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Effect of Different Pre-Treatments and Temperatures on Drying Characteristics of Beetroot Slices

Deepali Mudgal [a*], Puja [a], Sweta Singh [b], B. R. Singh [a], Samsher [a], Pankaj Kumar [a] and Kamlesh Sisodia [c]

[a] Department of Agricultural Engineering, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, (U.P.), India.
[b] College of Agriculture, Bhusawar, Bharatpur, Rajasthan, India.
[c] M.S.J. Government P.G. College, Bharatpur, Rajasthan, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experimental study was carried out to study the effects of different pretreatments and drying methods on beetroot slices. Drying is widely used and primary method for preservation. Dried beetroot slices were made by treating the slices with different pretreatments (control, KMS, blanching and KMS plus blanching). The drying was done under natural convection in direct sun drying method and under forced convection in cabinet tray drying at temperatures 50^0 C, 60^0 C and 70^0 C. Moisture content, drying rate and moisture ratio were computed to study the drying characteristics of beetroot slices. The study revealed that the highest drying rate and lowest final moisture level was recorded in hot air tray drying of beetroot slices at air temperature of 70^0 C. The

**Corresponding author: E-mail: mudgaldeepali@gmail.com;*

total drying time for beetroot slices dried under tray drying at 70°C took 240-360 min to be dried completely depending upon treatments. Sun drying took maximum drying time of 480 min. The increase in drying air temperature increased the drying rate in all the methods.

Keywords: Sun drying; tray drying; blanching; KMS; moisture content; moisture ratio; drying rate.

1. INTRODUCTION

Beetroot (Beta vulgaris L.) is a crop belonging to the Chenopodiaceae family having dark crimson color. It is also referred to as beet, chard, sea beet, spinach beet,white beet, garden beet, and Chukander [1,2]. Sugar beetroot is primarily grown in Europe with very little production occurring in Asia and North America [3]. The cultivation of sugar beetroot is now well-established in tropical and subtropical India, making India one of the fortunate nations blessed with erratic agro-climatic conditions. From the end of September until the middle of October is the best season to cultivate sugar beets [4,5]. This crop has a lifespan of 5 to 6 months. Beets are found in many different varieties, including Crimson globe, Egyptian early yellow, Sunset, Globe, Blood-red (long), etc. In addition to being used as food, beets are also used as a plant medicine and a food colouring. Other Beta vulgaris cultivars, particularly sugar beetroot, are used to produce a wide variety of beetroot products [6].

It has namely Vitamins A, B1, B2, B6, and C. It is also a good source of minerals like calcium, copper, magnesium, phosphorus, iron and sodium [7,8]. These are abundant in additional valuable compounds such as betacyanins [9], carotenoids [10], glycine betaine [11], folates [12], saponins [13], betanin, polyphenols, and flavonoids. According to several sources [14-16], beetroot roots provide a variety of therapeutic benefits, including antihypertensive, anti-microbial, anti-inflammatory, hepatoprotective, anti-hyperglycemic, and diuretic qualities. The main advantage of beetroot is that it does not contain fat, has low-calorie content and high fibre content [1].

The drying process plays a very important role in the preservation of agricultural products [17]. The shelf life is extended, and water activity is decreased [18]. Post-harvest losses of fruits and vegetables account for 30–40% of the total crop [19]. To increase shelf life, minimize packaging costs, lower weights, enhance appearance, preserve original flavour, and maintain nutritional content, a significant amount of food products are dried in many countries [20].

Beetroot is one such crop that has almost zero wastage [21]. All of the plant's parts, including its leaves, roots, pulp, molasses, and vinasse, as well as any leftovers, are used in one form or another for various industrial applications across a range of industries [22,5]. Because they contain a large amount of moisture, fresh beetroots are susceptible to spoilage. Drying is one of the preservation techniques that ensure the microbiological safety of biological products [7]. In place of traditional snacks that are high in trans fatty acids [23], dried beets can be eaten directly in the form of chips, or they can be prepared simply and added to instant food [24].

Pre-treatments for fruit and vegetables include washing with water, blanching, KMS, sugar, and salt, either alone or in combination, to suppress enzymatic browning and improve colour, flavour, and texture retention before drying [25]. Due to the pretreated sample's softer and looser structure, makes it easier to remove moisture during drying, and pretreatment speeds up the drying process [26]. This study aims to find the drying characteristics of beetroot slices for preserving them for a longer time and maintaining the quality and nutritional value.

