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Effect of different pretreatments and temperature on drying characteristics of sweet Potato

Jigar B Panchal, Champawat PS, Mudgal VD and Jain SK

Abstract

In this study slices of sweet potato were pretreated with different pretreatments such as; 0.1% w/v potassium metabisulfite (KMS), 1% w/v calcium chloride (CaCl_2) and blanching at 80°C for 5 min. Pretreated sweet potato slices were dried in a mechanical tray dryer at 50, 55, 60 and 65°C and their drying characteristics such as moisture content, drying rate, moisture diffusivity and rehydration ratio were studied. The initial moisture content of raw sweet potato was found 246.02 per cent (db). The initial moisture content of pretreated sweet potato slices ranged between 240.68 to 260.35 (db) and final moisture content was found ranged from 6.01 to 7.33 per cent (db) at temperature 50, 55, 60 and 65°C . The CaCl_2 pretreated sample taken less drying time and higher drying rate as compared with kms, hot water blaching and control samples. Moisture diffusivity ranged from 1.1×10^{-8} to $2.92 \times 10^{-8} \text{ m}^2/\text{s}$ as the drying temperature increased from 50 to 65°C . It was found that Moisture diffusivity and rehydration ratio increased with increase in drying air temperature.

Keywords: Sweet potato, pretreatments, tray drying, moisture content, rehydration ratio

1. Introduction

Sweet potato is oldest fiber crop grown almost all over the world. It ranks as fifth important food crop in developing countries. (Zhang *et al.*, 2000) ^[1] The total area and production of sweet potato in India is 1,34,900 ha and 16,38,800 MT in 2016-17 respectively. and in Rajasthan state area and production of sweet potato is 1100 ha and 10910 MT in 2016-17 respectively. (Anonymous, 2017) ^[2]. It is an important tropical root and tuber crop as it ranks second after cassava among the tropical tuber crops. Sweet potato plays an important role in promoting nutritional security particularly in agriculturally backward areas and also to be considered valuable staple crop worldwide.

The dry matter in sweet potato consists of average 70% starch, 10% total sugars, 10% total fiber, 5% total protein, 3% ash, 1% lipid and rest 1% vitamins, organic acids (e.g. folic acid and pantothenic acid) and other components. (Sablani and Mujumdar, 2006) ^[3] Sweet potato has a wide range of scope for value addition. Of the total sweet potato produced, 80-85% is consumed as fresh and around 15-20% in the processed form. It can be processed into products, such as biscuits, cookies, muffins, noodles, and breakfast foods with longer shelf life, and improved characteristics. The sweet potato can also be processed into flour, which is less bulky and more stable than the high perishable fresh root. (Mais and Brennan, 2008) ^[4].

Pretreatment is an essential step before processing of food materials. (Senadeera *et al.*, 2000) ^[5] It has been studied that pretreatment can not only accelerate drying rate but also improve quality of dehydrated product by expelling intercellular air from the tissues, softening the texture, destroying the enzymes and microorganisms, or by dissociating the wax on the products skin and forming fine cracks in the skin. (Jayaraman and Gupta, 2006) ^[6] Many researchers have investigated the effect of different pretreatments on various fruits, vegetables and other food drying. (Alvarez *et al.*, 1995) ^[7].

Most technical research on sweet potato flour has focused on the development of new food products using sweet potato flour rather than on efficient methods to produce the flour. Meanwhile, researchers have reported different characteristics of Sweet Potato flour processed from different varieties and under different conditions. (Van Hal 2000; Jangchud *et al.*, 2003) ^[8-9]. There is need to harmonize and apply some common processing conditions of pretreatment and drying and report the quality of flour.

This is important in order to understand the effect of interactions among these independent variables on quality attributes of sweet potato flour.

Processing the sweet potato into flour increases its storage ability and value. It can also be used to enhance food products colour, flavour, natural sweetness and supplement nutrients. In product development, the final quality of a product is highly dependent on the quality of the raw ingredients used. Therefore, if sweet potato flour is to be incorporated into products, it must be good in quality.

2. Material and Methods

2.1 Sample preparation

Samples of sweet potato slices were prepared after sorting based on size, washing and peeling using stainless steel knife manually and slicing with help of adjustable stainless steel slicer. The samples were cut into slices of approximate thickness 6 (± 0.1) mm.

2.2 Pretreatment process

The details of each pretreatment were described as follow:

The sweet potato slices were pretreated with 1) 0.1% w/v KMS with water solution (1 gm KMS in 1-liter water) for 30 min. 2) 1% w/v CaCl_2 with water solution (10 gm CaCl_2 1-liter water) for 1 min. 3) blanching at 80 °C for 5 min in water bath. 4) without any pretreatment (Control).

