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Research Paper

Effect of Pre-treatments and Solar Drying of Grapes on its Quality Evaluation

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ABSTRACT

Pre-treatment is a necessary step in raisin production in order to ensure the increased rate of water removal during the drying process Drying of grape can help in preserving it for longer duration. In present paper, the grapes of *Manikchaman* variety was treated with Treatment T_1 = 2.5% NaOH for 3 sec followed by 2% KMS for 2 minutes and Treatment T_2 = 2.5% potassium carbonate + 2% ethyl oleate solution for 5 minutes and dried by solar drying. The quality of dried raisins were evaluated. The drying data was fitted with various models the Henderson and Pabis model, the Lewis model, the Page model, and Two-term exponential model models fitted to the experimental data. Henderson and pabis and Exponential two term drying model was well fitted to the experimental data with r^2 = 0.9825 and 0.9902; MSE = 1.712 × 10^{-3} and 1.045 × 10^{-3}; χ^2 = 0.1949 and 0.1045 for treatment-1and treatment-2 solution, respectively. Nutritional analysis of fresh ripened grapes and grape raisins has also been determined i.e. Moisture content, TSS, Titrable acidity, pH, Reducing sugar, Total sugar, Non-reducing sugar, Ascorbic acid, colour yellowness index, Hardness. The moisture content in grape raisins 14.54%, TSS 73.88^{0}B, Titrable acidity 2.52 %, pH 4.13, Reducing sugar 64.65 %, Total sugar 66.13 %, Non-reducing sugar 1.48, Ascorbic acid 21.33 mg, yellowness 86.15 and hardness 8.57 for Treatment-2. The sensory score for best Treatment T_2 was colour 8.2, flavour 7.90, texture 8.22 and taste 8.08.

Keywords: Solar drying, moisture ratio, drying kinetics, quality parameters

Grapes (*Vitis vinifera* L.) belong to the *Vitaceae* family is believed to have originated in Armenia near the Black and Caspian seas in Russia. Grape production is widespread throughout the world, exceeding 68 million tons (FAOSTAT, 2010). The production of fresh grapes in India is about 26.83 million MT with an area of 1.36 million ha under cultivation. Maharashtra is the leading state occupying 72.76 per cent of total area of the country with an extent of 1.03 million ha, producing 21.37 million MT of grapes per annum (NHB, 2017).

Pre-treatment solution is very important parameter that affects the drying time. Samples dipped in ethyl oleate plus potassium carbonate solution prior to drying were found to have a shorter drying time compared to other pre-treatments (Doymaz, 2006). Pre-treatment reduces drying time, the moisture ratio decreased continuously with increase in drying time. The entire drying process for pre-treated as well as untreated grapes occurred in the range of falling rate period (Singh *et al.* 2016).

Grape drying to produce raisins is a very slow process

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(King, 1977; Peri & Riva, 1984; Rizvi, 1986; Labuza & Hyman, 1998), due to the peculiar structure of grape peel that is covered by a waxy layer (Mahmutoglu, Emõr & Saygi, 1996). Its removal has been so far carried out by using several chemical pretreatments (Pointing & Mc Bean, 1970; Bolin, Petrucci & Fuller, 1975; Bolin & Sta€ord, 1980; Riva & Peri, 1986; Saravacos & Marousis, 1988). For example, when grapes are dipped into an alkaline solution containing, for instance, ethyl oleate, this component penetrates into the waxy layer and causes the formation of many small pores. As a consequence, the drying time of pre-treated grapes is up to four times shorter than the drying time of untreated grapes.

One of the most important potential applications of solar energy is the solar drying of agricultural products. Losses of fruits and vegetables during their drying in developing countries are estimated to be 30–40% of production. The post-harvest losses of agricultural products in the rural areas of the developing countries can be reduced drastically by using well-designed solar drying systems (El-Sebaii *et al*. 2002).

The traditional methods open air sun drying, shade drying used for drying of grapes produce raisins of low quality which are unable to meet the market requirements. The use of industrial dryers for grape drying helped in improving the quality of raisins. The disadvantages of solar drying, shade drying, and forced farmers in many countries to look for alternate drying methods which could be a cost-effective and hygienic way of preserving fruits. The solar dryer being cost-effective with no running cost creates an absolutely hygienic situation for fruit preservation. The introduction of solar dryers can reduce crop losses and improve the quality of dried product significantly when compared to the traditional methods of drying (Yaldiz *et al*. 2001).

Solar-drying technology offers an alternative which can process the vegetables and fruits in clean, hygienic and sanitary conditions to national and international standards with zero energy costs. It saves energy, time, occupies less area, improves product quality, makes the process more efficient and protects the environment. Solar drying can be used for the complete drying process or as a supplement to artificial drying systems, in the latter case reducing the fuel energy required. Solar dryer technology can be used in small-scale food processing industries to produce hygienic, good quality food products.

