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Dehydration of Date Palm (*Phoenix dactylifera*) Halves Using Different Drying Methods

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Abstract: The date fruits are a food of high energy value. It is very popular both nationally and internationally. Date fruits are perishable fruit crops grown in the coastal region of Kutchh of Gujarat state A study was carried out to determine the drying characteristics of date halves using a hot air dryer, solar dryer, and open sun drying methods. The date halves were dried under a hot air flow dryer at temperature levels of 50, 60, and 70°C under pre-treatment of blanching. The rate of moisture of the blanched sample should only 7.5% reduction at 54 h drying period. In the case of date halves drying, the constant weight of the sample was achieved at 56 h of drying period in a solar cabinet dryer as compared to 320 h for open sun drying. The moisture content was reduced from 69.5 to 8.7% (w.b.) under a solar cabinet dryer for drying of 56 h, while the moisture content was reduced from 69.5 to 12.3% (w.b.) under open sun drying for a drying period of 320 h. The higher net return was obtained solar cabinet drying method as compared to the hot air flow dryer and open sun drying method. The cost of construction of a solar cabinet dryer is less than compared of a hot air flow dryer. The colour and flavour taste is superior in the case of solar cabinet dryer as compared to other dryers. Date halves dried at 70°C developed a dark brown colour, which might be due to higher drying temperatures. It resulted in higher selling prices to the growers. A higher net return (Rs. 89.83 kg^{-1}) was obtained in the case of the solar cabinet dryer. Solar cabinet dryer and hot air flow dryer protects the produce from insect, bird damage, animals, excreta from rodents and birds, unseasonal rain, and wind storm. The solar cabinet dryer and hot air flow dryer could also be used to dry other farm produce like tomato chips, cowpeas, fennel, potato slices, coriander leaves, chilly, etc. It is used to adopt solar cabinet dryers for drying date halves.

Key words: Date fruit, drying, product quality, moisture content, solar dryer.

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Drying is a heat and mass transfer process resulting in the removal of water moisture, by evaporation from a solid, semi-solid, or liquid to end in a solid state. The drying technique is probably the oldest and the most important method of food preservation practiced by humans (Bal *et al.,* 2011). The removal of moisture prevents the growth and reproduction of microorganisms which cause decay and minimizes many of the moisture-mediated deteriorative reactions (Bhosale *et al.,* 2004). It brings about a substantial reduction in weight and volume, minimizing packing, storage, and transportation costs, and enhances the shelf life of the product at ambient temperatures (Mujumdar, 1995). During drying many changes in structural and physico-chemical properties take place which in turn affect the quality of final product (Poonia *et al.,* 2017; 2018).

Date (*Phoenix dactylifera*) is well known for its nutritional content. It contains 1.9% protein, 70.6% carbohydrates, 2.5% fat, 1.2% minerals, and 10% fibre. Dates are considered prime fruit for their nutritional and therapeutic value. It is required to convert the unripe dates having short shelf life into value-added products through a dehydration technique to increase profit margins (Mennouche *et al.,* 2016; Sagarika *et al.,* 2019 and Uchoi *et al.,* 2020). During conventional sun drying of dates, the unhygienic environmental conditions contaminate the dates with bird droppings and insect infestation. Moreover, there is a great chance of fungal growth under high humid conditions. Faecal coliforms are frequently present in traditionally dried dates. The spoilage starts quickly under the influence of unfavourable climatic conditions. It results in a definite wastage of valuable consumable date fruits and minimizes the export potential of the produce. To curtail these losses, the traditional methods of date processing are being replaced by improved techniques. Today, on the global level as well, the production, utilization, and industrialization of dates are continuously improving. Keeping in view the growing importance of hygienically processed quality dates. The efficient processing and long-term storage of date require that the moisture content be reduced to suitable levels by various drying methods.

Currently, hot air drying is the most widely used method in post-harvest technology of agricultural products (Abbaspour-Gilandeh *et al.,* 2020). Using this method, a more uniform, hygienic, and attractively coloured dried product can be produced rapidly. However, it is an energy-consuming operation and has low energy efficiency, therefore, more emphasis is being given to solar dryers sometimes with and at other times without PCM (Jain and Tewari, 2015; Sharma *et al.,* 2015; Mandal *et al.,* 2020; Singh and Mall, 2020). Solar dryers could be an alternative to the hot air and open sun drying methods, especially in locations with good sunshine during the harvest season (Pangavhane *et al.,* 2002). But there are limitations with solar drying. Using a solar dryer, the drying time can be shortened by about 65% compared to sun drying. Solar dryers have a payback period of 2 to 4 years depending on the rate of utilization (Ouaabou *et al.,* 2020). Therefore, solar dryers may become a more convenient alternative for the rural sector and other areas in which electricity is scarce or irregular.