In chemical pretreatment samples were immersed in chemicals solution in a beaker, which was prepared by adding chemicals with water in desired concentration at room temperature. The ratio of sweet potato slices to the pretreatment solution was 1:5. After the soaking time interval samples were immediately removed and blotted gently using tissue paper. Then slices were weighed again.

2.2 Experimental procedure for tray drying of sweet potato

After the pretreatment, the sweet potato slices was dried in mechanical tray dryer at four different air temperature 50, 55, 60 and 65 °C. The details of the dryer of the present experiment are as follows:

Sweet potato was taken from the storage and allowed to equilibrate with ambient conditions for about 1 hour. Before beginning an experiment, the initial moisture content of sample was determined. The instrumentation was checked deliberately and dryer was started one hour before experiments keeping in mind the end goal to achieve enduring condition of temperature. Sweet potato sample was spread in aluminum trays having perforated surface and inserted into the mechanical tray dryer. The drying temperature was taken as 50, 55, 60 and 65 °C simultaneously at constant drying air velocity of 2 m/s in drying chamber. During drying, the samples were weighed at an interim of 20 minutes until the point that the sample attained constant moisture content (EMC).

Three replication were carried out and average values were used for calculation. At the completion of each experiment, the final moisture content of each sample was considered as EMC. The data were used to analyse the drying characteristics viz. moisture content, drying rate, moisture ratio and rehydration ratio determined.

Moisture content

Moisture content of the sample during experiments at various times was determined on basis of dry matter of sample.

Moisture content (db) during tray drying was calculated (Brooker *et al.*, 1997)^[10] as:

$$\text{Moisture Content (db)} = \frac{W_\theta - DM}{DM} \times 100 \quad \dots (1)$$

Where,

W_θ = Weight of sample at time θ , g

DM = Dry matter of the sample, g

Drying rate

The moisture content data recorded during experiments were analyzed to determine the moisture lost from the samples of sweet potato slices in a particular time interval. The drying rate of sample was calculated by following mass balance equation. (Brooker *et al.*, 1997)^[10].

$$R = \frac{WML(\text{g})}{\text{Time interval (min)} \times DM(\text{g})} \quad \dots (2)$$

Where,

R = Drying rate at time θ , g water/g-min

WML = Initial weight of sample-Weight of sample after time θ

DM = Dry matter, g

Moisture ratio

The moisture ratio was calculated by using the following equation:

$$\text{Moisture ratio} = \frac{M - M_e}{M_o - M_e} \quad \dots (3)$$

Where,

M = Moisture content at any specified time t (per cent db)

M_e = Equilibrium moisture content (per cent db)

M_o = Initial moisture content (per cent db)

M_e in comparison to M_o and M is very small, hence M_e can be neglected and moisture ratio presented in simplified form (Doymaz, 2004)^[11]

$$MR = \frac{M}{M_e}$$

Rehydration ratio

The rehydration ratio of sweet potato sample was estimated as per (AOAC, 1990)^[12] procedure. Rehydration of dried sweet potato was done by placing 10 g of the sample in a beaker and flooding it with 1000 g of distilled water at 20°C. Rehydration was continued for 5 h. Rehydrated sample was strained, blotted with filter paper and weighed. The sample weight before and after rehydration was calculated and from this rehydration ratio was determined as follows equation:

$$\text{Rehydration ratio} = \frac{W_r}{W_d} \quad \dots (4)$$

Where,

W_r = Sample weight after rehydration, g

W_d = Sample weight before rehydration, g

3. Result and Discussion

3.1 Effect of process variable on moisture content of sweet potato

The moisture content versus drying time for various pretreated sample of sweet potato slice and at the selected

temperature is shown in Fig 1 to 4. In the starting of drying process, decrease in moisture content was faster, which is evident due to availability of high moisture initially. At initial stages moisture depletion per hour was higher and then started to decrease with drying time. These results are good agreement with the earlier studies (Kumar *et al.*, 2011)^[13] for carrot pomace drying.

The moisture content of sweet potato slices decreased exponentially with drying time and all drying conditions. The drying followed a typical trend of drying behaviour for food material as noticed earlier by (Singh, 2009)^[14]. As the drying air temperature increased, the drying curve exhibited steeper slope indicating that the drying rate increased with increase in drying air temperature. This resulted into substantial decrease of drying time.

