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Drying characteristics of Bael pulp using different drying methods and different varieties

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■ **ABSTRACT :** Drying is an essential process in the preservation of agricultural products. Various drying methods are employed to dry different agricultural products. Each method has its own advantages and limitations. Choosing the right drying system is thus important in the process of drying agricultural products. An experimental study was performed to determine the drying characteristics of bael pulp subjected to drying in open sun, hot air oven at 60^0 C and 70^0 C and cabinet tray dryer at 60^0C and 70^0C with different varieties Pant Aparna (V_1), Pant Shivani (V_2) and Pant Urvashi (V_3). The entire drying process took place in the falling rate period. Drying curves were constructed using non-dimensional moisture ratio (MR) and time. Drying is the most widely used and a primary method for preservation. According to the experimental result this study revealed that the V_1 (Variety Pant Aparna) sample required lower drying time than the other Varieties sample. The drying time decrease with increase of drying air temperature. It was observed that drying process took place in falling rate period. The result indicated that the cabinet tray dryer at 70^0C was found better drying characteristics compare to other drying temperatures and methods.

■ **KEY WORDS :** Bael pulp, Sun drying, Tray drying, Hot air oven drying, Moisture content, Moisture ratio, Drying rate

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Bael (*Aegle marmelos* L.) belongs to Rutaceae family and it is an indigenous fruit of India. Its common names in India are Bengal quince (John and Stevenson, 1979), Bilva, Indian quince, Bel, Belwa, Sriphal, Stone apple, Golden apple, Holy fruit and Maredo. Bael is a sacred tree in Hindu religion and it is offered to Lord Shiva and Parvati in prayers. Arid conditions are tolerable by this plant (Chundawat, 1990) as well as high rainfall. Explorations are taken to witness to indicate the wide range of variability in thorniness on stem, fruit shape, scull thickness and pulp characteristics in eastern Uttar Pradesh and adjoining area of Bihar. High yield and quality fruits were identified as promising prospects (Rai *et al.*, 1991).The production of bael in India is 85.83 000 tonnes in 2015-16 (Anonymous, 2015).

Bael fruits are ready for harvest in April-May when the fruits shell changes its colour from deep green to yellowish green. The storage life of the fruit depends upon the stage of harvesting. Bael can be stored for 10-15 days at normal temperature, whereas fruit harvested at ripe stage can be stored for a week. The storage life of bael could be increased from 2 weeks at 30^0C to 12 weeks at 9^0C and 85-90 per cent relative humidity (Roy and Singh, 1979). The ripe bael could be made available 2-3

months prior to schedule with the treatment ethrel (1000-1500 ppm) and storing the fruits at 30^0 C after harvesting in January. It took 18-24 days for the fruit to be artificially ripened. The composition of fruits, ripened artificially or naturally, did not very much, with slightly less sugar content artificially ripened fruits (Roy and Singh, 1981).

Drying is the process of removal of most of the moisture present in the food. It is the oldest preservation method applied since ancient times (Ayhan and Alibas, 2005; Er and Akbulut, 2011 and Alibas, 2012). The removal of moisture from the food materials prevents the growth and reproduction of spoilage micro-organisms, slows down the action of enzymes and minimizes many of the physical and chemical reactions (Ceylan *et al.*, 2006; Wu *et al.*, 2007 and Guine and Barroca, 2012). During dehydration of bael pulp, carbohydrate and crude fat content increased while protein content decreased. It might be due to the destruction of some of the proteins while reacting with the peroxides produced during lipid oxidation. On dehydration as nutrients becomes concentrated, the proximate composition as fibre, ash, total carbohydrates, protein and fat were 4.09 per cent, 5.83 per cent, 79.82 per cent, 5.48 per cent, 4.55 per cent, respectively. Ascorbic acid content on drying increased *i.e.* from 13.35 to 39.62 mg/100g of bael powder. The shelf life of perishables could be extended by arresting the water activity through sun or mechanical means of dehydration. Food processed and dried occupies an important place among the traditional foods of India (Kapoor, 1998 and Geetha and Sarojoni, 1998).

Sun drying is the traditional method of preservation that takes longer time and depends on the weather condition. So, to achieve faster drying and to avoid uncertain whether condition, the mechanical drying method can be used for bael preservation. In mechanical dryer, desired temperature could be maintained and higher temperature could be utilized than sun drying. This leads to high production rates and improved quality products due to shorter drying time and reduction of insect infestation and microbial spoilage (Kumar *et al.*, 2017). Therefore, present study was undertaken to the drying kinetics of bael using different drying methods and different varieties of bael.

■ METHODOLOGY

Materials:

Three varieties Pant Aparna (V_1), Pant Shivani (V_2) and Pant Urvashi (V_3) were procured from the H.R.C., S.V.P. University of Agricultural and Technology, Meerut. For the present studies.

Sample preparation:

The raw material was washed thoroughly in running water to remove the adhering soil and extraneous matter. The undesirable portions were removed manually. They were again washed and cleaned properly soil dirt and other foreign matters were removed. The stainless steel knife were used in Peeling/Remove the hard shell of selected variety of bael. The Scooping of Pulp with seed and fibres. The cleaned product was then weighed and 500 g samples were made for each methods of drying, then the samples were placed in open air for surface moisture evaporation. Experiments were planned and conducted on the basis of earlier work on drying of bael.

In view of different varieties available for dried bael, the present study was carried out to observe the effect of different varieties on the drying characteristics at various drying temperatures under different drying methods. The following varieties were taken for conducting the experiment.

- V_1 (Variety Pant Aparna)
- V_2 (Variety Pant Shivani)
- V_3 (Variety Pant Urvashi)

Method of drying:

In rural areas, the fruits and vegetables are dried using natural energies as wind and sunlight. But due to slow drying and unhygienic conditions, the product quality is difficult to maintain. Moreover, it is weather dependent process. In the present study, an attempt was made to compare the drying characteristics and quality of the dried bael pulp using different drying methods. The bael samples were dried using three methods *viz.*, sun drying, cabinet drying at 60^oC and 70^oC and hot air oven drying at 60^oC and 70^oC. Initial moisture content of the bael was determined by oven drying method at 105 ± 1^0C till constant weight occurred (Ranganna, 1995).

Open sun drying:

Sun drying is used to denote the exposure of the food material to direct solar radiation and the convective power of the wind. Black polyethylene sheets are mostly used as drying platform because it absorbs most of the solar radiations. To create the sun drying experiments, a

black polyethylene sheet was selected to better absorption of solar radiations. The surface area of the sheet was enough large to spread 500 g of bael.

Black polyethylene sheets were completely cleaned and the samples were spread over the sheets uniformly. The loss of moisture was recorded at every 60 min for rest of drying period, by means of an electronic balance. Surface temperature was also measured periodically with the help a of thermometer mercury in glass bulb. Relative humidity was noted by means of hygrometer. Drying was continued till the sample attained a constant weight. The drying time and drying rate depended on the ambient temperature. The dried product was cooled to normal temperature in a desiccators containing silica gel and then packed in polyethylene bags, which were then heat-sealed and stored at room temperature. The experiments were repeated twice and the average of the moisture ratio at each value was used to draw the drying curves.