Materials and Methods

Selection and procurement of raw material

Fresh date palm fruits of the variety Zahidi (pale brown skin and a thick, golden inner flesh surrounding a single seed)., harvested in June were selected as a raw material and were procured from Main Date Palm Research Station, SD Agricultural University, Mundra (Kutchh). The manual method of sorting was adopted to remove foreign materials, leaves and immature dates, which was followed by the water-washing operation of date palm fruits. Five samples each of 100 grams were drawn randomly for determination of their initial moisture content. The sample of fresh date palm fruits was selected for the study of moisture content.

Preparation of samples for drying

The pure date palm fruits were cut into slices by a special kind of knife to separate the date pit and flesh Fresh date halves are weighed on an electronic balance of 200 kg ±0.1 g accuracy (Model: Swisser, India). The weighed halves of date palm fruits were soaked in hot water at 85°C for two minutes for blanching. The blanched samples each of 5 kg were kept in perforated trays before drying. Other samples without any pre-treatment are taken as control samples. Both the samples were put to dry under three drying methods viz., open sun drying, hot air flow drying at three temperature levels of 50, 60 and 70°C and solar cabinet drying.

Experimental set up

The experimental parameters measured were physiological loss in weight, colour change,

Open sun drying

Hot air flow dryer

Solar cabinet dryer

texture, temperature, relative humidity and moisture loss of the product. All parameters were recorded at an interval of half an hour initially for the first three hours and every one hour thereafter till four and eight hours of drying. The open sun and solar cabinet drying experiments were carried out during the periods of July under clean sky conditions. Solar cabinet dryer and sun drying experiment was commenced at 9:00 hr and continued till 17.00 hr. Hot air flow drying was continued day and night.

Drying analysis

Moisture content was determined as per the following formula and expressed in terms of percentage of moisture content (w.b.).

$$Moisture\ Content\ (\%) = \frac{M_w - M_d}{M_d} \times 100 \quad \ldots (1)$$

where, M_w = Initial mass of sample, grams; M_d= Final mass of sample, grams

Relative humidity is the ratio of the partial pressure of water vapor in an air-water mixture to the saturated vapor pressure of water at a prescribed temperature. The relative humidity of air depends on temperature and the pressure of the system of interest.

$$RH = \frac{P_w}{P_{ws}} \times 100 \quad \ldots (2)$$

where, RH = Relative Humidity, %; Pws = Saturation vapor pressure, kpa; Pw=Partial vapor pressure, kpa

The mass of water loss was found by the equation

$$Mw = Mc \frac{W_i - W_f}{100 - W_f} \times 100 \quad \ldots (3)$$

where, Mw = Mass of water loss, kg; Mc = Mass of product to be dried, kg; Wi = Initial moisture content (w.b.), %; Wf = Final moisture content (w.b.),%

Drying rate is the amount of evaporated moisture over time

$$DR = \frac{M_i - M_d}{t} \times 100 \quad \ldots (4)$$

where, DR= Drying rate, g h^{-1}; Mi = Mass of sample before drying, gram; Md = Mass of sample after drying, gram; t = Drying period (h)

Result and Discussion

Solar radiation intensity and temperature profile

The inside temperature of the drying structure was measured by RTD sensors using a data logger of range 0-100ºC (±0.05°C). The test was carried out from time 9.00 a.m. to 17.00. Variation of solar radiation intensity and temperature profile inside the solar dryers with time of the day during drying of 5 kg of fresh date slice under load conditions is shown in Fig. 1. Maximum value of solar radiation intensity, inside temperature and ambient temperature were measured as 613 W m^{-2}, 60°C and 35°C respectively at 1:00 pm while minimum values were recorded at 9:00 am and 5:00 pm. The temperature inside the drying chamber was found to be higher than the ambient temperature. Minimum temperature recorded inside the solar cabinet dryer at 9:00 a.m. was 29°C, with the corresponding ambient temperature of 25°C. The maximum drying air temperature under the solar dryer was 60°C in the tray T1 followed by tray T2 (59°C),