Solar tunnel drying method was newly explored in Tunisia. This method is also cheap. The grape berries are spread over trays arranged in two levels or more. In this case, the grapes are protected with the transparent sheet so that the weather risk is reduced. The quality of the raisins is also better in comparison to that when dried in other drying methods (Fadhel *et al*. 2005). Thin layer drying model is generally used to understand the drying characteristics of agricultural products. Mathematical models that are extensively suitable for high moisture content crops such as grapes are page model, newton model, Henderson and Pabis model, logarithmic model, exponential two term model and Wang and Singh model (Sundari *et al*. 2014).

Zomorodian *et al*. (2009) reported that Page model was the most suitable model to illustrate the drying kinetics of Sultana grape. Doymaz (2006) reported that Page model was most suitable for describing drying curves of black grapes.

In the present study, solar drying of pre-treated grapes has been carried out. The influence of dipping solutions such as ethyl oleate + potassium carbonate and NaOH plus KMS were studied. Also, drying time and quality of grape raisins were compared with those pre-treated dipping solutions.

MATERIALS AND METHODS

Construction of solar dryer for grape drying:

Fig. 1 shows a schematic view of natural convection solar tunnel drying system, designed and developed in the department of post-harvest engineering, post graduate institute of post-harvest management, killa-Roha for drying of grapes. Solar tunnel dryer having floor area of 5.49 m × 3.66 m was designed for grape drying. The height of solar dryer was 2.20 m and the door was 1.75 m × 0.8 m which was convenient for person to enter into the dryer to carry out the operations like loading / unloading of the material to be dried and weighing of the sample.

The solar tunnel dryer was made up with galvanised iron framed structure and four dome shaped angles 1.83 m length and 12 mm size fitted and oriented in north – south direction. An exhaust fan of 0.75 kW power rating is provided at the back side of the dryer at 1.35 m height from the ground level for occasional removal of moist air to maintain humidity inside the drying chamber, for obtaining higher drying rate. The structure was raised on floor. The structure was covered with ultraviolet stabilized polythene sheet of 200 micron size to capture ultraviolet rays in the dryer and to increase the temperature inside the dryer. The detailed structure of the dryer is shown in Fig. 1. Front elevation, back elevation, top view and side view.

The trays for drying of grapes was placed on the compartment made up of bamboo purchased from local market. Drying compartment was having size 2.75 × 1.13 × 0.87 m (*l* × *b* × *h*). The dryer was designed for 24 kg capacity of grape and accommodates at least twelve perforated trays of size 81 × 41 × 3.4 cm (*l* × *b* × *h*) in solar dryer. The mesh size was 1 × 1 mm. The bamboos were cut at 0.97m height of each are fitted at 1.38m distance with the screws. The supportive bamboos were fitted to fix the trays in the drying chamber having length 2.75 m. The first stack of the compartment for placing the perforated trays was at 0.51m from the ground level and second stack of the compartment was at 0.36m apart from the first compartment. This facilities to fix up the six trays of size 81 × 41 cm (*l* × *b*) in each compartment easily. Fig. 2 Shows the photograph of the developed solar dryer for drying of grapes.

