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Investigations on effect of elevated temperatures and reduced relative humidity on drying of grapes

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Abstract

Drying of grapes is a complex process involving physical or chemical pre-treatment to create micro-cracks in waxy cuticle on berry skin followed by drying to 15-16% moisture level by different methods. Weather factors prevailing during grape drying particularly temperature and relative humidity play a very important role in determining the quality of raisins. Since last few years, major grape drying areas in India are experiencing untimely rains during grape drying season resulting in the production of inferior quality raisin. To address such recurring problems, modified grape drying chamber containing heavy duty heaters and fans was fabricated at ICAR National Research Centre for Grapes, Pune. Berries of Thompson Seedless and Manik Chaman were dried in single layer in this chamber in March 2017 and April 2018. Average temperature and average relative humidity during the drying duration and drying periods required to reduce moisture level in the berries up to 15-16% moisture level were compared with drying in chamber having ambient conditions. Average temperatures and relative humidity in heated chamber were high and low, respectively than in ambient chamber in both the years. Thompson Seedless required 25% and 28.6% less drying period in 2017 and 2018, respectively. Whereas, Manik Chaman required 37.5% and 42.9% less drying period in 2017 and 2018, respectively. Under ambient drying conditions, both varieties exhibited similar drying periods (8 days in 2017 and 7 days in 2018) in both the years, however, faster drying of Manik Chaman in heated chamber in both the experimental years may perhaps be due to different wax structure on berry skin and its faster degradation under high temperatures in this variety. Drying under heated chamber conditions would be beneficial to grape growers as the grapes are dried at faster rate and are not exposed to unfavorable drying conditions created by the untimely rains for a longer time. The quality of raisins is also expected to be far better due to absence of dust and other debris which are otherwise present in open drying conditions.

Keywords: Grape drying, raisin, grape drying time, grape wax cuticle

1. Introduction

Grape is one of the important fruit crops in India. Averaged over the last 3 years (2015-16 to 2017-18), the area and production under grapes in India is estimated to be 0.1324 million ha and 2.8105 million tons, respectively (NHB, 2018) [5]. Maharashtra and Karnataka producing about 2.70 million tons of grapes from an area of 12,464 ha are leading grape producing states in the country. Being a perishable commodity, diversified utilization of grapes is a major problem faced all over the world. In India, about 72% grapes are used for table purpose, out of that about 10% is exported, 4% are used for processing into wine and juice and 18% are dried into raisins. Diversified use of grapes eases proper utilization of this perishable commodity, thereby, avoiding price crashes and gluts in the markets during peak harvest periods. After production of table grapes for domestic use and export, drying grapes to make raisins is the second most important activity in Maharashtra and Karnataka. Generally, Thompson Seedless and its clonal selections such as Tas-A-Ganesh, Sonaka, Manik Chaman, Sharad Seedless and its clonal selections (Krishna Seedless, Sarita Seedless, Nanasaheb Purple, etc.) are used for raisin production in these states (Sharma *et al*, 2018) [10].

Pre-treatment with Australian dip (oleate treatment) followed by sun/shade drying is predominantly used for raisin production. The waxy cuticle covering on grape berries restricts moisture diffusion and is the main hinderance in quick drying. In order to increase the drying rate, Australian dip (oleate treatment) is used which helps to create microcracks on the cuticular surface and thus decrease the skin resistance and improves moisture diffusion (Ponting and Mebean, 1970) [7].

Grape drying methods vary in different parts of the world depending on their agro-climatic conditions. There are three main methods that are used in raisin production. These are sun drying, shade drying, and mechanical drying (Pangavhane and Sawhney, 2002) [6]. The important factors for drying are temperature, humidity, light and wind velocity. At low temperatures the drying process is slow and high temperatures affect colour of the raisin. Lower humidity (20-30%) coupled with ideal temperatures (35-40 ^{0}C) enhance the drying process and quality of raisin. If humidity is higher, the resulting raisins are dark in colour and if such conditions prevail for longer duration rotting and mould development starts. Long drying time and high temperature damages the texture, colour, taste and nutritional value of raisins. Drying of grape should, therefore, needs to be carried out quickly at ideal drying temperature and relative humidity (Carranza-Concha *et al*, 2012) [1].