2. MATERIALS AND METHODS

2.1 Materials

Fresh beetroots were procured from the local market in Meerut. Prepared dried slices were stored in LDPE pouches at room temperature.

2.2 Preparation of Beetroot Slices

Leaves and end portion of beetroots were removed with a sharp-edged knife, and washed with tap water to remove the dust and dirt over the surface. It was peeled and again washed with tap water followed by slicing with a chips cutter, the thickness of the slices was kept at 2 mm. The slices were then weighed and 500g samples were made for each pretreatment and method of drying.

2.3 Pretreatments

Before drying, three different pretreatments were carried out to the beetroot slices, and an untreated sample was used as a control in this study. The sliced beetroot was subjected to pre-treatments such as dipped in 0.5% potassium metabisulphite (KMS) for 20 minutes (T_1), hot water blanching for 3 minutes (T_2), blanching with 0.5 % potassium metabisulphite (KMS) for 3 minutes (T_3) and control (T_0). The slices were then removed from water and the surface moisture was removed by blotting paper.

2.4 Drying of Beetroot Slices

2.4.1 Tray drying

The drying was conducted at varying temperatures. Initially, the tray dryer was run idle for about 30 minutes to maintain the desired temperature. Once the temperature got maintained, the slices (500 g of each sample) were spread uniformly over the drying trays in a single layer and placed in the drying chamber. Then, at a pre-determined time interval of 60 minutes, samples were taken out of the dryer, weighted and placed again into the dryer for further drying. An electronic balance was used for weighing samples. The drying process was continued till the constant weight of the samples was achieved. The corresponding moisture content of the samples was computed through mass balance. At the end of drying, samples were cooled at room temperature and packed for further studies.

2.4.2 Sun drying

To carry out sun drying experiments, slices spread in black polyethylene sheets were kept under the sun and loss of moisture was recorded every 60 min for the rest of the drying period. Surface temperature and relative humidity were recorded periodically with the help of a thermometer and hygrometer. The drying process was continued till the constant weight of the sample was attained. The drying time and drying rate were dependent on the ambient temperature. The dried product was then cooled to normal temperature and then packed.

2.5 Drying Characteristics of Beetroot Slices

2.5.1 Moisture content

The initial moisture content of beetroot slices was determined by the hot air oven method recommended by Ranganna [27].

$$IMC = \frac{M_1 - M_2}{M_0} \times 100$$

Where,

IMC = Initial moisture content of sample, % (w.b.)
M_0 = Initial weight of sample taken
M_1 = Weight of sample before oven drying plus weight of dish with cover, g
M_2 = Weight of dried and desiccated sample plus weight of dish with cover, g

2.5.2 Drying rate analysis

The drying rate was calculated using the following equation [28,29]

$$\text{Drying Rate} = \frac{M_{t1} - M_{t2}}{t_2 - t_1}$$

where M_{t1} and M_{t2} are the moisture contents of slices at different drying times (t_1 and t_2, minutes) expressed on a dry weight basis.

2.5.3 Moisture ratio

MR of pretreated beetroot slices was calculated according to the method of Osae et al [30]:

$$MR = \frac{M_t - M_e}{M_0 - M_e}$$

where MR is the dimensionless moisture ratio, M_0 is the initial moisture content, M_t is the moisture content at the drying time t, and M_e is the equilibrium moisture content. All the moisture contents were expressed on a dry weight basis.

3. RESULTS AND DISCUSSION

3.1 Drying Characteristics of Beetroot Slices

The drying behavior of beetroot slices was analyzed using the experimental data on the moisture of the product at various time intervals for different drying conditions. After applying selected pretreatments, the samples were dried up to the final safe level of moisture content. The initial moisture content of beetroot was obtained as 809.09% on a dry basis. The dry matter was observed as 11%. The moisture content, moisture ratio, and drying rate for different times were compared and drying curves were drawn for all the treated and untreated samples under different drying conditions.