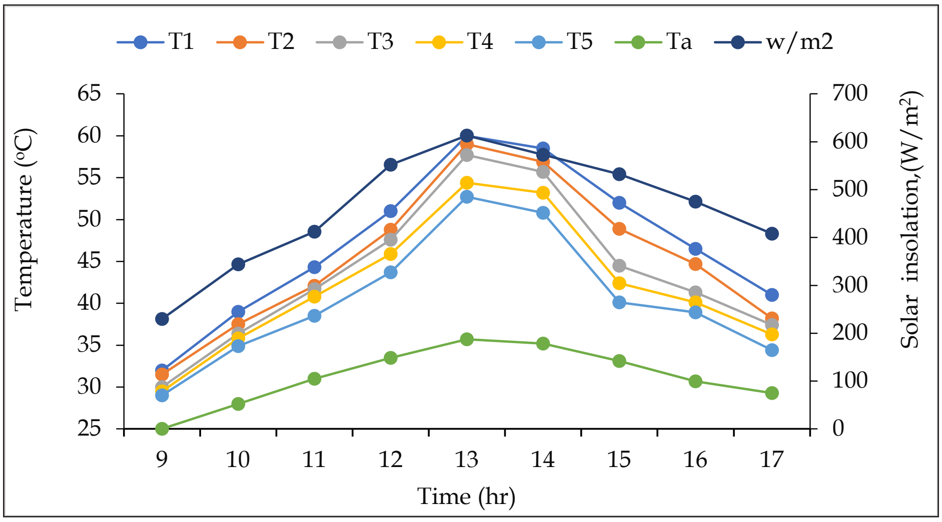

Fig. 1. Solar radiation and thermal profile inside the solar dryer under load condition.

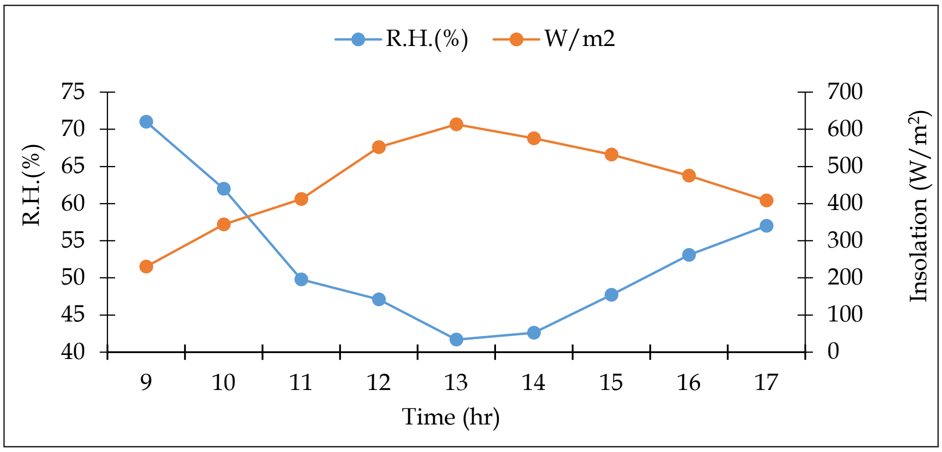

Fig. 2. Solar Insolation and relative humidity profile.

tray T3 (57.7°C), tray T4 (54.4°C) and tray T5 (52.7°C). Figure 2 shows the relation between solar intensity and relative humidity.

Figure 4 shows the reduction of moisture content versus time for the three treatments under different temperature levels. The moisture content at any time of the simulated conditions was determined using equation 3.1. Initial moisture content on a wet basis was determined for the date slice samples using equation 3.1, and it was 69.50%. The moisture

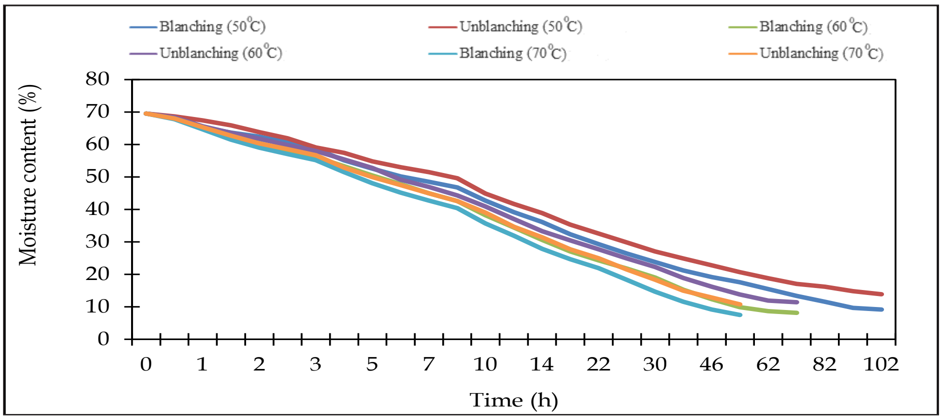

Fig. 3. Moisture content variations for different drying method with drying time.