Raisin quality is very important for domestic and international trade and is judged in terms of factors related to appearance, texture, flavor, food value, and cleanliness. Quality of raisin is influenced by the quality of grapes used and method of drying employed for their production. Among the various raisin quality indices, colour is the most important factor which is affected by drying conditions and determines marketing value and acceptability of the final product (Doymaz and Pala, 2002) [2].

In recent years, grape drying areas in Maharashtra and other regions of the country are encountering untimely rains and hail storms during grape drying periods (March-April) resulting into high humidity leading to production of low-quality raisins as well as spoilage of drying grapes due to moulds. Such huge economic losses result in panic sell of fresh grapes by the growers/processors causing price crash and glut in the market. Thus, there is an urgent need to develop improvised grape drying method that is equally effective both under normal and adverse climatic conditions during drying. For this, grape drying chambers having different drying conditions were fabricated at the ICAR National Research Centre for Grapes, Pune to study effects of these drying conditions on grape drying for two consecutive years 2017 and 2018.

2. Material and Methods

The studies were carried out in 2017 and 2018 at the ICAR-National Research Centre for Grapes, Manjri Farm, Pune (18.29570 N; 73.59168 E; 559 Meters above sea level).

2.1 Grape drying chambers: Two drying chambers were fabricated and used in the study. The first drying chamber (Heated Chamber) was equipped with insulating material, sensor-controlled heating and air circulating/exhaust system. The sensors were fixed at appropriate positions in the drying chamber. Temperature in this chamber was set at 40 ± 2 °C. Data on temperature and humidity inside the chamber were recorded on hourly basis through data loggers. The second drying chamber (Ambient chamber) was without any gadget and grapes in this chamber were dried under ambient atmospheric conditions prevailing in Pune. This chamber had 4 netted cross windows for ventilation.

2.2 Sample preparation and pre-treatment: Fresh Thompson Seedless and Manik Chaman grapes were used in the studies. Prior to harvesting, fresh fruit sugar content was determined with the help of refractometer. Infected and damaged berries were removed and experimental berries were washed with tap water to remove the dust and impurities adhering to the surface. Twenty lots, each of 1 Kg were weighed for each variety. The lots were individually dipped in a solution of 1.5% ethyl oleate and 2.5% potassium carbonate for 2-3 minutes in order to breakdown the waxy circular fruit surface and to create microscopic cracks for enhancing moisture permeability. Ten lots of each variety were used for drying in heated chamber and 10 lots for drying in ambient chamber. The pre-treated samples were arranged in single layer uniformly in each chamber.

2.3 Determination of % moisture during drying periods: Moisture levels in 1 Kg lots kept for drying under different drying conditions were determined at different drying intervals using standard oven drying at 60 °C for up to a period after which there is no reduction in weight of dried sample. Initial moisture levels in berries of each variety were determined before placing them in drying chambers. Daily moisture contents (wet basis) of samples during the drying period were determined by using standard oven drying method using following equation:

$$\%\, moisture\ content\ (\mathrm{Mwb}) = \frac{\mathrm{Wi} - \mathrm{Wf}}{Wi} \times 100$$

Where, W_i is the initial weight of berries and W_f is the weight of oven dried berries.

3. Results and Discussion

Average temperatures and relative humidity in heated and ambient drying chambers ranged from 39.8 °C to 23.30 °C and 36% to 44.5%, respectively during the grape drying period March 8-16, 2017. In general, the temperatures (38.5 °C to 41.5 °C) in heated chamber were higher than in ambient chamber (19.6 °C to 25.8 °C) during drying period. Consequently, the relative humidity was also lower in heated chamber (31% to 41%) as compared to ambient chamber (38% to 53%) (Figure 1a). Typical average ambient tempearatures and relative humidity during different time periods of a day indicated that the ambient temperatures and relative humidity were low (14.4 °C and 23 °C) and high (73.6% and 42.7%) during evening to morning hours (18.00 to 00.00 and 00.00 to 6.00 hrs), respectively (Figure 1b). Drying periods required to reduce berry moisture to 15-16% level in Thompson Seedless and Manik Chaman under ambient and heated conditions are shown in figure 2a &b. Thompson Seedless required about 25% less time for drying in heated chamber than in ambient chamber, while, Manik Chaman required 37.5% less time in heated chamber in comparision to ambient chamber. Although the drying period was same for both the varieties under ambient conditions, drying of Manik Chaman was 17% faster than Thompson Seedless in heated chamber.