Cabinet tray and hot air oven drying:

Bael pulp sample weighing 500g was taken and spread uniformly over the perforated bottom trays in single layer. It was carried by drying the samples at 60^0C and 70^0C Cabinet tray and hot air oven drying temperatures. Drying air temperature was adjusted to the desired level using the thermostat. During drying operation, weight of the sample was taken at every 60 min interval for rest of drying period. All the measured observations were recorded for further calculations. Drying was stopped when the drying mass reached the required moisture content.

The dried product was cooled to normal temperature in a desiccators containing silica gel and then packed in polyethylene bags, which were then heat-sealed and stored at room temperature. The experiments were repeated twice and the average of the moisture ratio at each value was used to draw the drying curves. The experiments were conducted at the temperatures of 60 and 70°C by changing the position of the thermostat. Drying experiments were also conducted for bael pulp with the specified different varieties at different temperatures.

Drying time and curves:

During drying of bael, samples were weighed at the specified intervals mentioned above for determining moisture content. The drying curves were drawn for all three drying methods of drying. The values of moisture content (% db) were plotted against time of drying. The total time required for complete drying was also recorded in each case. The curves between drying rate and average moisture content (% db) and between drying rate (g/min) and drying time (min) were also plotted.

Drying characteristics of bael pulp:

Moisture content:

Moisture content was calculated using the following expression (Ranganna, 1995).

$$M_c = \frac{M_i - M_d}{M_i} \times 100$$

where M_i is the mass of sample before drying and M_d is the mass of sample after drying

Drying rate:

$$R = \frac{M_i - M_d}{T} \times 100$$

where R is the Drying rate (g/min) and T is the Time taken (h)

Moisture ratio:

$$MR = \frac{M - M_e}{M_{ci} - M_e} \times 100$$

where MR is the dimensionless moisture ratio, M, M_e and M_{ci} are the moisture content at any time, the equilibrium moisture content and the initial moisture content in kg, respectively.

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Drying characteristics of bael fruit pulp under different drying conditions:

This research deals with the results of drying characteristics of bael fruit pulp dried under different drying conditions are summarized below.

Moisture content:

The initial moisture content of different cultivars of bael fruits were obtained as 170.27%, 203.03% and 233.33% on dry basis for V_1 (Variety Pant Aparna), V_2 (Variety Pant Shivani) and V_3 (Variety Pant Urvashi),

respectively. The dry matter contents were observed as 37%, 33% and 30% for V_1 (Variety Pant Aparna), V_2 (Variety Pant Shivani) and V_3 (Variety Pant Urvashi), respectively. Study revealed that Variety Pant Aparna had highest dry matter content followed by Variety Pant Shivani and Variety Pant Urvashi.

Open sun drying:

The drying behaviour of bael fruit pulp of different Variety for sun drying is presented in Fig. 1, as a plot of moisture content (% db) versus time of exposure to sunlight. The variations of surface temperature and relative humidity (RH) of the ambient air with respect to time during the drying of bael fruit pulp. 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 drying of bael fruit pulp. The RH of ambient air decreased with the increase in surface temperature. In all the drying methods, the maximum temperature was achieved at mid noon time between 12 to 2.00 PM. In this open sun drying used black sheet material and this sheet absorbing more heat than normal conditions then bael fruit was drying faster.

The change in moisture content of different varieties of bael fruit pulp samples were calculated. It can be seen that the amount of moisture removal at the initial period of drying was higher in all the samples. In general it was found that it tooks 720 min in open sun drying to reduce the moisture content of bael fruit pulp at constant level for all samples. The bael fruit pulp were dried open sun drying for intervals of 60 mins to achieve the final moisture content. The moisture content was found highest in V_1 (Variety Pant Aparna) as compared V_2 (Variety Pant Shivani) and V_3 (Variety Pant Urvashi) samples. The variation in moisture content with drying time is shown in Fig.1 different variety of bael fruit. It was found that bring down to the required final moisture level of 15.13 per cent (db) V_1 (Variety Pant Aparna), 13.33 per cent (db) V_2 (Variety Pant Shivani) and 10 per cent (db) V_3 (Variety Pant Urvashi) sample.

Cabinet tray drying:

The bael fruit pulp were dried at 60°C, and 70°C for intervals of 60 mins in a cabinet tray dryer to achieve the final moisture content. The drying time was longest at 60°C and least at 70°C in the tray drying. The final moisture content of V_1 (Variety Pant Aparna) bael fruit pulp was 16.21 per cent and 10.81 per cent at 60°C and 70°C, respectively. The final moisture content of V_2 (Variety Pant Shivani) bael fruit pulp was 17.57 per cent and 4.24 per cent at 60°C and 70°C, respectively. The final moisture content of V_3 (Variety Pant Urvashi bael fruit pulp was 12 per cent and 10.66 per cent at 60°C and 70°C, respectively. The drying times at 60°C, and 70°C in cabinet tray dryer, were observed as 720 and