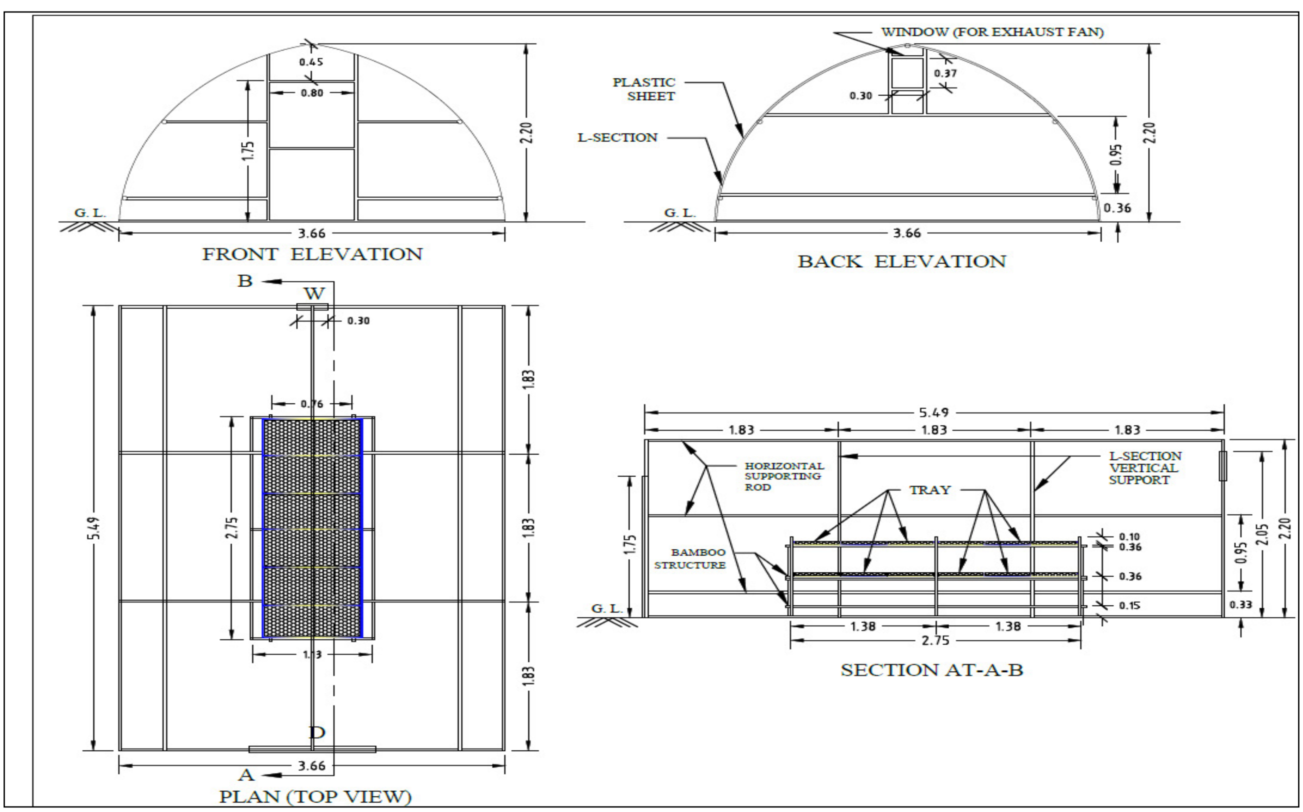
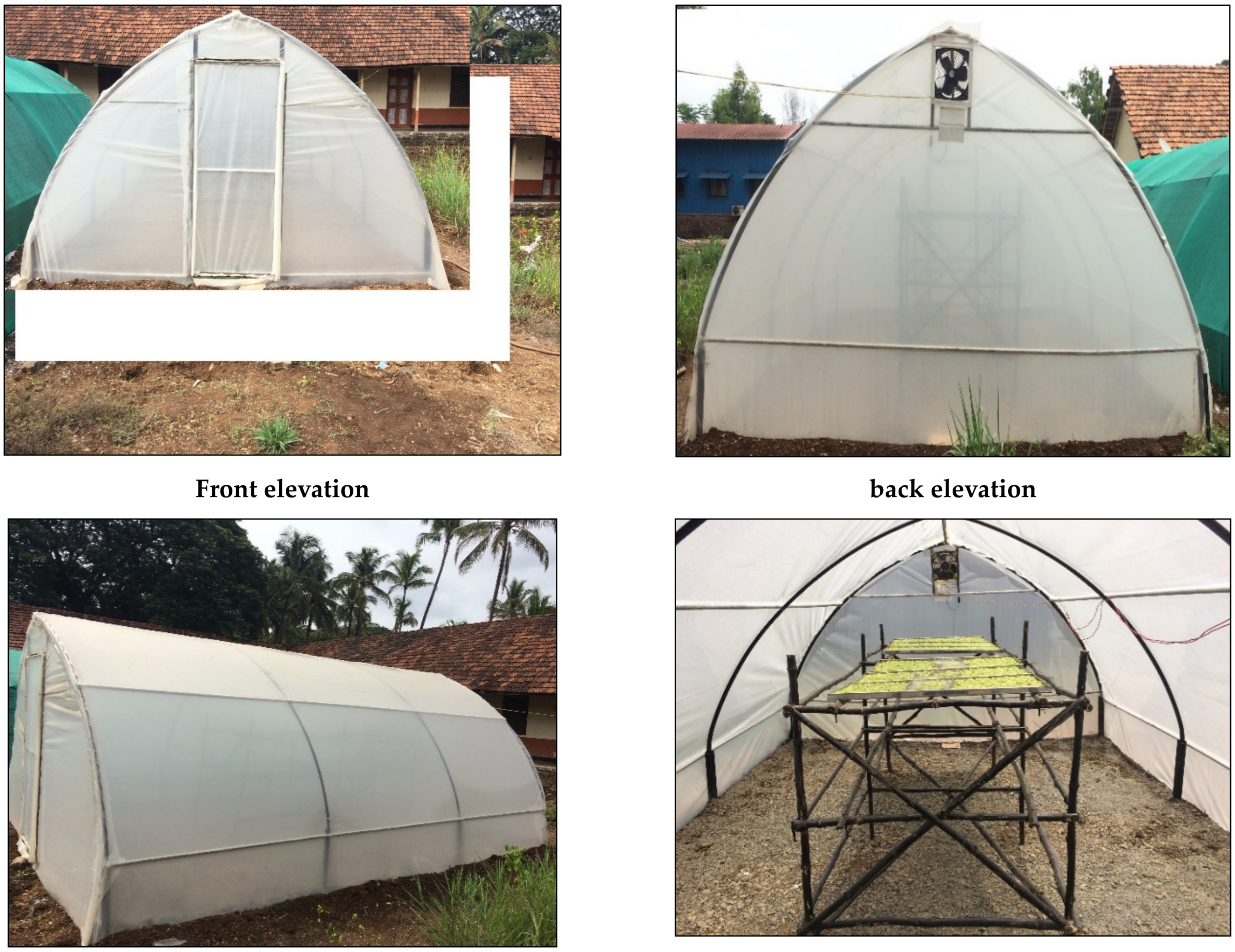