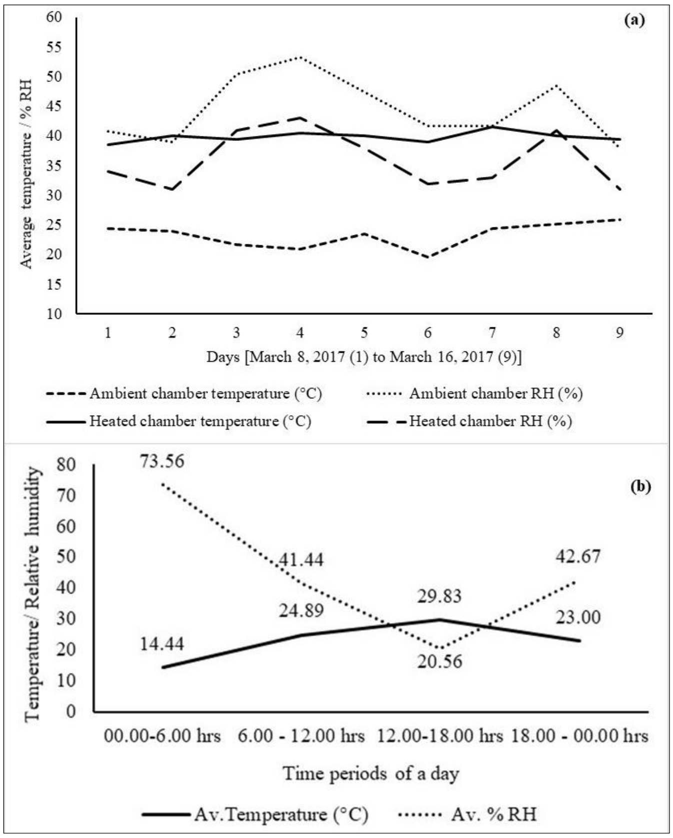

Fig 1: (a) Average daily temperatures (^{0}C) and RH (%) in ambient and heated grape drying chambers during March 8-16, 2017. (b) Typical average ambient temperatures and relative humidity during different times of a day between March 8-16, 2017.

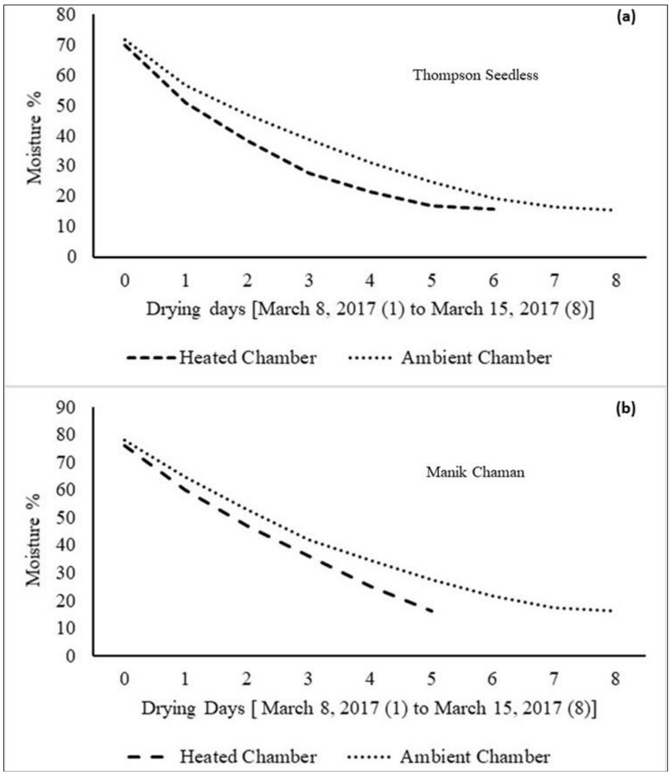

Fig 2: Number of days required to dry Thompson Seedless (a) and Manik Chaman (b) berries up to 15-16% moisture level in heated and ambient drying chambers in March 2017.