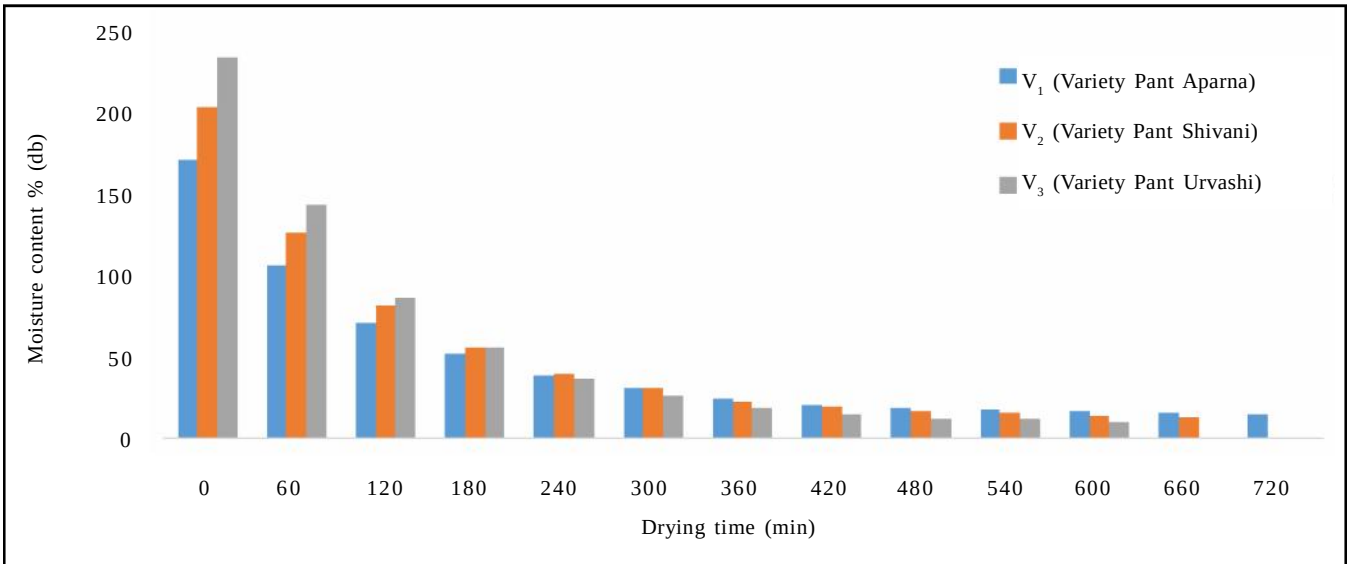

Fig. 1 : Variation of moisture content with drying time in open sun drying

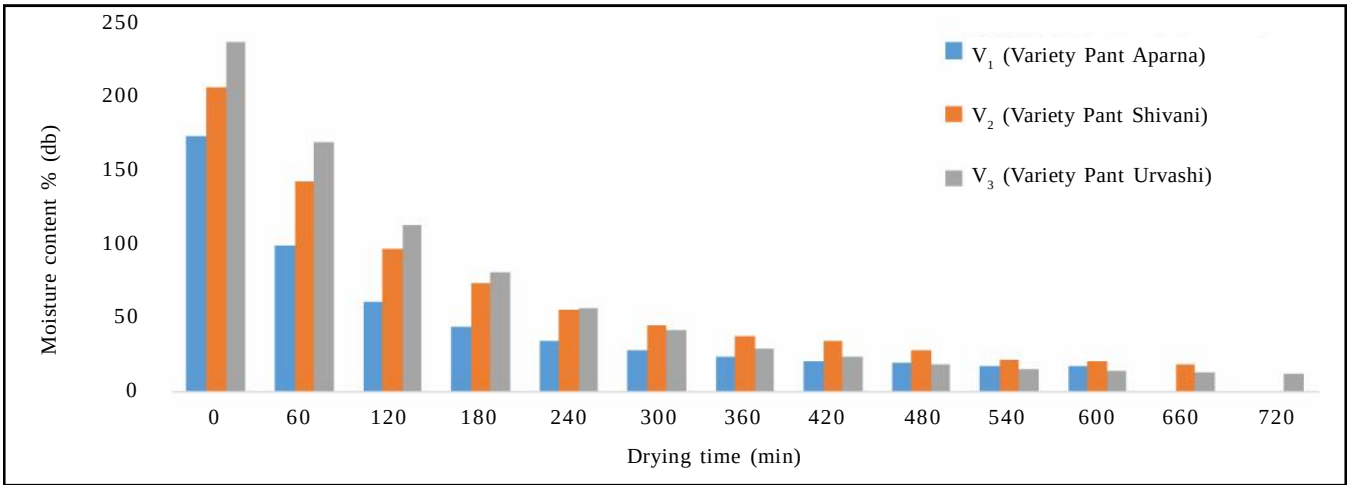

Fig. 2 : Variation of moisture content with drying time in cabinet tray drying at 60°C

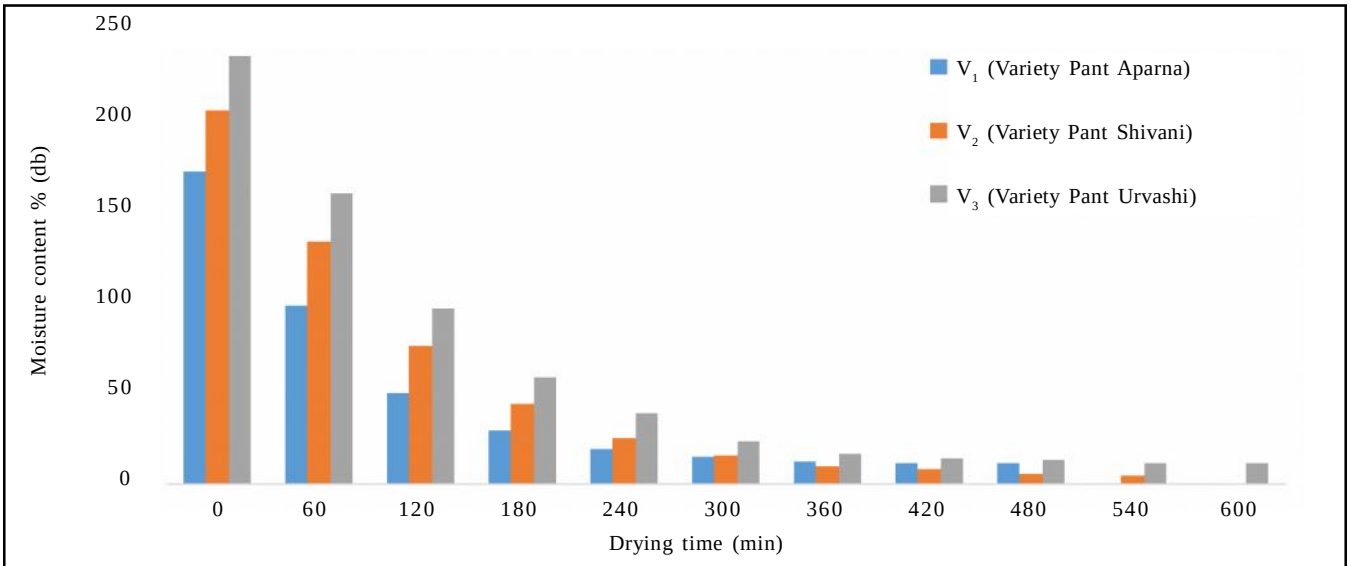

Fig. 3 : Variation of moisture content with drying time in cabinet tray drying at 70°C

600 min, respectively. The variation in moisture content with drying time is shown in Fig. 2 and 3 at different temperatures and different variety.

Hot air oven drying:

The bael fruit pulp were dried at 60°C, and 70°C for intervals of 60 mins in a hot air oven to achieve the final moisture content. The drying time was longest at 60°C and least at 70°C in the tray drying. The final moisture content of V_1 (Variety Pant Aparna) bael fruit pulp was 8.1 per cent and 2.7 per cent at 60°C and 70°C respectively. The final moisture content of V_2 (Variety Pant Shivani) bael fruit pulp was 2.63 per cent and 1.81 per cent at 60°C and 70°C, respectively. The final moisture content of V_3 (Variety Pant Urvashi) bael fruit pulp was 6.66 per cent and 2 per cent at 60°C and 70°C, respectively. The drying times at 60°C, and 70°C in hot air oven were observed as 900 and 660 min, respectively. The variation in moisture content with drying time is shown in Fig. 4 and 5 at different temperatures and different varieties.