Fig. 1: Schematic diagram of solar dryer for grape drying (Front Elevation, Back elevation, Top view and Side view)



Front elevation | back elevation

Side elevation | Experimental setup for solar drying

Fig. 2: Photograph of the developed solar dryer for drying of grapes

Sample preparation and solar drying of grapes

Grapes (*Vitis venifera* L.) of *Manikchaman* variety were purchased from local market located at Agricultural Produce Market Committee (APMC), Vashi. Grapes fruits were washed thoroughly under running tap water and weighed then dipped in two different pre-treatment solution i.e. Treatment T_1 = 2.5% NaOH for 2-3 sec followed by 2% KMS for 2 minutes and Treatment T_2 = 2.5% potassium carbonate + 2% ethyl oleate solution for 5 minutes. Then the berries were separated from bunch and put on perforated trays. Pre-treated grapes were dried in the solar dryer having capacity of 24 kg. Solar drying of grape was performed at Department of Post-Harvest Engineering, Post Graduate Institute of Post-Harvest Management, Killa-Roha. The samples were dried and also the weight loss of each sample were recorded at regular interval using electronic weighing balance (accuracy 1mg) yet this reaches to moisture content 14-15% (db) and drying characteristics were studied. 2% smoking treatment of sulphur was given to the dried grapes by sulphur.

Solar dryer parameter measurement:

Humidity and ambient air temperature was measured using a digital thermo-hygrometer (Make: Crystal instruments, Mumbai; Model: Temptec) with accuracy of 1°C and 1% RH. Air velocity of ambient air was measured by anemometer (Make: Lutron Electronics, Taiwan; Model: AM4202) having the accuracy of 0.1 $m.s^{-1}$. The product temperature measured by inserting the sensors into the product during the drying using data logger (Make: Ambetronics; Model: TC800D). The longitude for Roha is 69° 16′ 14.74′′ E and Latitude for Roha is 23° 11′14.26′′ N. The experiment was triplicated for each treatment. Moisture content versus time was calculated from drying data. The drying data include Initial moisture content, weight loss, average moisture content versus time, drying rate versus moisture content and moisture ratio versus time.

Moisture Content

The moisture content of fresh grape sample and dried grapes was determined as per AOAC, 2010. Initial moisture content of fresh grape sample and dried grapes was calculated by the hot air oven at 105°C ±1 °C for 24 hours. The final weight of dried grapes were recorded after 24 hours. The moisture content of the fresh grape sample and dried grapes were determined by following formula (Chakraverty, 1994).

$$\text{Moisture content (db)\%} = \frac{W_1 - W_2}{W_2} \times 100 \qquad \ldots(1)$$

Where,

W_1 = Weight of sample before drying, *g*

W_2 = Weight of sample after drying, *g*

1. Moisture ratio

The moisture ratio of grapes was calculated on dry basis using following formula (Chakraverty, 2005).

$$\text{Moisture ratio} = \frac{M - Me}{Mo - Me} \qquad \ldots(2)$$

Where,

MR = Moisture ratio

M = Moisture content at any time θ, %(db)

M_e = EMC, % (db)

M_0 = Initial moisture content, %(db)

2. Drying model

Moisture Content (% db) versus drying time (min) and drying rate (g of water/ 100g bone dry material/min) with respect to moisture content was determined for drying of grapes. Moisture ratio versus drying time (min) was also determined from the experimental data.

Table 1: Mathematical models tested with the moisture ratio of grapes

Sl. No.	Model	Equation	Reference
1	Newton	$MR = exp(-kt)$	Westerman *et al.* 1973
2	Page	$MR = exp(-kt^n)$	Zhang and Litchfield, 1991
3	Modified Page equation-II	$MR = a.exp(-kt)^n$	Zhang and Litchfield, 1991
4	Exponential	$MR = exp(-kt)$	Liu and Bakker-Arkema, 1997
5	Henderson and Pabis	$MR = a.exp(-kt)$	Henderson and Pabis, 1961
6	Logarithmic	$MR= a.exp(-kt) + C$	Zhu and Shen., 2014
7	Wang and Singh	$MR= 1 + at + bt^2$	Wang and Singh 1978
8	Two term	$MR = aexp(-k0t) + bexp(-k1t)$	Henderson 1974

Various mathematical models listed in Table 1 were tested on the experimental data on moisture ratio versus drying time in minutes of grapes dried with solar drying. The moisture ratio determines the unaccomplished moisture change, defined as the ratio of the free water still to be removed, at time *t* over the initial total free water (Henderson and Pabis, 1961).

The root mean square error (RMSE) was determined as per equation (3). The model was considered as best fit based on higher r^2 (Corelation coefficient) values, lower MSE and lower χ^2 (chi-square) value.

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{n}(MR_{exp} - MR_{pre})^2\right] \qquad \ldots(3)$$

Where,

MR_{exp}= experimental moisture ratio

MR_{pre}= predicted moisture.