3.2 Moisture Content

3.2.1 Open sun drying

The variations in moisture content of beetroot slices with the time of exposure to the sun are graphically represented in Fig. 1 for four pretreatments (i.e. Control, KMS, Blanching and KMS Blanching) exhibiting a non linear decrease of moisture content (%db) with drying time. The ambient temperature and relative humidity were measured at an interval of 60 min during the drying experiment. The surface temperature and relative humidity of prevailing ambient air were observed to vary from 39^0 C to 43^0 C and 45 to 55 per cent respectively during the drying of beetroot slices. The relative humidity of air decreased with the increase in temperature. In all the drying methods, the maximum temperature was achieved at mid noon time between 12 to 2.00 PM.

It was seen that moisture content decreased rapidly in the earlier phase of time with an increase in drying time for all pretreatments, and then slowed down considerably. It was observed that drying time decreases with an increase in temperature i.e. it took 480 min in open sun drying to reach a constant level of moisture content. KMS-treated slices were found with a highest moisture content of 14.54% and the lowest in KMS+Blanching treated samples with 5.45%.

3.2.2 Cabinet tray drying

The beetroot slices were dried at 50°C, 60°C and 70°C for intervals of 60 min in a cabinet tray dryer to achieve the final moisture content. The drying time was the longest at 50°C. The drying time at 50^0C was 360 min and at 60^0C and 70^0C were 240 min. Final moisture content at 50^0C for T_0, T_1, T_2 and T_3 samples were 13.27%, 9.27%, 5.81% and 5.27% respectively. Final moisture content at 60^0C for T_0, T_1, T_2 and T_3 samples were 9.09%, 9.09%, 4.54% and 3.45% respectively. Final moisture content at 70^0C for T_0, T_1, T_2 and T_3 samples were 12.72%, 6.72%, 7.27% and 5.45% respectively. The variations in moisture content of beetroot slices with drying time are graphically represented in Fig. 2 to 4 for all pretreatments and temperatures.

A significant reduction in drying time with an increase in drying temperature was observed. Hence it can be concluded that the removal of moisture from the product was faster at higher temperatures than drying at lower temperatures [31].

3.3 Drying Rate

Drying rates were calculated from the observed data by estimating the change in moisture content that occurred in each consecutive time interval. Although the initial moisture contents of the beetroot slices were quite high, a constant drying rate period under the experimental conditions was not observed and the overall drying process took place in the falling rate