There was significant reduction in drying time with increase in drying temperature. In hot air ovenand tray drying with increasing temperature drying time found to

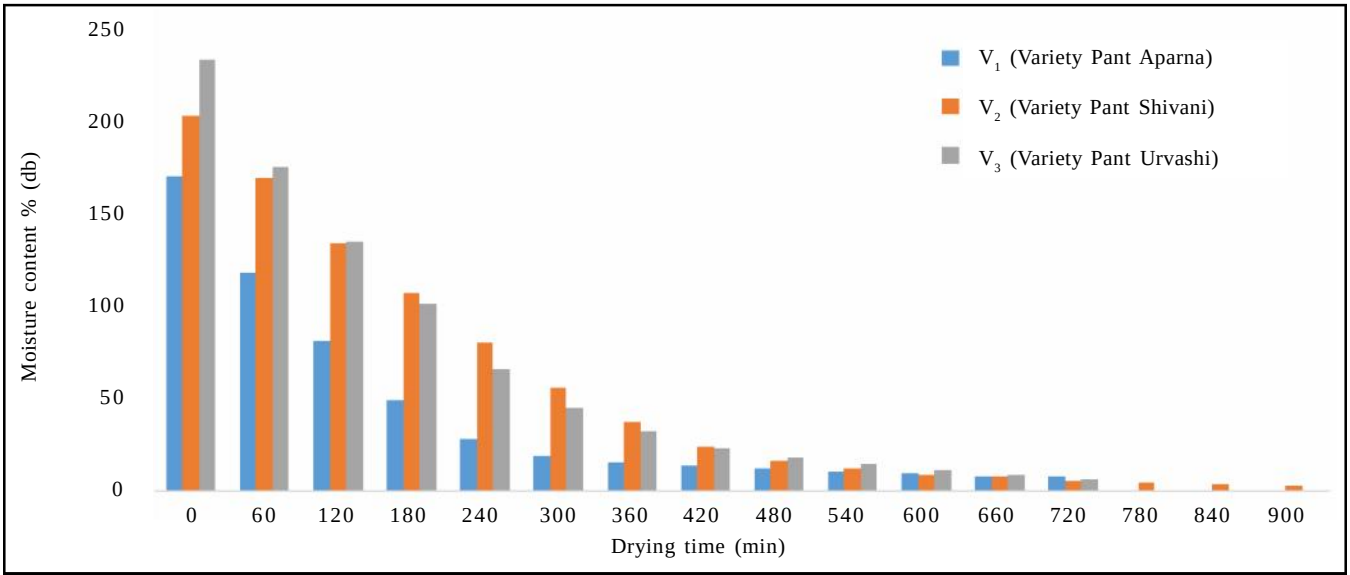

Fig. 4 : Variation of moisture content with drying time in hot air oven drying at 60^{0}C

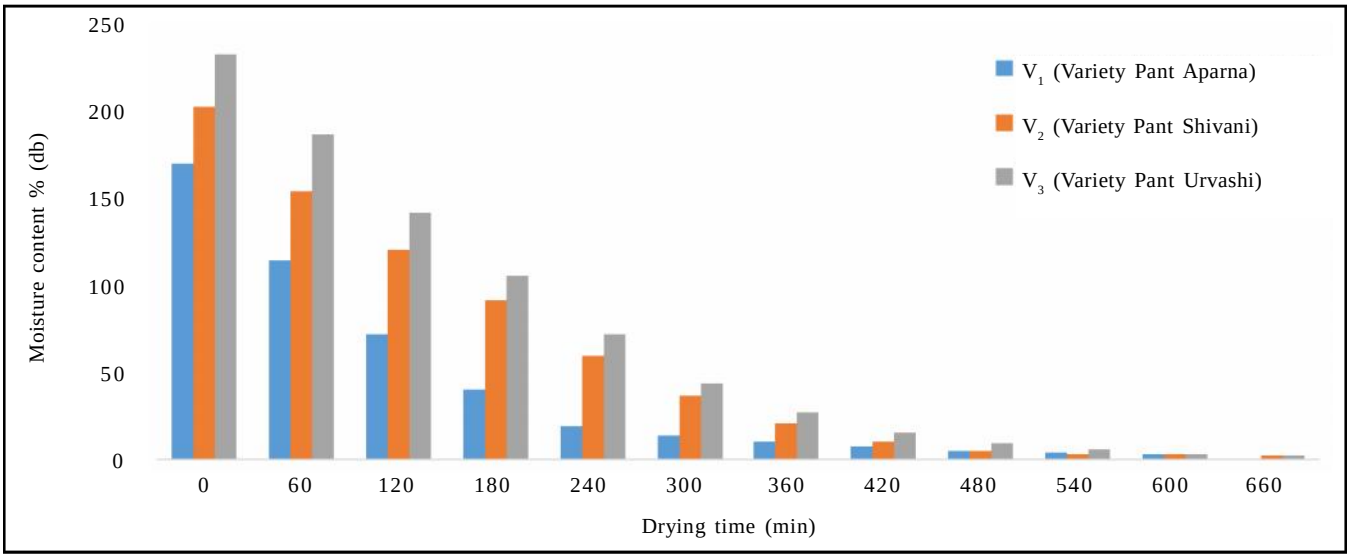

Fig. 5 : Variation of moisture content with drying time in hot air oven drying at 70^{0}C

be decreased. It can be concluded that at higher temperature the removal of moisture from the product was faster than drying at low temperature (Chaudhary *et al.*, 2019).

Drying rate:

The drying behaviour of bael fruit pulp was analyzed using the experimental data of moisture of product at various intervals and different temperatures. It was observed from the bars that the drying rate was higher in the initial period of drying and subsequently it was reduced with decrease in moisture content. The drying in falling rate period indicates that, internal mass transfer occurred by diffusion. Similar results have been reported for the drying studies on onion slices (Rapusas and Drisoll, 1995 and Doymaz, 2004). The higher drying rate at the start of drying is due to high surface moisture availability, which evaporates rapidly. Further decrease in drying rate is owed to decrease in available moisture due to low driving force and low moisture diffusion from

centre to surface of the dried product. Similar results were found by Rocha *et al.* (1992).

The changes of drying rate (g/min) with drying time (min) under different varieties of bael fruits are shown in Fig. 6 to 10 from the figure it was noted that during the process of drying, the bael fruit pulp did not show any constant rate drying period and complete drying took place only in the falling rate period. It was also found that the moisture content of the flakes at any time was directly proportional to the drying rate *i.e.*, as the moisture content of the product decreased, the drying rate also decreased (Sahay and Singh, 2004).