N and n are the number of observations and the number of constants respectively (Togrul and Pehlivan, 2003).

3. Correlation regression coefficient and error analysis

The goodness of fit of the tested mathematical models to the experimental data was evaluated with the higher correlation coefficient (r^2), lower chi-square (χ^2) and lower value of RMSE. The higher the r^2 value and lower the chi-square (^{2}) equation (4) and lower value of *RMSE* values, the better is the goodness of fit (Ozdemir *et al*, 1999; Ertekin and Yaldiz., 2004; Wang *et al*. 2007). According to Wang *et al.* (2007) reduced chi-square (χ^2) and root mean square error (*RMSE*) can be calculated as follows;

$$\chi^2 = \frac{\sum_{i=1}^{N}\left(MR_{exp,i} - MR_{pre,i}\right)^2}{N - Z} \quad \ldots(4)$$

Where,

$MR_{exp,i}$ = is the i^{th} experimental moisture ratio,

$MR_{pre,i}$= is the i^{th} predicted moisture ratio ,

N = is the number of observation, and

z = is the number of constant.

The non-linear regression analysis was performed by using the statistical software SAS 6.5.

4. Effective moisture diffusivity

The effective moisture diffusivity was calculated by using the simplified Fick's second law of diffusion model (Doymaz, 2004) as given in Eq (5).

$$\frac{\partial M}{\partial t} = D_{eff}\,.\nabla^2 M \quad \ldots(5)$$

Where,

M = moisture content (kg water/kg dry matter);

t = time (s);

D_{eff}= effective moisture diffusivity, (m^2/s);

∇^2 = differential operator.

The solution of Fick's second law in sphere geometry, with the assumption that moisture migration was caused by diffusion, negligible shrinkage, constant diffusion coefficient and temperature was given by Crank (1975) as follows:

$$MR = \frac{8}{\pi^2}\sum_{i=1}^{n}\frac{1}{(2n-1)^2}exp\left(\frac{-(2n-1)^2\pi^2 D_{eff}t}{4H^2}\right) \quad \ldots(6)$$

Where,

H = is the half thickness of the slab m;

n = 1, 2, 3 … the number of terms taken into consideration.

For long drying time Eq (7) can be simplified further (Lopez *et al.* 2000; Doymaz, 2004) as:

$$ln(MR) = ln\frac{8}{\pi^2} - \frac{\pi^2 D_{eff}t}{4L^2} \quad \ldots(7)$$

The diffusivities are typically determined by plotting the experimental drying data in the terms of ln (MR) vs drying time (t) in equation (8), because the plot gives a straight line with the slope as follows:

$$Slope = \frac{\pi^2 D_{eff}}{4L^2} \quad \ldots(8)$$

Where,

L= half thickness

Evaluation of Quality parameters for the grape raisins

1. Total soluble solids

The TSS was determined by using hand refractometer (M/s. Atago, Japan) and the values were corrected at 20^0 C with the help of temperature correction table (Mazumdar and Majumder, 2003). For the fresh berries, the grapes were squeezed and extracted the juice. The fresh juice was placed on prism plate to record the visible value on scale. The reading of juice sample as °Brix was obtained and digital reading of the Total soluble solids expressed accordingly. Three observations were taken for replication.

For the raisins, 5 g of raisins sample was crushed and mixed with 15 ml of distilled water (A.O.A.C. 1990). Then the juice prepared was used for the TSS determination. The TSS of the juice was determined as per the procedure explained earlier. Three observations were taken and used as a replications.

2. Titratable acidity

Acidity of fresh berries and raisins were estimated adopting the procedure given by Ranganna (1978). The fresh berries of grapes was crushed and juice was extracted. 10 ml of juice was extracted and diluted to the volume of 100 ml with distilled water. Using phenolphthalein indicator, 10 ml of diluted juice was titrated against 0.1 N NaOH till it changed juice to pink colour of end point.

Titrable acidity of raisins was determined as per the procedure (A.O.A.C., 1975). 10 g of sample was grounded and added with small quantity of distilled water. The content was filtered using filter paper. 10 ml of filtrate was used for titration to estimate the acidity as was done for fresh juice. The titrated acidity was expressed in percentage.

$$\text{Titratable acidity (\%)} = \frac{N \times T \times E}{W \times V \times 1000} \times 100 \quad \ldots(9)$$

Where,

N = Normality of alkali

T = Titrate reading, ml

E = Equivalent mass of acid, g

W = Weight of the sample, g

V = Total volume of the sample, g

3. pH:

pH of fresh grape and dried grapes (raisins) for Treatment T_1 and Treatment T_2 was measured using digital pH meter. The digital pH meter is firstly calibrated by using 4 pH and 7 pH buffer solution. The electrode was washed with distilled water and blot led with tissue paper. 10 ml of fresh grape juice was taken in beaker, then the tip of electrode and temperature probe was then submerge in to the sample. The pH reading display on the primary LCD and temperature on secondary one. The pH of fresh grape juice was determined by three replication.