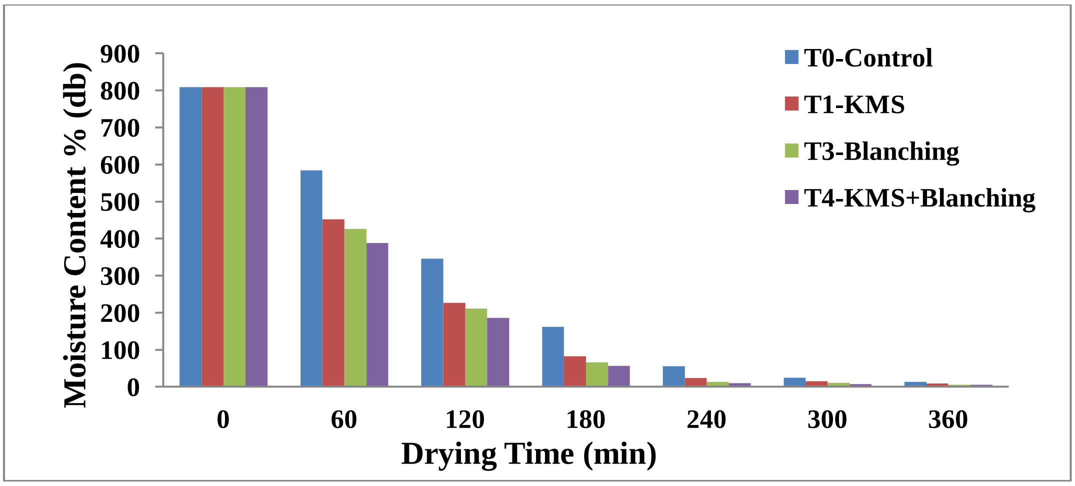

Fig. 1. Variation in moisture content with drying time under tray drying at 50°C

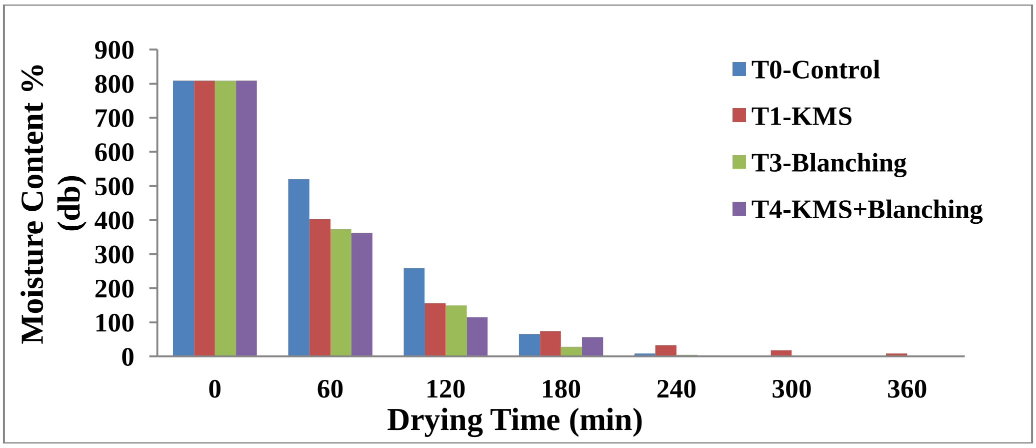

Fig. 2. Variation in moisture content with drying time under tray drying at 60°C

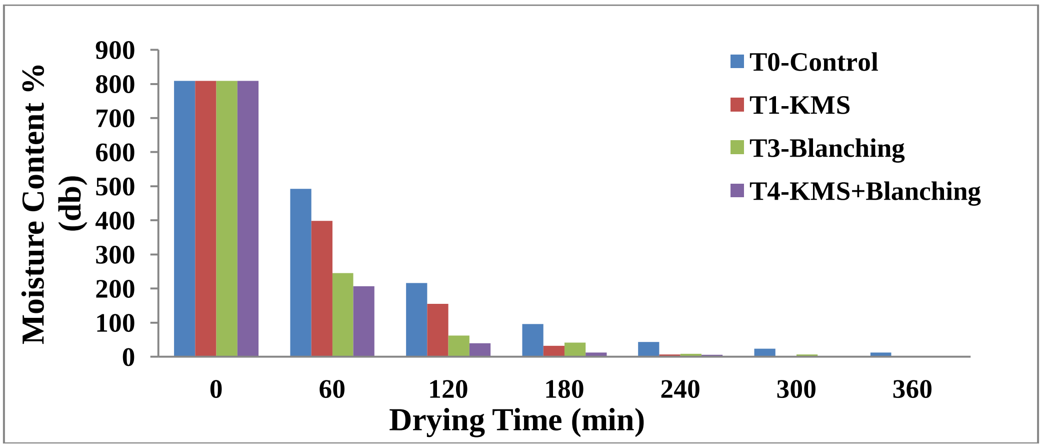

Fig. 3. Variation in moisture content with drying time under tray drying at 70°C

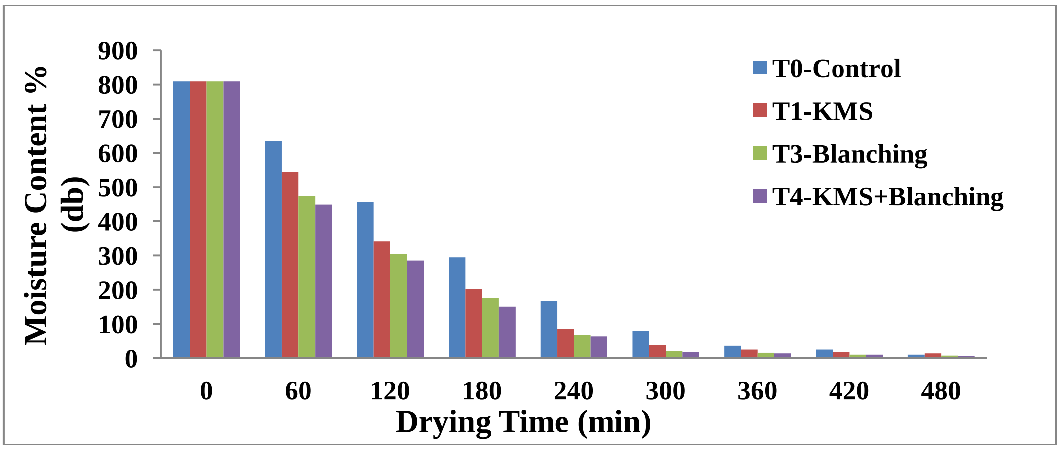

Fig. 4. Variation in moisture content with drying time under sun drying

period. The variations of drying rate with drying time under different pre-treatment are shown in Fig. 5 to 8. It was observed from the graph that the drying rate was higher in the initial period of drying and subsequently, it was reduced with a decrease in moisture content and the drying rate was higher at higher temperatures. Similar results were obtained by other authors working on apple slices as reported by Vega-Gálvez et al [32].