The change in moisture content of pretreated sweet potato slices with elapsed drying time, at 50, 55, 60 and 65 °C drying temperature and air velocity of 2 m/s are presented in Fig 1 through 3.4. In case of control sweet potato slices, at drying temperature of 50, 55, 60 and 65 °C drying time was 1560, 1300, 1060 and 800 min respectively (Table 1). The initial moisture content ranging from 246.02 per cent (db) and the

final moisture content was ranging from 6.38 to 7.27 per cent (db). Moisture content sweet potato of slices is within range of 2.50 to 13.2 per cent reported by (Osundahunsi *et al.*, 2003)^[15].

In case of KMS (0.1 per cent) pretreated sweet potato slices, at drying temperature of 50, 55, 60 and 65 °C drying time was 1460, 1180, 940 and 700 min respectively (Table 1). The initial moisture content of KMS pretreated slices was found in 249.90 per cent (db) and the final moisture content was ranging from 6.01 to 7.33 per cent (db).

In case of CaCl_2 (1 per cent) pretreated sweet potato slices, at drying temperature of 50, 55, 60 and 65 °C drying time was 1420, 1140, 900 and 660 min respectively (Table 1). The initial moisture content of CaCl_2 pretreated slices was found in 257.01 per cent (db) and the final moisture content was ranging from 5.91 to 7.17 per cent (db).

In case of hot water blanched (80 °C for 5 min) sweet potato slices, at drying temperature of 50, 55, 60 and 65 °C drying time was 1500, 1240, 1000 and 740 min respectively (Table 1). The initial moisture content of hot water blanched pretreated slices was found as 247.58 per cent (db) and the final moisture content ranging from 6.67 to 7.04 per cent (db).

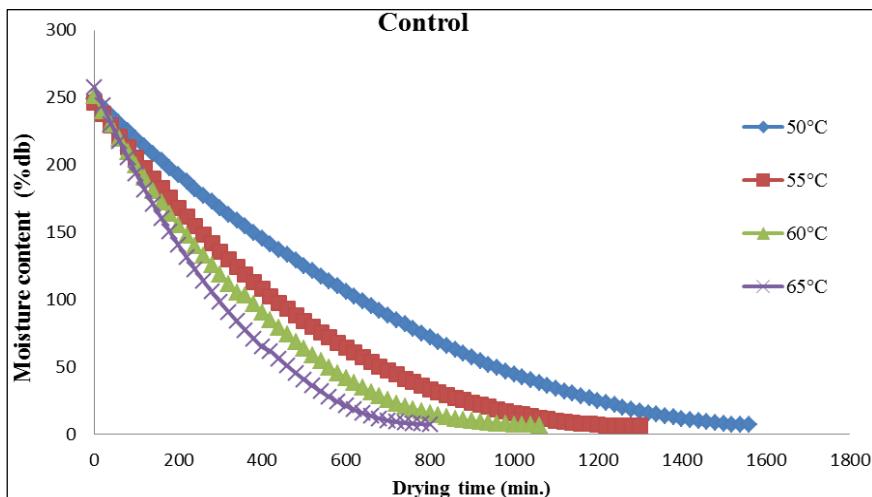


Fig 1: Variation in moisture content of control sweet potato with drying time at 50, 55, 60 and 65 °C temperature