Grape raisins were dissolved in distilled water 1:2.5 (sample: water) and kept for 4 hours (Babaji, 2009). There after the solution was stirred well and the pH of the solution was determined as per the procedure explained earlier.

4. Reducing sugars

The reducing sugars of berries was determined as per procedure of Ranganna (1978). 10 ml of fresh grape juice was squeezed was grounded well into juice with 20 ml of water then the sample juice volume was made up to 100 ml with distilled water using volumetric flask. And for raisins, 10 g of sample was grounded well into juice with 20 ml of water then the sample juice volume was made up to 100 ml with distilled water using volumetric flask. This solution was neutralized with 20 % NaOH using few drops of phenolphthalein indicator until the solution turned pink and acidified with 1 N HCl until it caused pink colour disappeared. To this 2 ml of 45 % lead acetate was added, shaken well and kept to settle for 10 minutes. Then 2 ml of 22 % potassium oxalate was added to remove excess lead and the volume was made up to 250 ml with distilled water. The content was filtered using filter paper. Reducing sugars in the lead free extract was then estimated by taking the solution into burette and titrated against mixed Fehling's solutions (A and B).

10 ml of mixed Fehling's solution taken into 250 ml conical flask to which 50 ml of water was added and ran the burette into flask to the required volume of sugar solution as was prejudged incrementally to reduce the Fehling's solution which indicated by turning the solution to brick red colour on boiling. Then the boiling was continued for 2 minutes and added methylene blue indicator, titrated with sugar solution on heating until indicator was completely decolorized and formed brick red colour precipitate which was the end point. The titrate value obtained and calculated as below (Eq. 10). The experiment was repeated three times to get the replication.

Reducin gsugar % =

$$\frac{100}{Burette\ reading} \times \frac{Volume\ prepared}{Inital\ volume} \times GV\ of\ fehling'ssolution \quad \ldots(10)$$

Where,

GV = Glucose value

5. Total sugars

Total sugars of fresh berries and raisins were for Treatment T_1 and Treatment T_2 estimated adopting the Lane and Eynon method (Ranganna, 1978). Exactly 50 ml of lead free filtrate was taken to 100 ml volumetric flask. To it 10 ml of HCl (5 ml Conc HCl + 5 ml water) was added and allowed remain stand for 24 hours at ambient temperature in dark room. The invert solution was neutralized and the volume was made up to 100 ml with distilled water. This solution was taken in to burette and titrated against mixed Fehling's solutions as was done for reducing sugars. The aliquot was determined as invert sugars and the total sugars content was calculated below (Eq.11). The experiment was repeated three times to get the replication.

Total sugar (%) =

$$\frac{Factor \times Dilution}{Titre\ reading \times Weightn\ of\ sample} \times 100 \quad \ldots(11)$$

6. Non-Reducing Sugars

The non-reducing sugars present in the samples were derived by deducting the reducing sugars from total sugars.

% Non-reducing sugars = [% of Total sugars – % of Reducing sugars]

7. Ascorbic acid (Vit. C)

The ascorbic acid (vit. c) was determined for fresh grape juice samples and grapes raisins for Treatment T_1 and Treatment T_2 respectively. Determination of ascorbic acid was done by 2, 6-dichlorophenol indophenol dye method of Johnson (1948) as described by Ranganna (1986). 3% metaphosporic acid (HPO_3) is prepared by dissolving sticks of HPO_3 in distilled water, Dye solution was made up by adding 2,6 dichlorophenol indophenol and standardise with standard ascorbic acid. Fresh grapes are crushed into mortal and pestle and a crushed grapes sample of 10g was mixed with 3% metaphosphoric acid solution and volume was made to 100 ml using volumetric flask. The extract was filtered by using filter paper.10ml aliquot was taken by using pipette into the conical flask and titrated against standard dye solution at room temperature. End point of the titration was pink colour. The ascorbic acid content of the fresh grapes was calculated taking into consideration the dye factor as given below.

For grape raisins, 10 g raisins were taken from each replication was grounded well using small amount of 3% meta-phosphoric acid (HPO_3) and the volume was made up to 100 ml with 3% meta-phosphoric acid using volumetric flask. The ascorbic acid determination procedure was performed as per the procedure discussed earlier.

Ascorbic acid mg/100g =

$$\frac{Titre\ value \times Dye\ Factor \times Volume\ made\ up}{Aliquate\ of\ extract\ taken\ for\ estimation \times Weightn\ of sample} \times 100 \quad \ldots(12)$$