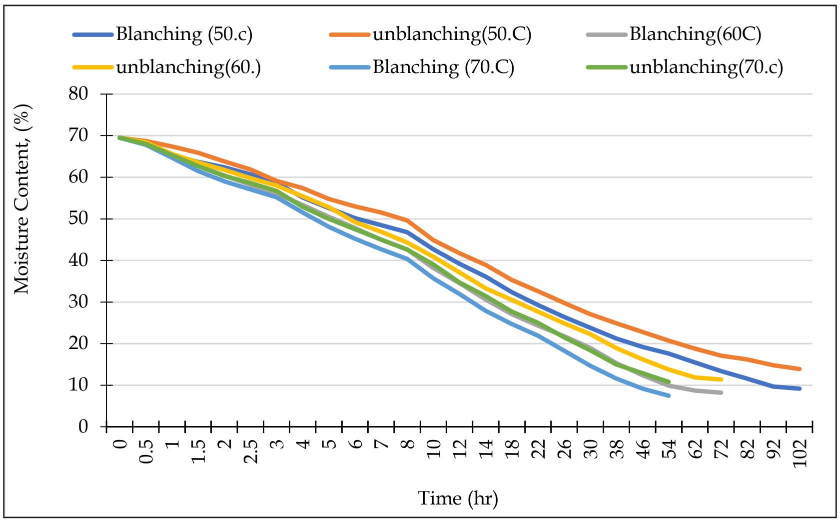

Fig. 4. Moisture content with respect to time under different levels of temperature under hot air flow dryer.

content at all measurement times was calculated starting from the initial moisture content, thus moisture content trend and behaviour were obtained. The moisture loss rate for blanched and unblanched ample was high in the first 22 hours, reaching as high as 40.2 and 36.9, 45.2 and 41.8, 47.6 and 44.5% for 50, 60 and 70°C temperature, respectively. So it was found that moisture loss was maximum in the case of the unblanched sample as compared to the blanched sample. During the second day, moisture was reduced to 10.1, 11.9 and 12.7% 50, 60 and 70°C temperature, and reduced further to 5.8, 4.2 and 1.7% on the third daye. However, an agreement with the finding of this work was found in a convective date drying and modeling study, linear relations between moisture loss and time were reported by (Mohamed and Mohamed, 2016 Missing Ref). Also, a linear relation between moisture content and time was reported for drying several other agricultural commodities. In this study, the temperature was kept virtually stable. The higher moisture loss was for 70°C treatment followed by 60°C and 50°C.

Figure 5 shows the moisture content concerning time under open sun drying and solar dryer. It was found that loss of moisture was faster in solar dryers as compared to sun drying. The drying time for solar dryer and sun drying were 56 and 320 hours respectively. The loss of moisture for the solar dryer was 69.5 to 8.7%, whereas the loss of moisture in the case of sun drying was 69.5 to 12.3%. It was also found that the blanched sample obtained less moisture content as compared to the unblanched sample in two different drying methods.

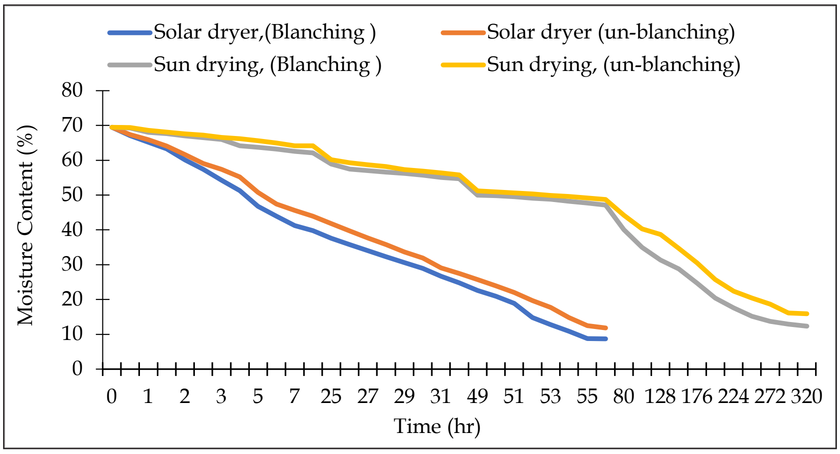

Fig. 5. Variation of Moisture content with respect to time under open sun drying and solar dryer.