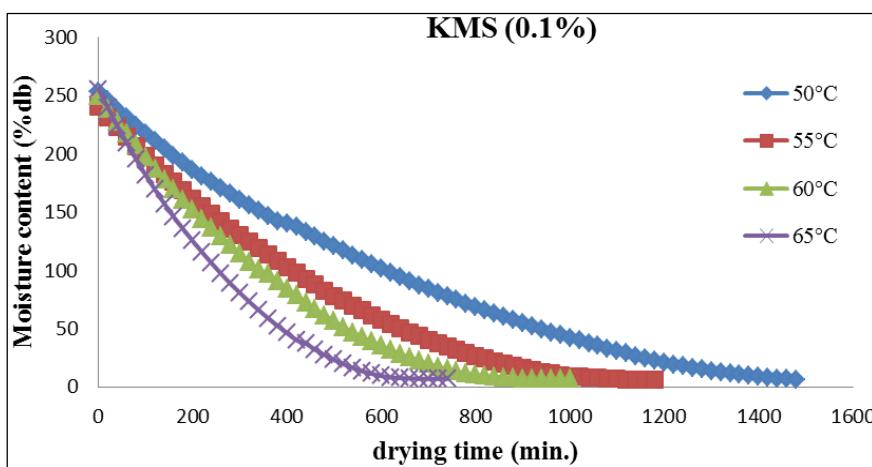
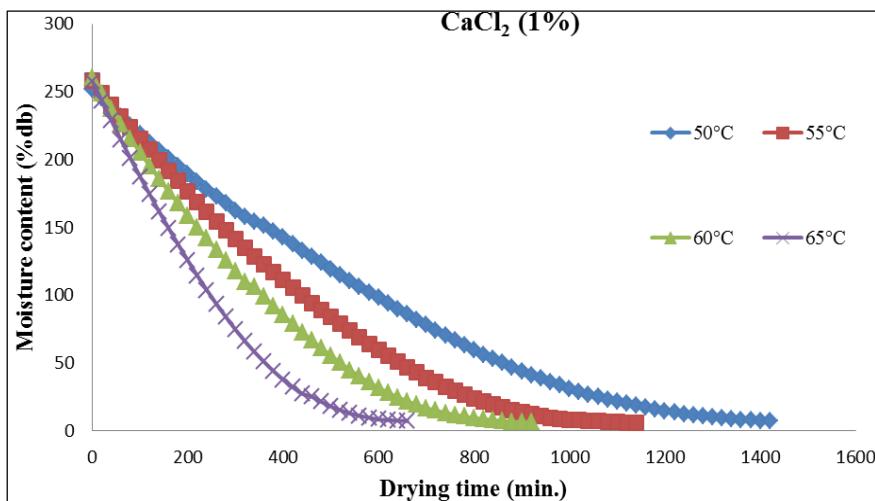
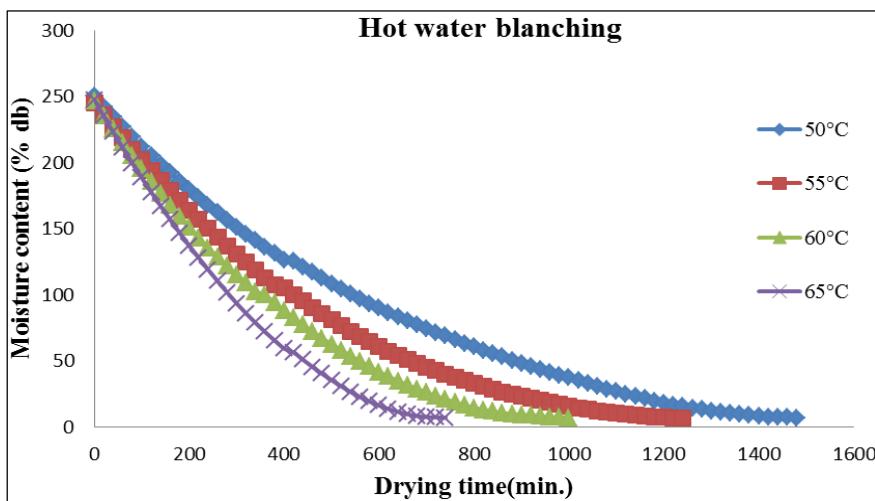


Fig 2: Variation in moisture content of KMS pretreated sweet potato slices with drying time at 50, 55, 60 and 65 °C temperature

**Fig 3:** Variation in moisture content of CaCl_2 pretreated sweet potato slices with drying time at 50, 55, 60 and 65 °C temperature**Fig 4:** Variation in moisture content of hot water blanched pretreated sweet potato slices with drying time at 50, 55, 60 and 65 °C temperature.

Results showed that the variation in drying time for different pretreatments applied for sweet potato slices at 50, 55, 60 and 65 °C drying temperature. It was observed that the constant rate period of drying was totally absent and complete drying took place in falling rate period for all the experiments.

The CaCl_2 pretreated sample took less drying time as compared with kms, hot water blanching and control samples. Minimum and maximum drying time were taken by pretreated with CaCl_2 sample at 50, 55, 60 and 65 °C (1420, 1140, 900 and 660 min) and control sample (1560, 1300, 1060 and 800 min) respectively. Blanched samples dried faster than the unblanched samples. (Leeratanarak *et al.*, 2006)^[16]

In general, blanching can expel the air entrapped intercellularly inside the sample tissues and elimination the resistance of cell membranes and cell walls to water diffusion by structure softening. (Alvarez *et al.*, 1995^[7]; Mukherjee and Chattopadhyay 2007^[17]) However, the result of the experiment is contrary to this general knowledge. This phenomenon was probably due to the fact that when the sweet potato samples was suffered from HWB pretreatments starch gelatinization occurred and during the subsequent drying process a resistant film layer was formed on the surface of the samples, which reduced water transfer and increased the drying time. Similar findings were reported by (Maté *et al.*, 1998)^[18] for drying blanched potato slices and (Leeratanarak *et al.*, 2006)^[16] for potato chips undergoing low-pressure superheated steam drying.