8. Colour

The fresh grapes and dried grapes was used to measure the colour value (*L*, *a* and *b*) by using colorimeter (Konica Minotta, Japan model-Meter CR-400). The equipment was calibrated against standard white tile and black tile. Around 20 g of fresh grape and dried grapes (grape raisins) was taken in the glass petri dish, the equipment was placed on the sample petri dish. The colour was recorded in terms of *L*= lightness (100) to darkness (0); *a* = Redness (+60) to Greenness (-60); *b* = yellowness (+60) to blueness (-60). The yellowness index of the fresh grapes and grapes raisins was determined from *L*, *a*, and *b* values as per equation (13) reported by (Rhim *et al.* 1999)

$$YI = \frac{142.86\,b}{L} \quad \ldots(13)$$

Where,

L = Lightness to darkness

B = Yellowness to blueness

9. Hardness

The texture of fresh grape and dried grape raisins measured with TexVol instruments TVT-300 XP texture analyser. A fresh grape and dried grape sample was placed on a hollow planar base to compression test with spherical probe and size 5 mm diameter and pre-test speed was 0.5 mm/s, compression depth was 4.5 mm and trigger force was 5 g for fresh grapes and dried grapes. The maximum compression force of a rupture test of each sample was used to describe the sample texture in terms of hardness. All tests were triplicated and the average values were reported

Sensory analysis

The sensory attribute of dried grapes (raisins) of Treatment 1 and Treatment 2 was determined with trained panelists as per nine point hedonic scale. The Panelists were trained for the product testing and were familiar with product sensory evaluation. The dried grapes (raisins) samples were placed into petri dish dried grapes (raisins) were coded as A and B for evaluation of sensory parameter i.e. colour, flavor, texture and taste attributes. Code A and B for Treatments T_1 and T_2 and code C was for control sample. The rating was based on nine- point hedonic scales. 09 scales for colour, 09 scales for flavour attribute, 09 scales for texture attribute and 09 scales for taste. The attribute were summed up for total score 36 for each panelist for each Treatment. The average score for total 14 panelists have been reported. The data were analyzed statistically for the significance of each attributes by ANOVA.

RESULTS AND DISCUSSION

Fig. 3 shows moisture content (db) % with respect to time (min) of grapes treated with T_1 (2.5% NaOH plus 2% KMS) and T_2 (2.5% potassium carbonate + 2% ethyl oleate) dried by solar drying. The grapes were dried from average initial moisture content of 370.57% (db) to 14.39% (db) for Treatment 1 and 405.25% (db) to 14.65% (db) for Treatment 2. It took around 7 days (52 hrs) and 6 days (45 hrs) to dry the product with pre-treated with Treatment 1 and Treatment 2, respectively.

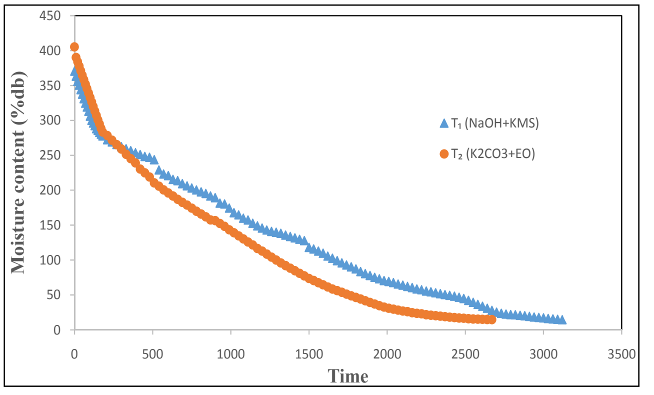


Fig. 3: Moisture content %(db) versus time (min) solar drying for grape

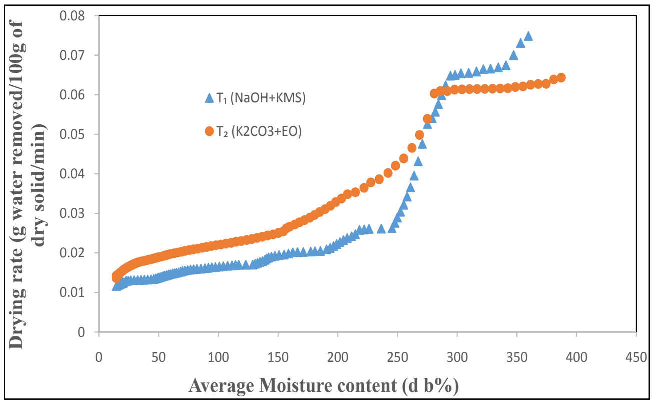


Fig. 4: Drying rate (g water removed/100 g of bone dry material/min) versus moisture content % (db) of grape dried by solar drying

Fig. 4 shows the drying rate (g water removed/100 g of bone dry material; /min) with respect to moisture content % (db) of grapes dried by solar drying. The drying took place in falling rate period for the both treatments. Similar behaviour had been observed in the literature for grape sample was soaked in alkali solution (1% of sodium hydroxide) heated to 90°C for 3 second and solar drying (Hamdi *et al*. 2018). The initial drying rate of treated grapes decreases from 0.0748 g to 1.2 × 10^{-2} g water removed /100g of dry solid/min and 0.0643 g to 1.3 × 10^{-2} g water removed /100g of dry solid/min for Treatment T_1 and Treatment T_2, respectively.