In 2018, average temperatures and relative humidity in heated and ambient drying chambers ranged from 40.5 °C to 28.9 °C and 33.7% to 37.4%, respectively during the grape drying period April 6-15, 2018. In general, the temperatures (38.5 °C to 42.0 °C) in heated chamber were higher than in ambient chamber (28.0 °C to 30.3 °C) during drying period. Consequently, the relative humidity was also lower in heated chamber (28.2% to 38.5%) as compared to ambient chamber (32.3% to 41.5%) (Figure 3a). Typical average ambient tempearatures and relative humidity during different time periods of a day indicated that the ambient temperatures and relative humidity were low (22.6 °C and 27.6 °C) and high (57.0% and 41.6%) during evening to morning hours (18.00 to 00.00 and 00.00 to 6.00 hrs), respectively (Figure 3b). Drying periods required to reduce berry moisture to 15-16% level in Thompson Seedless and Manik Chaman under ambient and heated conditions are shown in figure 4a &b. Thompson Seedless required about 28.6% less time for drying in heated chamber than in ambient chamber, while, Manik Chaman required 42.9% less time in heated chamber in comparision to ambient chamber. Although the drying period was same for both the varieties under ambient conditions, drying of Manik Chaman was 20% faster than Thompson Seedless in heated chamber.

Grape drying is a complex process that dependents on many factors such as variety, berry attributes, pre-treatment and drying conditions. In our studies all the other factors were assumed to be constant except drying conditions (temperature and relative humidity). Temperatures and relative humidity in ambient and heated chambers in 2017 and 2018 were different due to drying in different months in these years. In both these years, drying of grapes in heated chamber was quicker than in ambient chamber in both varieties. This may perhaps be due to the higher air temperature and low relative humidity in heated chamber. Such drying conditions enhance heat transfer between air and berry surface and accelerate water migration and transfer from berry surface to the surroundings.

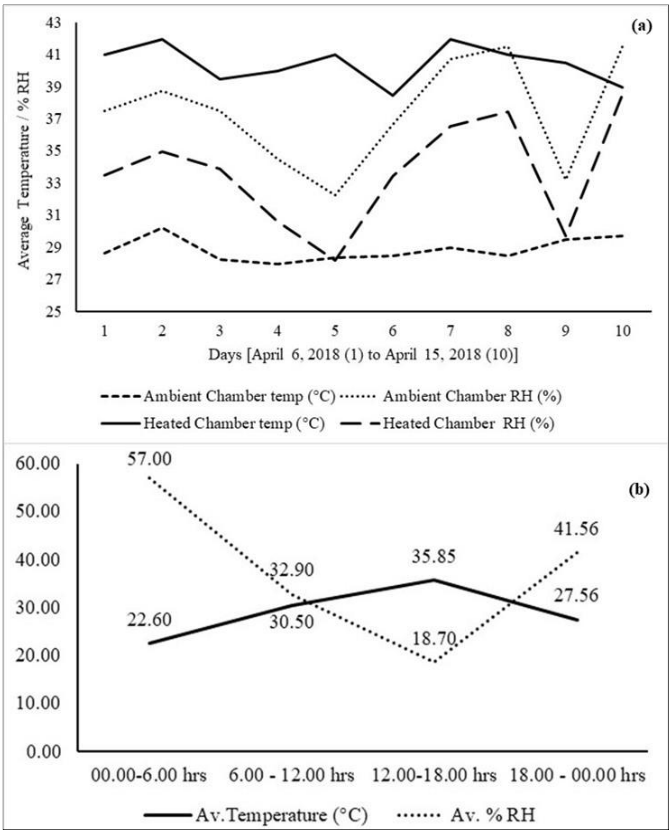

Fig 3: (a) Average daily temperatures (^{0}C) and RH (%) in ambient and heated grape drying chambers during April 6-15, 2018. (b) Typical average ambient temperatures and relative humidity during different times of a day between April 6-15, 2018.