Table 1: Drying time for different pretreatments of sweet potato slices in mechanical tray dryer

Temperature (°C)	Pretreatment	Drying time (min.)
		Control
50	KMS (0.1%)	1460
	CaCl_2 (1%)	1420
	HWB (80 °C)	1500
	Control	1560
55	KMS (0.1%)	1180
	CaCl_2 (1%)	1140
	HWB (80 °C)	1240
	Control	1300
60	KMS (0.1%)	940
	CaCl_2 (1%)	900
	HWB (80 °C)	1000
	Control	1060
65	KMS (0.1%)	700
	CaCl_2 (1%)	660
	HWB (80 °C)	740
	Control	800

3.2 Effect of process variable on drying rate of sweet potato

The drying rate for the pretreated sweet potato slices was estimated from the difference in its moisture loss in a known time interval and expressed as g of moisture evaporated per gram (g) of dry matter per min. The drying rate of sweet potato under different pretreatments at 50, 55, 60 and 65 °C tray drying temperature were calculated and plotted with moisture content presented in Fig 5 to 8.

It was seen that the drying rate subsequently reduced with drying time. It can also be seen that drying rate follow typical drying rate curves. In case of control samples drying rate were found in intial stage of drying 0.18, 0.25, 0.32 and 0.41 g-water/g-dm-h at 50, 55, 60 and 65 °C drying temperature respectively. While KMS pretreated samples drying rate was observed at initial stage of drying 0.23, 0.26, 0.36 and 0.47g-water/g-dm-h at 50, 55, 60 and 65 °C drying temperature

respectively. In case of CaCl_2 pretreated samples drying rate were found in intial stage of drying 0.20, 0.26, 0.35 and 0.43 g-water/g-dm-h at 50, 55, 60 and 65 °C drying temperature respectively. In case of HWB pretraeted samples drying rates were found in intial stage of drying as 0.24, 0.27, 0.32 and 0.38 g-water/g-dm-h at 50, 55, 60 and 65 °C drying temperature respectively.

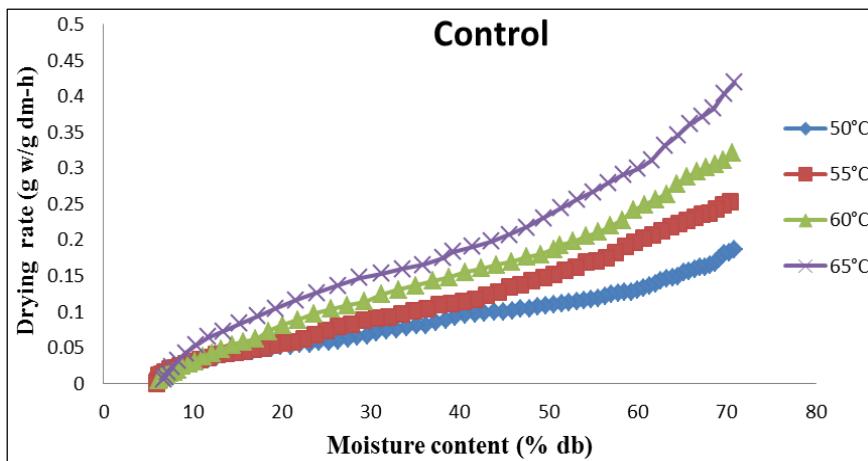


Fig 5: Variation in drying rate of control sweet potato slices at 50, 55, 60 and 65 °C drying temperature

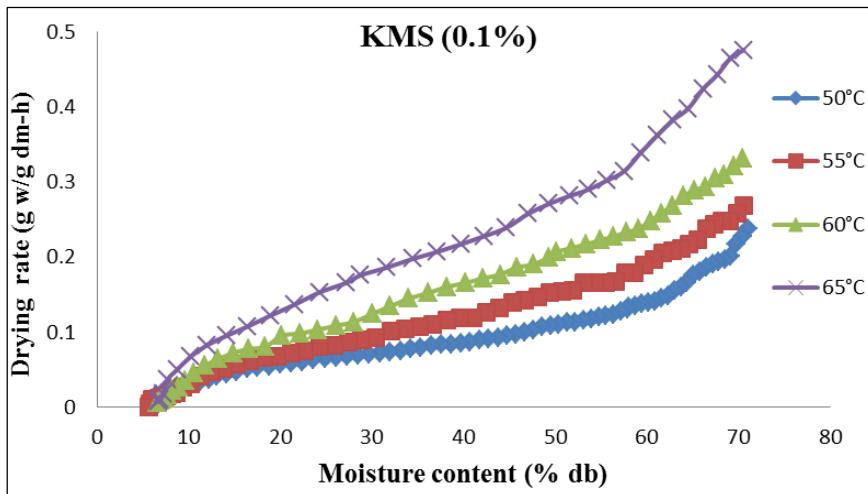


Fig 6: Variation in drying rate of KMS pretreated sweet potato slices with moisture content at 50, 55, 60 and 65 °C drying temperature.