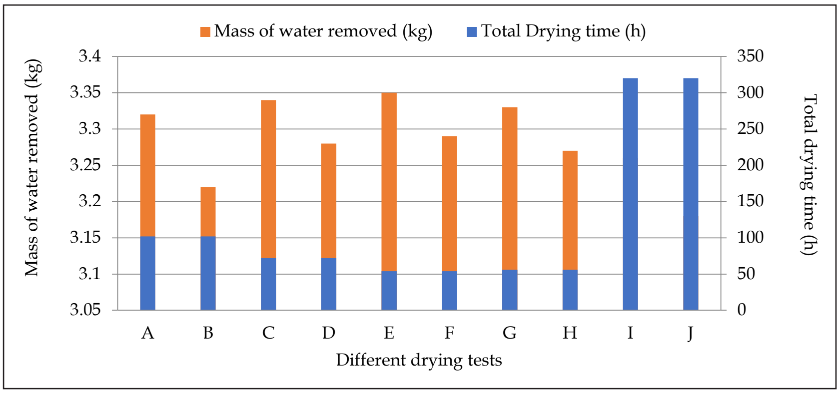

Fig. 6. Moisture removal under different drying methods.

Details of different drying tests	
A	Hot air flow dryer at 50°C (Blanch)
B	Hot air flow dryer at 50°C (Un-Blanch)
C	Hot air flow dryer at 60°C (Blanch)
D	Hot air flow dryer at 60°C (Un- Blanch)
E	Hot air flow dryer at 70°C (Blanch)
F	Hot air flow dryer at 70°C (Un-Blanch)
G	Solar drying (Blanch)
H	Solar drying (Un-blanch)
I	Sun drying (Blanch)
J	Sun drying (Un-blanch)

Figure 6 shows that the total drying time was maximum in the case of open sun drying and less in the case of the hot air flow drying method and solar cabinet drying method. It was found that the highest drying rate was 62.03 g h^{-1} for the drying time of 54 h under a hot air flow dryer at 70°C, while the minimum drying rate was found 9.95 g h^{-1} for a drying time of 320 h under open sun drying method. It was found that the drying rate was 59.45 g h^{-1} for a drying time of 56 h under a solar cabinet dryer. So it was found that the drying rate was higher in the case of solar cabinets and hot air flow dryers as compared to open sun drying.

Table 1. Drying rate for dates halves

Drying test	Total drying time (h)	Drying rate (g/h)
Hot air flow dryer at 50°C(Blanch)	102	32.54
Hot air flow dryer at 50°C(Un-Blanch)	102	31.56
Hot air flow dryer at 60°C(Blanch)	72	46.37
Hot air flow dryer at 60°C(Un- Blanch)	72	45.53
Hot air flow dryer at 70°C(Blanch)	54	62.03
Hot air flow dryer at 70°C(Un-Blanch)	54	60.93
Solar drying (Blanch)	56	59.45
Solar drying (Un-blanch)	56	58.41
Sun drying (Blanch)	320	10.19
Sun drying (Un-blanch)	320	9.95

The drying rate for the different tests performed is presented in Table 1. For hot air flow drying, the drying rate for date halves was found to be 32.54, 46.37 and 62.03 g h^{-1} at temperature levels of 50°C, 60°C and 70 for blanched samples, while it was 31.56, 45.53 and 60.93 g h^{-1} at same temperature level under unblanched samples. For the solar cabinet drying method, the drying rate of date halves was found 59.45 and 58.41 g h^{-1} for blanched and un-blanched samples. For the open sun drying method, the drying rate of date halves was found as 10.19 and 9.95 g h^{-1} for blanched and un-blanched samples. So it was found that the drying rate was higher in the case of solar cabinet dryers and hot air flow dryers as compared to open sun drying.

Conclusion

The three drying methods used significantly impacted the drying characteristics of date halves. Among them, the solar dryer proved to be more efficient than open sun drying and provided complete protection from insects, birds, rain, and dust. The commonly consumed date halves were dried using conventional drying, sun drying, and open sun drying methods. The drying characteristics, duration, and final dry weight of the date halves were thoroughly studied. It was observed that date halves dried using hot air drying required the least amount of time and achieved the maximum moisture removal. The initial hour of both hot air drying and sun drying, as well as the first six hours of open sun drying, resulted in the greatest moisture reduction. Specifically, date halves dried in a hot air dryer at 70°C required 54 hours to complete the drying process.

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