Open sun drying:

The presented results of open sun drying experiments showed the changes of drying rate with drying time under different varieties are shown in Fig. 6. It was observed that the maximum drying rate was observed during the initial stages of drying. As the drying time increased the drying rate decreased showing an inverse proportion between the drying rate and the drying time. The drying rate was found to be maximum for the

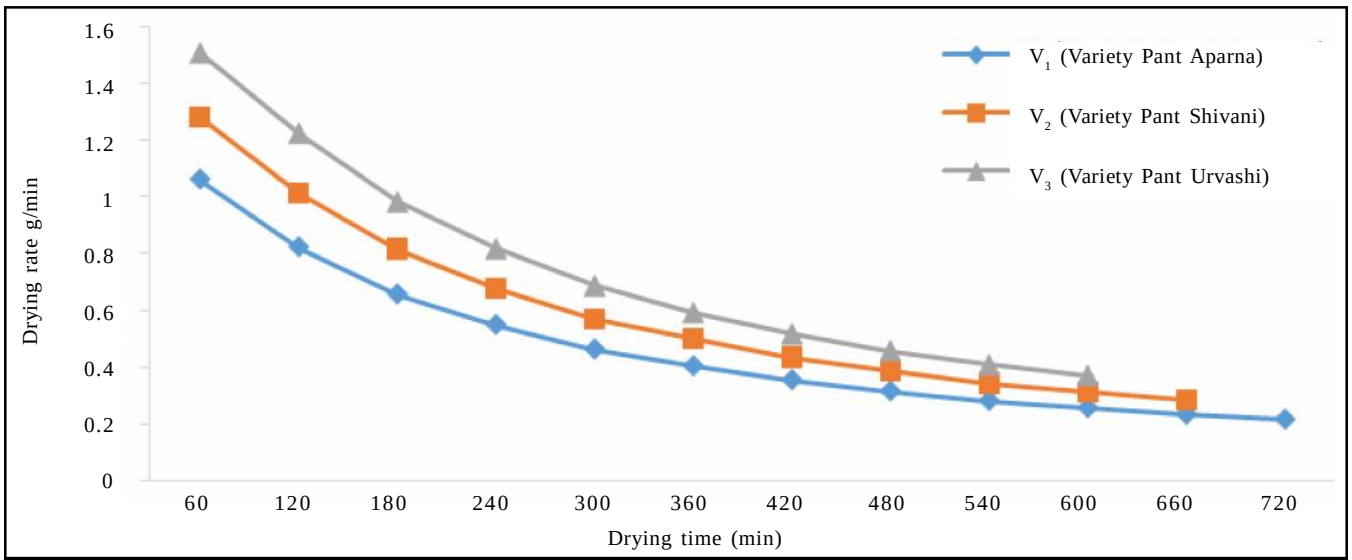

Fig. 6 : Variation of drying rate with drying time in open sun drying

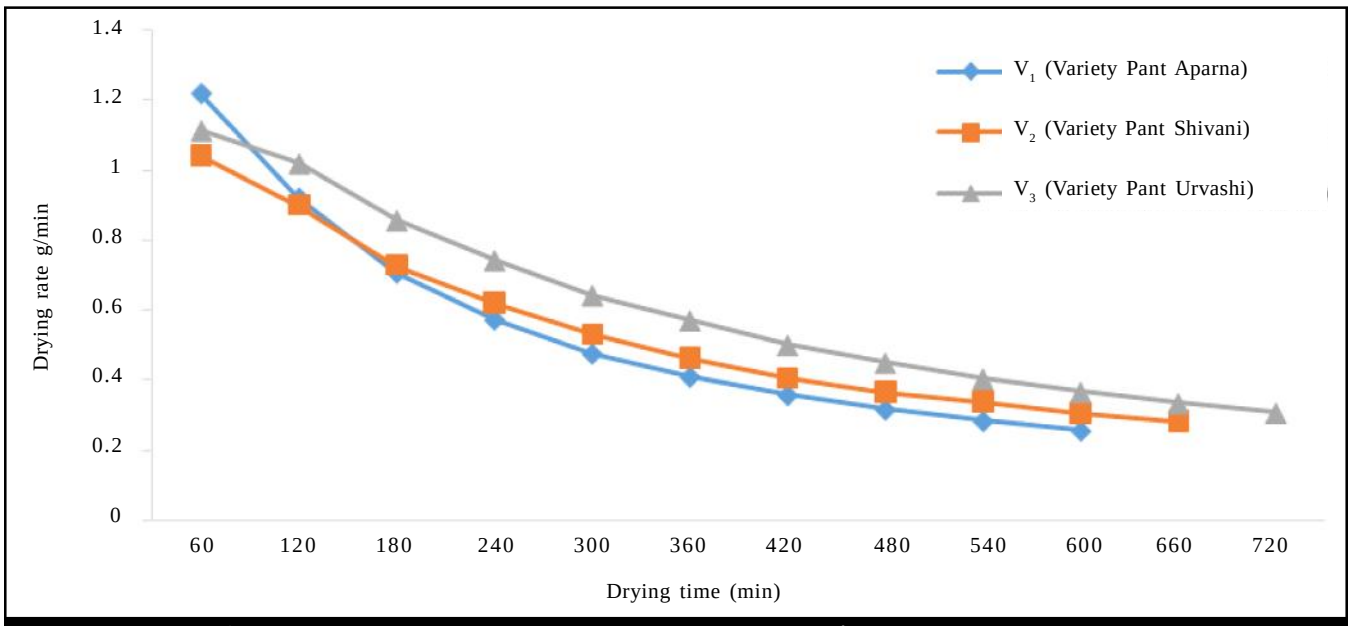

Fig. 7 : Variation of drying rate with drying time in cabinet tray drying at 60^{0}C

Variety Pant Urvashi (V_3) and was minimum for the Variety Pant Aparna (V_1). The relationship between drying rate and drying time was found to be liner for all the samples.

Cabinet tray drying:

The presented results of cabinet tray drying experiments showed when the drying temperature was increased it was found higher drying rate and lower temperature lower drying rate. The drying rate with drying time for the Variety Pant Aparna (V_1), Variety Pant Shivani (V_2) and Variety Pant Urvashi (V_3) bael fruit dried at temperature of 60°C and 70°C has been presented in Fig. 7 and 8. Drying rates during bael fruit at 60°C was found 0.25, 0.28 and 0.30 for Variety Pant Aparna (V_1), Variety Pant Shivani (V_2) and Variety Pant Urvashi (V_3) samples, respectively, at 70^0 C was found 0.33, 0.36 and 0.37 for Variety Pant Aparna (V_1), Variety Pant Shivani (V_2) and Variety Pant Urvashi (V_3) samples, respectively.

Hot air oven drying:

The presented results of hot air oven drying experiments showed when the drying temperature was