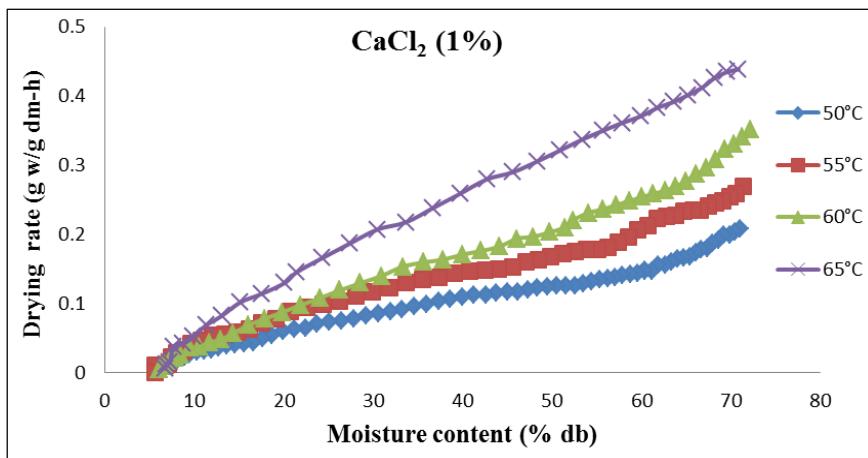


Fig 7: Variation in drying rate of CaCl_2 pretreated sample with moisture content at 50, 55, 60 and 65 °C drying temperature.

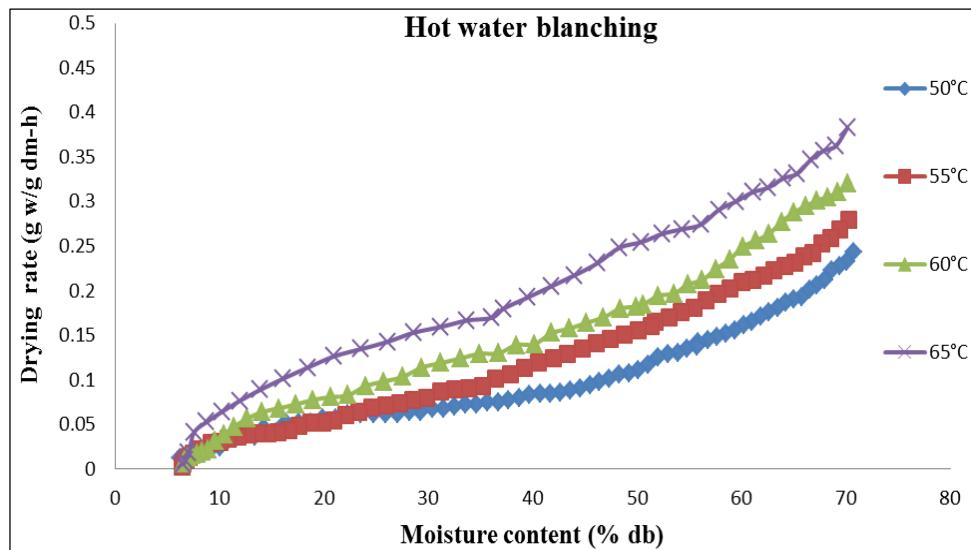


Fig 8: Variation in drying rate of hot water blanching sweet potato slices with moisture content at 50, 55, 60 and 65 °C drying temperature

From the observation it can be seen that, a constant rate-drying period was not found in drying curves. The entire drying process took place in the falling rate period; the curves typically demonstrated smooth diffusion controlled drying behaviour under all pretreatments.

Result found that the variation in drying rate for different pretreatments applied for sweet potato slices at 50, 55, 60 and 65 °C drying temperature. The CaCl₂ pretreated sample has a higher drying rate as compared with Kms, hot water blaching and control samples. Similar findings were reported by (Maté *et al.*, 1998) [18] for drying blanched potato slices and (Leeratanarak *et al.*, 2006) [16] for potato chips undergoing low-pressure superheated steam drying. The highest values of drying rate were obtained during the experiment at 65°C and

CaCl₂ pretreated sample.

