Rehydration ratio of dried kachri slices at different drying conditions.

Temperature	Pretreatments	Rehydration ratio
40	Control	2.21
40	HW	2.45
40	KMS	2.67
40	MgO	2.56
50	Control	2.64
50	HW	2.72
50	KMS	3.03
50	MgO	2.89
60	Control	2.83
60	HW	3.10
60	KMS	3.48
60	MgO	3.23

Similarly for hot water blanched samples was from 4.82×10^{-07} to 7.83×10^{-07} m^2/s. for KMS blanched sample was from 5.23×10^{-07} to 8.09×10^{-07} m^2/s similarly for MgO treated sample from 5.03×10^{-07} to 8.28×10^{-07} m^2/s, respectively. Trends obtained in this study are in line with the results reported by Srinivas *et al.* (2018) for papaya cubes, Komonsing *et al*. (2021) for turmeric and Panchal *et al.* (2019) for drying of sweet potato.

Effect of air temperature and pretreatments on rehydration ratio of kachri fruit slices

The rehydration ratio indicates the quality of the products, higher the rehydration ratio better the quality of the product. Table 3 indicates the rehydration ratios of dried kachri slices at different drying conditions the rehydration ratio varies from 2.21 to 3.48. The rehydration ratio increases with increases in air temperature and the minimum rehydration ratio was 2.21for control sample dried at 40°C. The maximum rehydration ratio was 3.48 for KMS treated sample dried at 40°C. Similar results were found for Panchal *et al*. (2019) for drying of sweet potato.

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