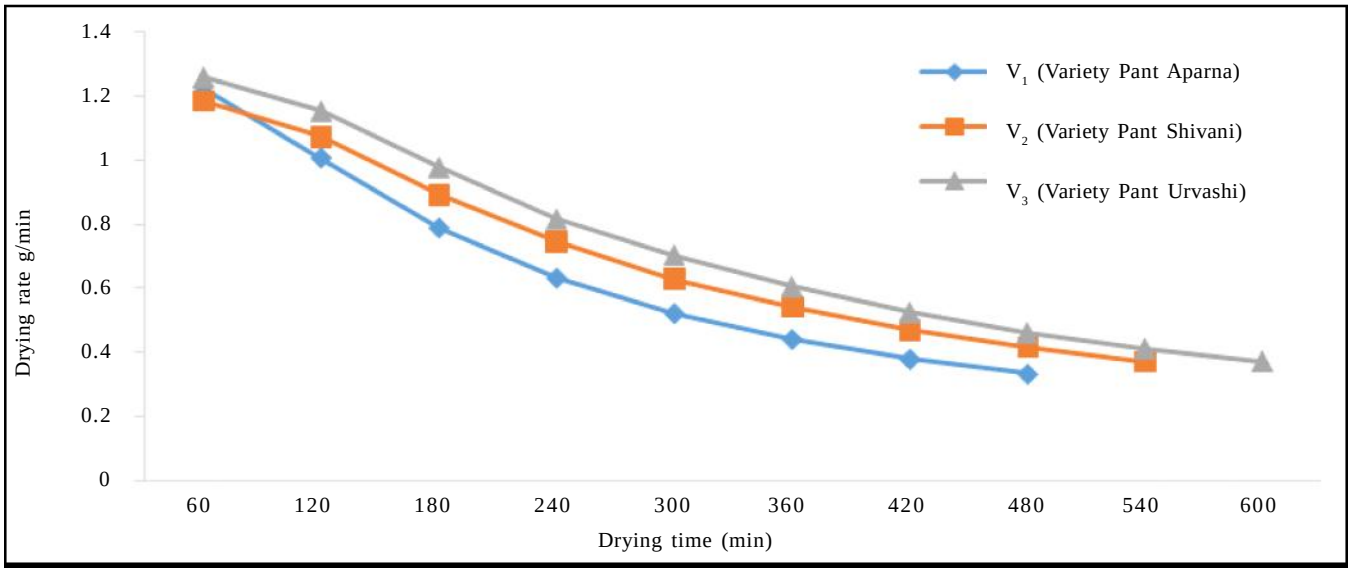

Fig. 8 : Variation of drying rate with drying time in cabinet tray drying at 70^0C

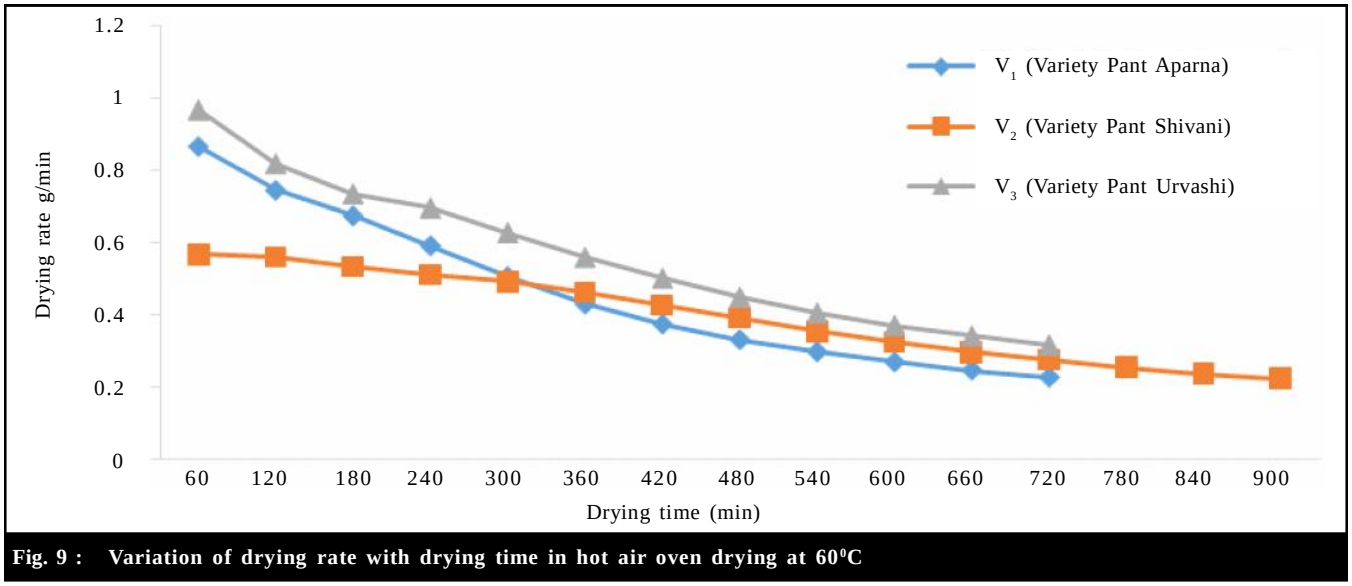

Fig. 9 : Variation of drying rate with drying time in hot air oven drying at 60^0C

increased it was found higher drying rate and lower temperature lower drying rate. The drying rate with drying time for the Variety Pant Aparna (V_1), Variety Pant Shivani (V_2) and Variety Pant Urvashi (V_3) bael fruit dried at temperature of 60°C and 70°C has been presented in Fig. 9 and 10. Drying rates during bael fruit at 60°C was found 0.225, 0.221 and 0.31 for Variety Pant Aparna (V_1), Variety Pant Shivani (V_2) and Variety Pant Urvashi (V_3) samples, respectively, at 70^{0}C was found 0.27, 0.30, and 0.35 for Variety Pant Aparna (V_1), Variety Pant Shivani (V_2) and Variety Pant Urvashi (V_3) samples, respectively.

Moisture ratio:

The moisture ratio represents the unaccomplished moisture content given by the equation. The value of moisture content (% d.b.) and moisture ratio observed in experiment at different temperatures and varieties. The relation between moisture ratio and drying time is given in Fig. 11 to 15, which clearly shows moisture ratio initially decreased very rapidly and in later stage moisture ratio decreased at slower rate (Chaudhary *et al.*, 2019). The graphs in general showed that moisture ratio decreased slower rate. The graphs showed that moisture ratio decreased continuously as drying progressed with the diffusion process slowing down.

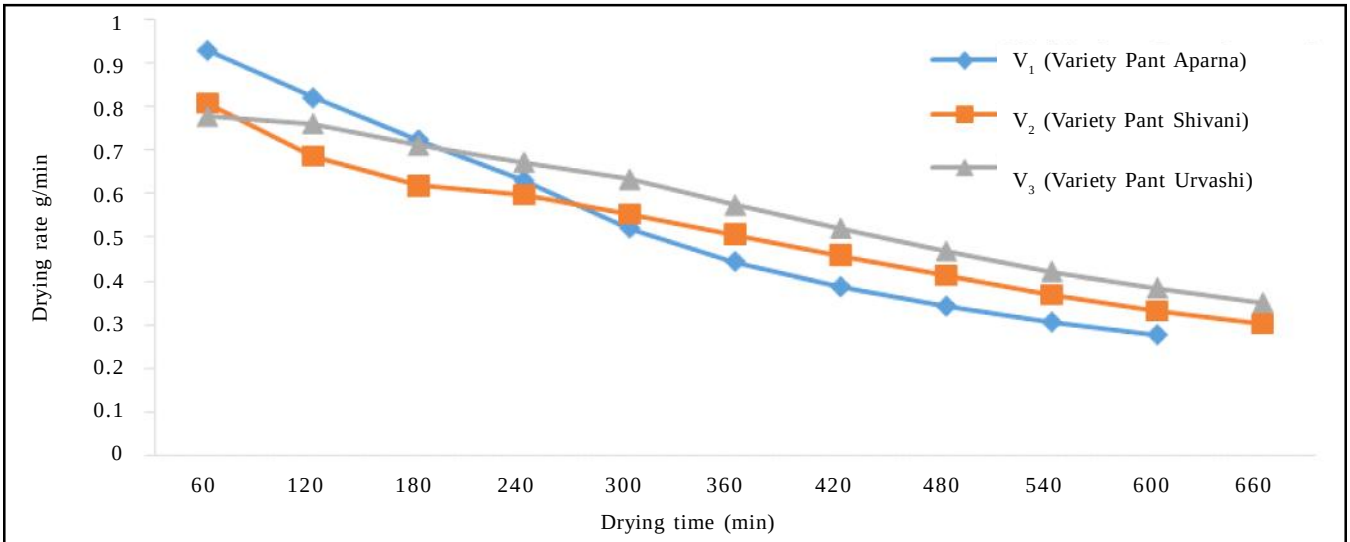

Fig. 10 : Variation of drying rate with drying time in hot air oven drying at 70^{0}C