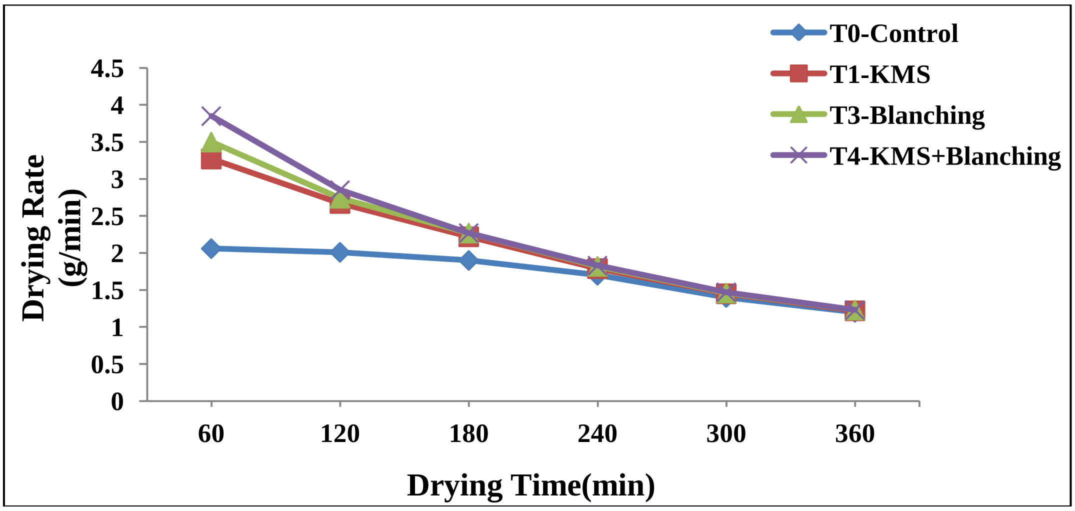

Fig. 5. Variation in drying rate with time under tray drying at 50°C

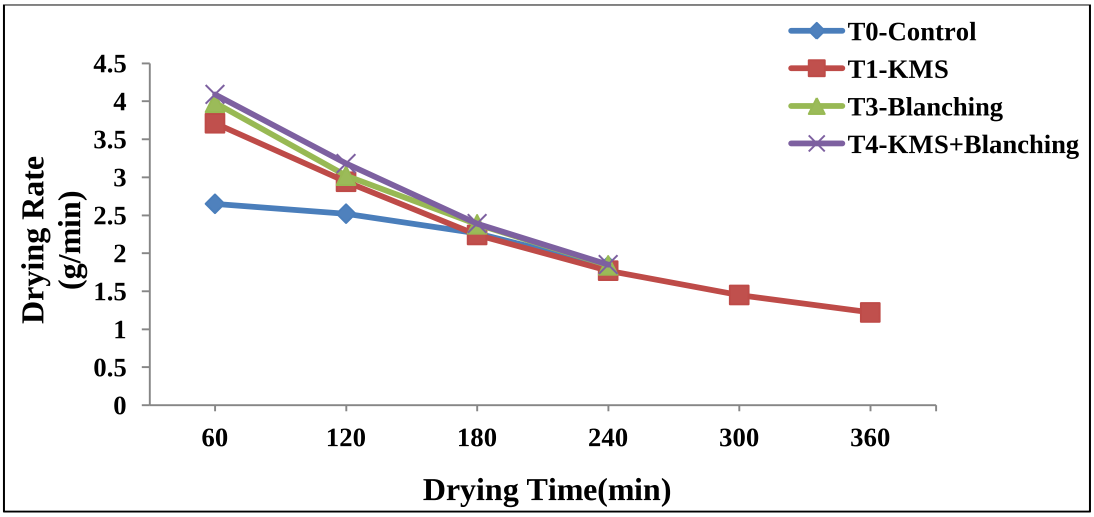

Fig. 6. Variation in drying rate with time under tray drying at 60°C

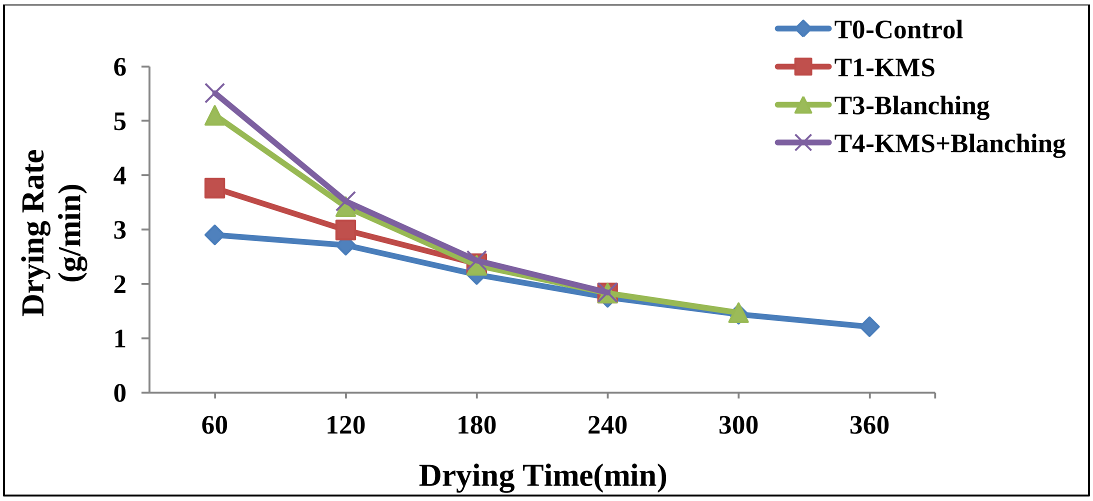

Fig. 7. Variation in drying rate with time under tray drying at 70°C

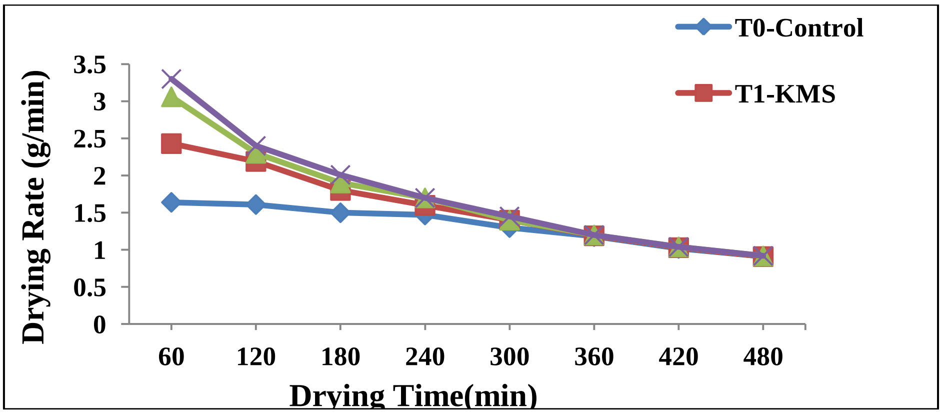

Fig. 8. Variation in drying rate with time under sun drying

It can also be seen from the drying rate curves, that the constant rate period was not observed in drying the beetroot slices. The drying process took place in a falling rate period except for a short accelerating period in the beginning. During the falling drying rate period, the predominant mechanism of mass transfer was that of internal mass transfer. The internal mass transfers was therefore by molecular (liquid) diffusion or vapour diffusion or by capillary forces in the interior (wet) region of the product and the water was evaporated as it reached the surface. Similar results have been reported for the drying studies on onion slices [33,34].

The drying rate was highest in tray drying at a temperature of 70°C and lowest at sun drying temperature. The total drying time for beetroot slices dried under a tray drying at 70°C took 240-360 min to be dried completely depending upon treatments. Sun drying took a maximum drying time of 480 min. Under sun drying, the highest drying rate was observed for T_3 (KMS+Blanching) followed by T_2 (Blanching), T_1 (KMS) and lowest for T_0 (Control). At 50°C, the drying rate was observed highest for pretreatment T_3 (KMS+Blanching) followed by T_2 (Blanching), T_1 (KMS) and lowest for T_0 (Control). At 60°C and 70°C also, similar results were obtained.