3.3 Effect of process variable on moisture ratio of sweet potato

Effective diffusivities are typically determined by plotting experimental drying data in terms of ln (MR) versus time. The moisture loss data during mechanical tray drying were analysed and moisture ratios at various time intervals were determined. The variation in MR with drying time of pretreated sweet potato slices has been presented in Fig. 9 through 12 for mechanical tray drying.

The variation in ln (MR) with drying time for each case was found to be linear with inverse slope, but at later stages of drying the curves did not follow the straight line.

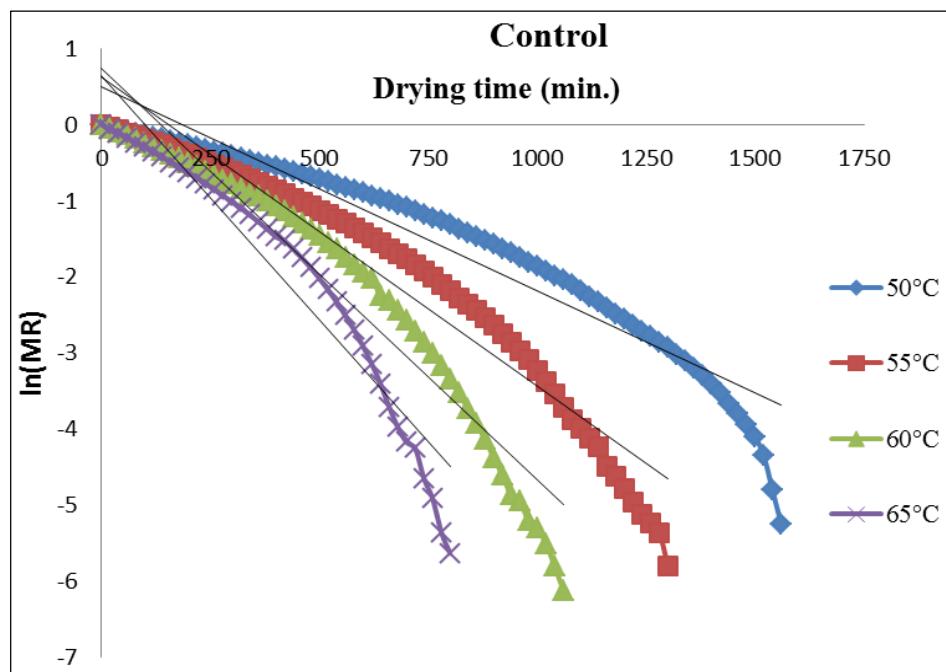


Fig 9: Variation in MR of control sample at 50, 55, 60 and 65 °C drying temperature

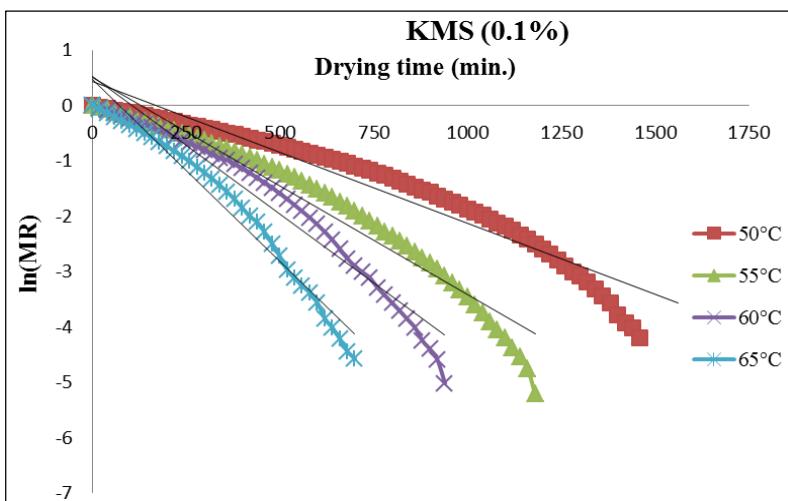


Fig 10: Variation in MR of KMS pretreated sample at 50, 55, 60 and 65 °C drying temperature