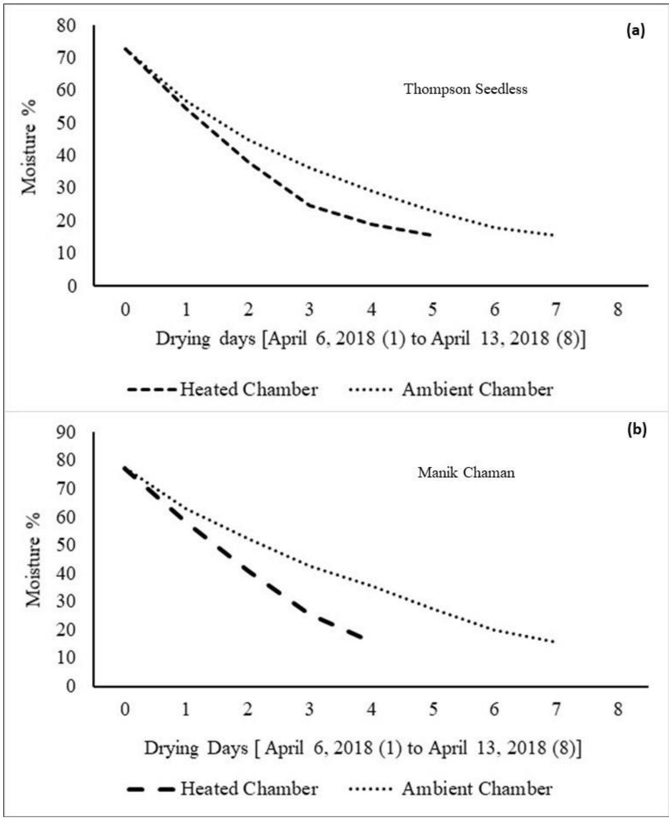

Fig 4: Number of days required to dry Thompson Seedless (a) and Manik Chaman (b) berries up to 15-16% moisture level in heated and ambient drying chambers in April 2018.

Our results are in agreement with several well documented reports that higher temperatures and low relative humidity are favourable for quick drying of grapes. Pangavhane *et al*. (2002) [6] observed that drying of grapes in shade, open sun and solar dryer took 15, 7 and 4 days, respectively and raisins produced in solar dryer were more hygienic and quality-wise better than other two methods. El-Mashriki (2005) [3], also, reported that drying time for grapes decreased from 356 h in case of traditional method to 44 h using drier at 45 °C compared to average ambient temperature of 29 °C. Serratosa *et al*. (2008) [9] a reported shortening of the drying time by about 40%, as against traditional sun drying, when Pedro Ximenez grapes were dried in chamber at a controlled temperature of 40 or 50 °C. Hong *et al*. (2010) [4] studied drying kinetics and quality of Monukka seedless grapes under different drying temperatures and air velocities. They observed that effect of drying temperature on drying time was more distinct than air velocity.

Similar drying periods for both varieties in ambient chamber but faster drying of Manik Chaman in heated chamber in both the experimental years is interesting. This may perhaps be due to different wax structures on berry surfaces of these two varieties. Roichev and Botiyanski (1998) [8] established that the specific wax structures on grape fruit surfaces varied between cultivars and were destroyed to a varying degree after preliminary treatment with alkaline solution and high temperature, which enhances drying and increases raisin quality. Thus, in Manik Chaman it appears that after pre-treatment, surface wax structures are destroyed more at higher temperatures than in Thompson Seedless.

Drying rate is very important factor in production of quality raisins. Drying under heated chamber conditions would be beneficial to grape growers as grapes are dried at faster rate and are not exposed to unfavourable drying conditions created by the untimely rains or other weather vagaries for a longer time. Moreover, the quality of raisins is better due to freedom from dust and other debris which are otherwise present in grapes dried under open drying conditions. Though the chamber drying method is fast, reliable but it requires energy to operate the system. Therefore, further work is needed to reduce cost and drying time. One possibility to reduce cost on electricity can be heating during evening to morning hours (18.00 to 00.00 and 00.00 to 6.00 hrs).

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6. Conflict of interest

All the authors declare that there is no conflict of interest.

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