From Fig. 5 to 8 it could be seen that the drying rates of pretreated beetroot slices were higher than those of control or un-pretreated slice. This could be probably due to the softer and looser texture of the pretreated samples, which facilitated the faster removal of moisture during drying. The fastest drying rate occurred in the KMS+Blanching treated samples. It is evident from the data that the pretreatments affected the drying rates of beetroot slices.

3.4 Moisture Ratio Variation

The drying curves were normalized by converting the moisture content to moisture ratio. The change in moisture ratio with drying time for an experimental range of temperatures (50°C, 60°C and 70°C) under tray drying and open sun drying is shown in Fig. 9 to 12. The curves were plotted

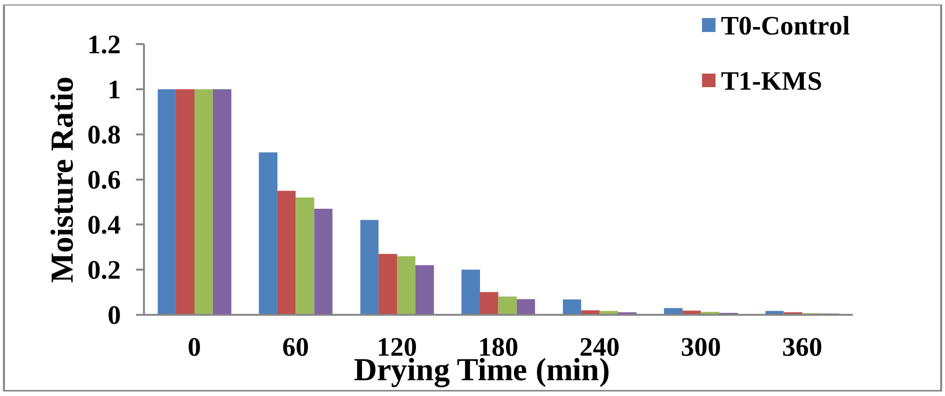

Fig. 9. Variation in moisture ratio with drying time under tray drying at 50°C

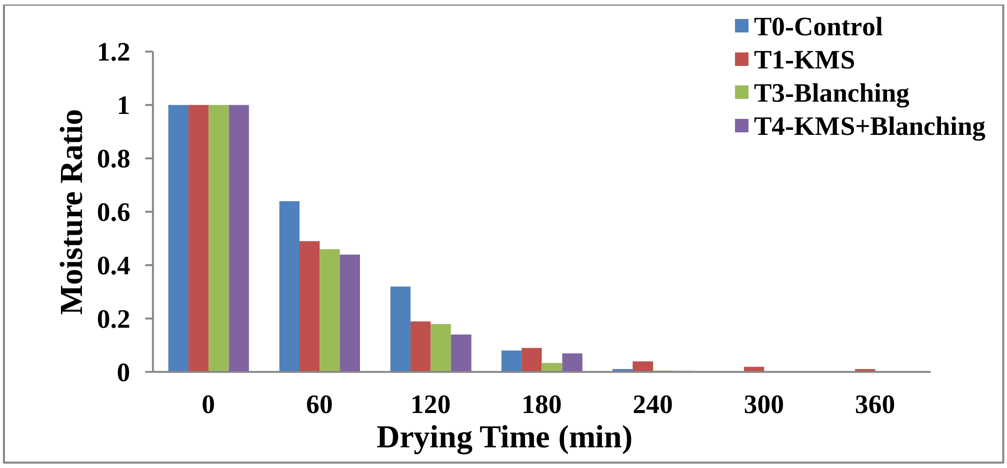

Fig. 10. Variation in moisture ratio with drying time under tray drying at 60°C

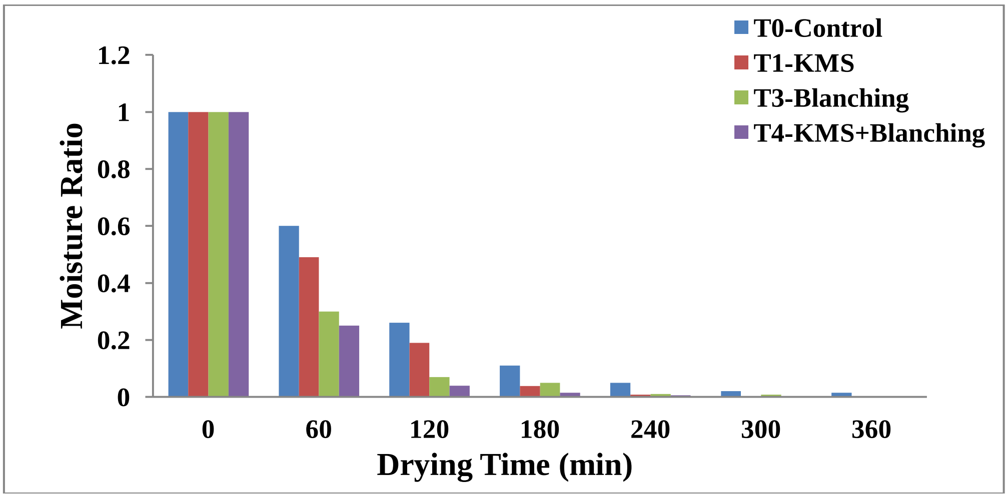

Fig. 11. Variation in moisture ratio with drying time under tray drying at 70°C

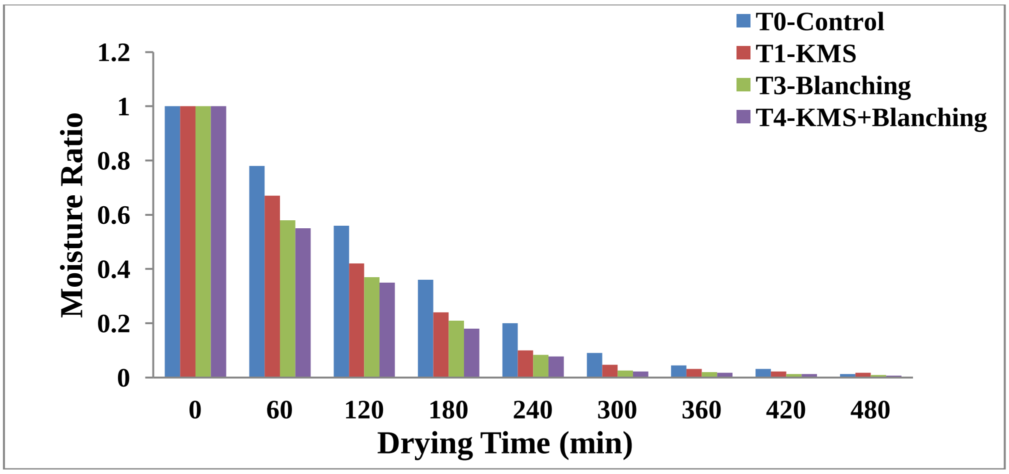

Fig. 12. Variation in moisture ratio with drying time under sun drying

between the moisture ratio and drying time. The relationship shows that there was a rapid decrease in moisture ratio during the initial stage of 0 to 180 min of drying in all cases. However, in the later stage of drying the decrease in moisture ratio was at a slower rate. The values of the moisture ratio ranged from 0.005 to 0.017. According to the graphs, the diffusion process slowed down as drying advanced, and the moisture ratio continued to decline. In all cases, the moisture ratio values at zero time of drying were one but in successive drying it decreased non-linearly. Therefore, the moisture ratio versus drying time graph could better describe the drying phenomena than curves of moisture content versus drying time.

4. CONCLUSION

One important aim of drying agricultural produce is a reduction in crop losses and an improvement in the storage quality of dried products. Beetroot slices were pretreated with KMS solution, blanching, KMS plus blanching, and control under different drying methods (sun and cabinet hot air drying). The study revealed that drying time, pretreatments and air temperature influenced the moisture content of slices during drying. Pretreatments as a factor of observation showed that pretreated samples took lower drying time to attain final moisture content than control samples. KMS plus blanching treated samples achieved the highest value of drying rate and control slices achieved the lowest value of drying rate. The entire drying took place in the falling rate drying period and no constant rate period of drying was observed. This demonstrates that the primary physical mechanism controlling moisture mobility in the samples is diffusion. Sun drying required more time than hot air drying, which increases the chance of microbial growth. As the temperature increased, drying became faster. The cabinet tray drying was seen as more efficient than open sun drying as it reduced the drying time and also kept the samples free from dust and dirt.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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