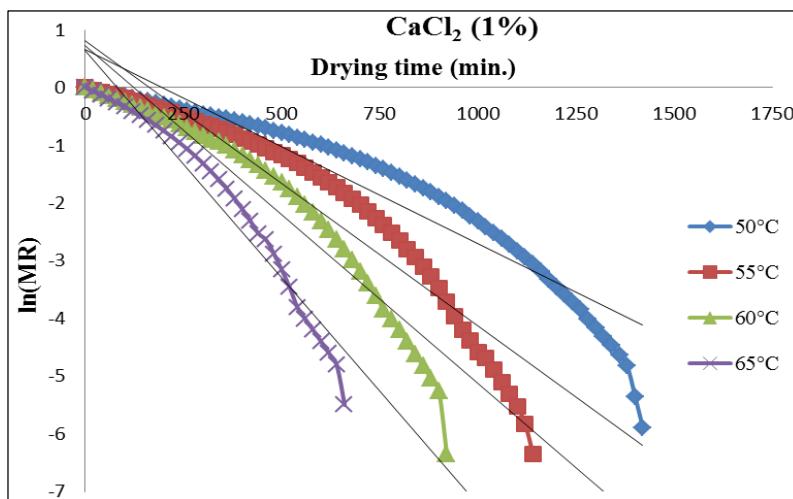


Fig 11: Variation in MR of CaCl_2 pretreated sample at 50, 55, 60 and 65 °C drying temperature

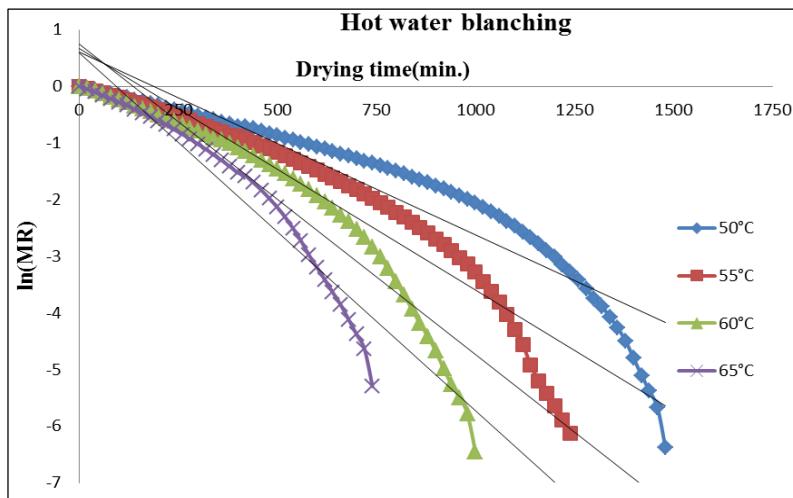


Fig 12: Variation in MR of HWB pretreated sample at 50, 55, 60 and 65 °C drying temperature

For sweet potato slice in control treatment moisture diffusivity increased from 1.46×10^{-9} to $2.19 \times 10^{-8} \text{ m}^2/\text{s}$ as the drying temperature increased from 50 to 65 °C. In KMS pretreated sample moisture diffusivity increased from 1.46×10^{-8} to $2.19 \times 10^{-8} \text{ m}^2/\text{s}$ as the drying temperature increased from 50 to 65 °C. CaCl_2 pretreated sample moisture diffusivity increased from 1.1×10^{-8} to $2.92 \times 10^{-8} \text{ m}^2/\text{s}$ as the drying temperature increased from 50 to 65 °C. In HWB pretreated sample moisture diffusivity increased from 1.1×10^{-8}

m^2/s to $2.19 \times 10^{-8} \text{ m}^2/\text{s}$ as the drying temperature increased from 50 to 65 °C.

3.3 Effect of process variable on Rehydration ratio of sweet potato

The 10 g samples of dried sweet potato slices were rehydrated by soaking them in cold water at room temperature for 5 hr. The minimum rehydration ratio of 2.14 was obtained for control treatment at 50 °C and the maximum rehydration ratio

of 2.71 was obtained for CaCl_2 samples at 65 °C. Rehydration ratio are presented in Table 2. It was found that rehydration ratio increased with increase in drying air temperature. Similar findings were reported by (Akoy, 2014) [19] for mango slices.

Table 2: Rehydration ratio for different pretreatments of sweet potato slices

Temperature (°C)	Pretreatment	Rehydration ratio
50	Control	2.14
	KMS	2.33
	CaCl_2	2.44
	HWB	2.29
55	Control	2.23
	KMS	2.45
	CaCl_2	2.50
	HWB	2.39
60	Control	2.38
	KMS	2.58
	CaCl_2	2.63
	HWB	2.47
65	Control	2.49
	KMS	2.67
	CaCl_2	2.71
	HWB	2.59

4. Conclusions

The following conclusions may be derived from the study:

- The drying time depends on the temperature of drying air and the pretreatment given, up to a certain limit.
- The CaCl_2 pretreated sample took less drying time and higher drying rate as compared with kms, hot water blaching and control samples
- The moisture diffusivity was found increase with increase drying temperature.
- The rehydration ratio was found increase with increase drying temperature and maximum was found for CaCl_2 pretreated sample at 65 °C.

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