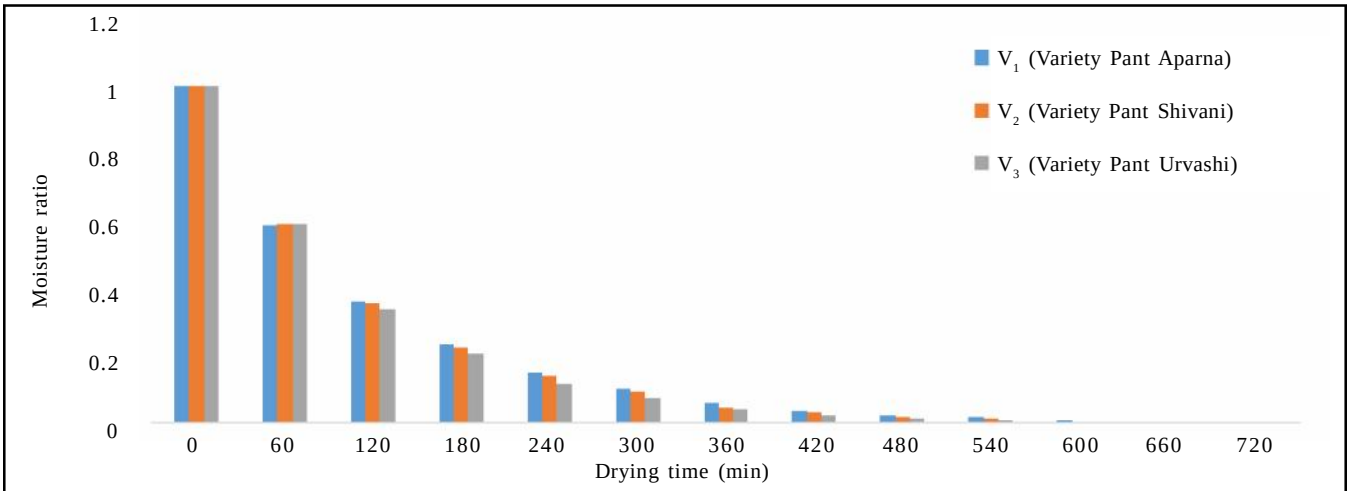

Fig. 11 : Variation of moisture ratio with drying time in open sun drying

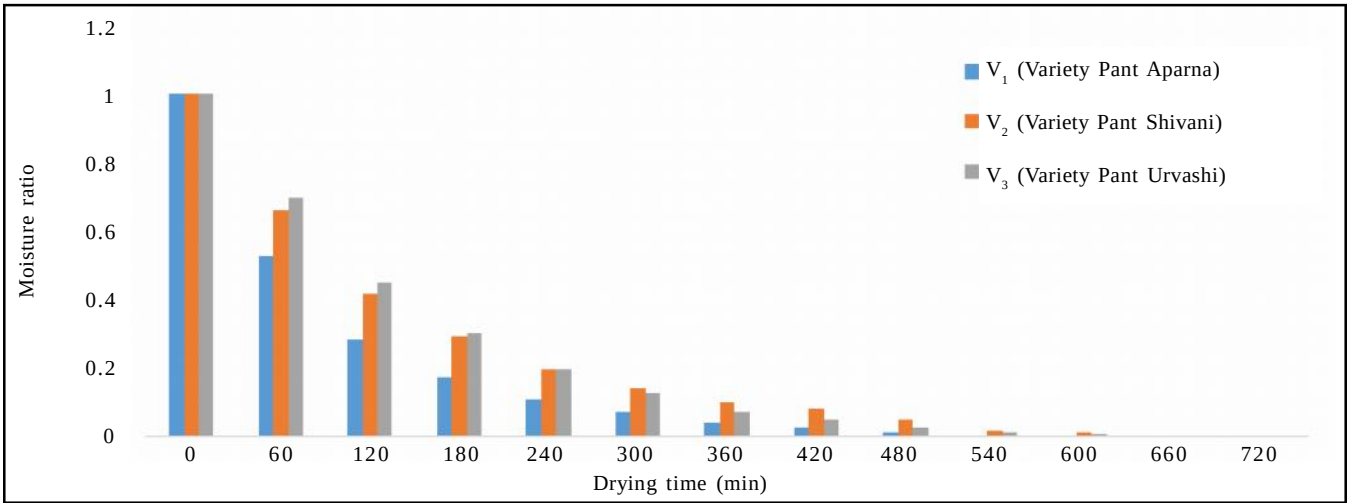

Fig. 12 : Variation of moisture ratio with drying time in cabinet tray drying at 60^{0}C

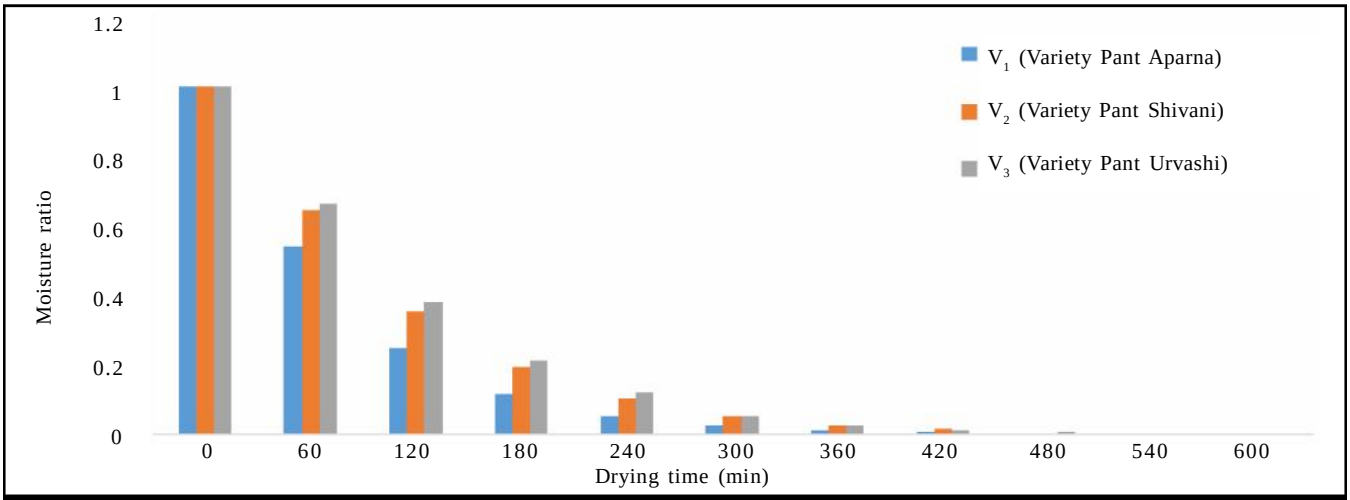

Fig. 13 : Variation of moisture ratio with drying time in cabinet tray drying at 70^{0}C

The moisture ratio values at zero time of drying was one in all cases but in successive drying it decreased non-linearly. Therefore, moisture ratio versus drying time graph could better describe the drying phenomena than curves of moisture content versus drying time because initial value of moisture ratio (M.R.=1) but later have different initial moisture content.

Conclusion:

The three drying methods used greatly affected the drying characteristics of bael pulp. According to the results, it can be stated that drying characteristics of Bael pulp in the drying process effect due to air temperature on drying rate and drying time, the drying of bael pulp occurred in the falling rate period and no constant rate period of drying was observed. The cabinet tray drying technique was more efficient than that open sun drying and hot air oven drying for bael pulp which resulted in saving of time up to greater extent. The cabinet tray dryer and open sun drying were found to be more efficient thanthe hot air oven drying. In addition, the samples of cabinet tray dryer and hot air oven were completely protected from insects, birds, rain and dusts. Highest drying rate was achieved with cabinet tray drying followed by open sun drying and least in the hot air oven drying. The bael pulp dried in cabinet tray dryerat 70^{0}C gives better results in maintaining better appearance, and color. These two methods are better

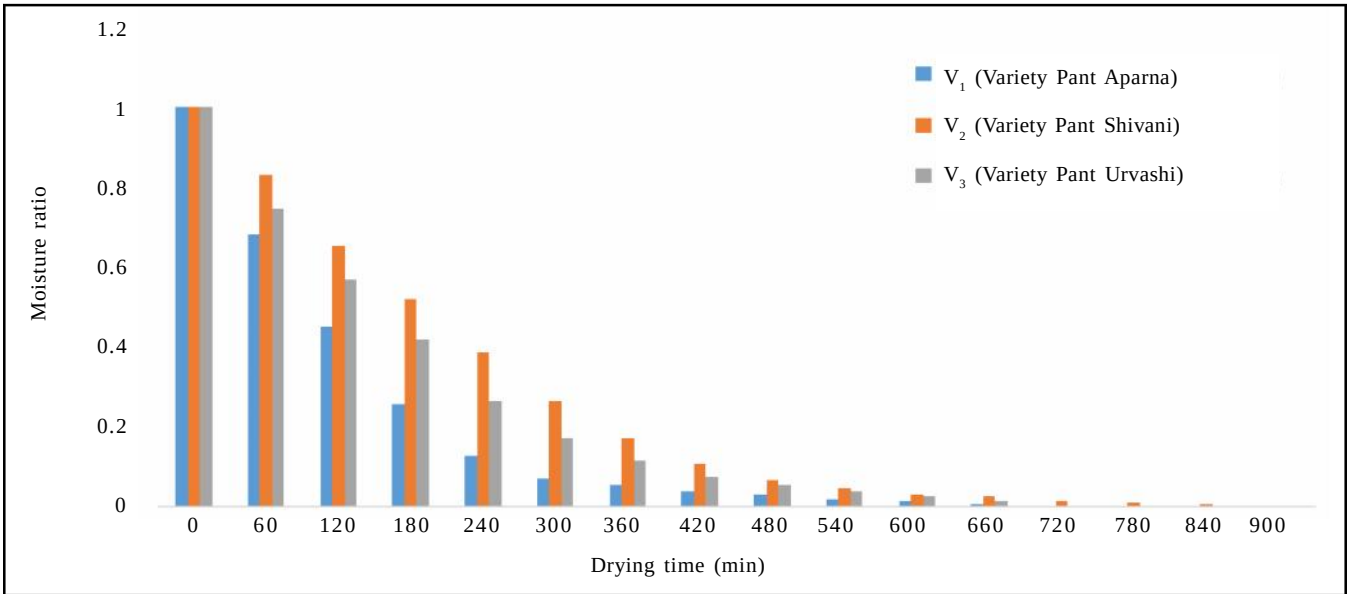

Fig. 14 : Variation of moisture ratio with drying time in hot air oven drying at 60^{0}C

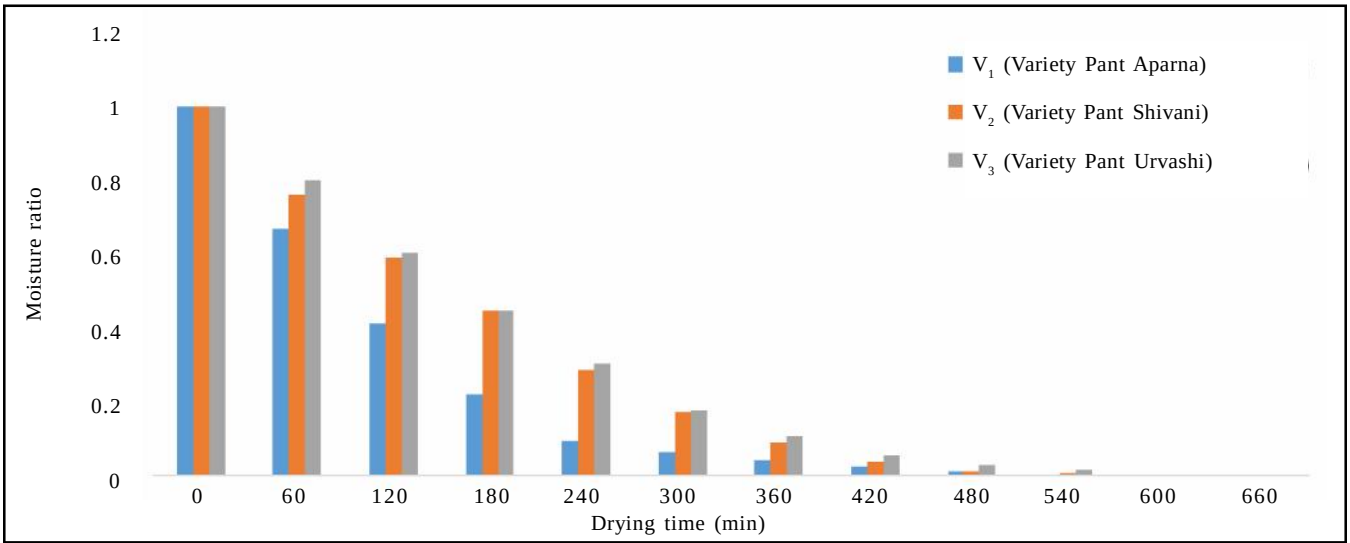

Fig. 15 : Variation of moisture ratio with drying time in hot air oven drying at 70^{0}C

time saving gives better results obtained during drying process.

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