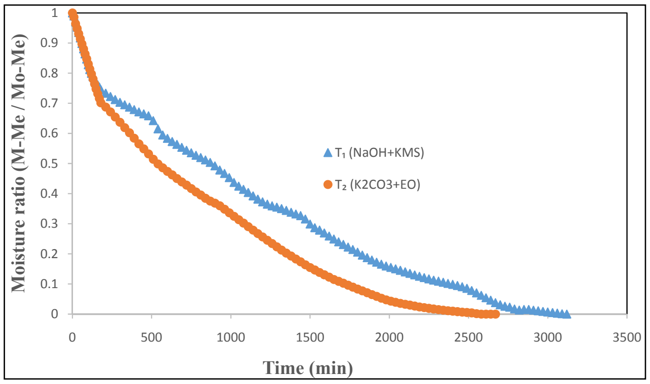


Fig. 5: Variation in moisture ratio with respect to time, min for grape during solar drying

Fig. 5 shows variation in moisture ratio with respect to time in minute. During the drying experiment moisture ratio decreases from 1 to 5.2×10^{-7} and 1 to 2.22×10^{-6} for the pre-treatment solution Treatment-1 and Treatment-2, respectively. Similar curve was observed for sultana grapes by solar drying (yaldiz *et al*. 2001).

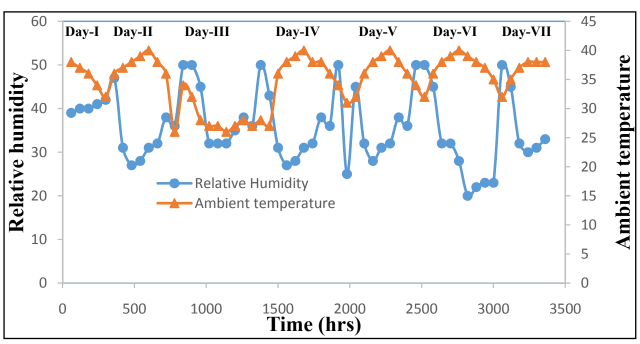


Fig. 6: Variation in ambient temperature and relative humidity with time in solar drying of grapes

Fig. 6 shows the change in the ambient temperature (°C) and relative humidity (%) with respect to the time during the 7 days (54 hrs) of solar drying. The product temperature ranges from 34.7 to 54.2°C and relative humidity ranges from 20 to 50 %.

Fig. 7 shows the variation in product temperature, ambient air temperature variations with respect to time during 6 days of drying of grapes. The average product temperature was 44.90°C. The average solar temperature was 50.19°C. The ambient air temperature was in the range 27-40°C. The product temperature ranges from 34.7 to 54.2°C.

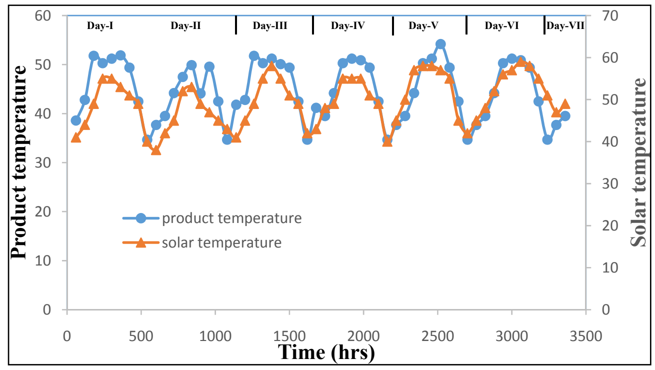


Fig. 7: Variation in product temperature and ambient air temperature with time

Evaluation of thin layer-drying model of grape pre-treated with Treatment T_1 and dried by solar drying

Table 2 shows the model parameters of various model fitted to the experimental data for solar drying of grape. Newton model, Page model, Henderson and pabis, Exponential, Logarithmic etc.

Among the models fitted to the experimental data for Treatment-1 and Treatment-2, the Henderson and pabis drying model was well fitted to the experimental data with $r^2 = 0.9825$, MSE = 1.712×10^{-3}, chi square (χ^2) = 0.1949 for Treatment-1 and Exponential two term drying model was well fitted to the experimental data with $r^2 = 0.9902$, MSE= 1.045×10^{-3}, chi square (χ^2) = 0.1045 for Treatment-2.

Table (2 and 3) shows the statistical regression results of the different models, including the drying model coefficients and comparison criteria used to evaluate goodness of the fit including the r^2, χ^2 and RMSE of grape at solar drying. Non-linear regression analysis was done according to the nine thin layer models for moisture ratio data. In solar drying and pre-treated with Treatment-1and Treatment-2 case r^2 values for the model were equal to 0.9825 and 0.9902 indicating a good fit. The model parameters like '*a*' and '*k*' are the characteristics constant, k is diffusivity (diffusion coefficient and it is temperature dependent). The model parameter i.e a = 0.9419,

Table 2: Model parameters, R^2, RMSE and Chi square ($\chi 2$) values of grape pre-treated with Treatment (T_1) and dried by solar drying

Sl. No.	Model name	Model Parameters	R^2	MSE	χ^2
1	Newton	k= 9.026×10^{-4}	0.9786	2.228×10^{-3}	0.2585
2	Page	k= 1.258×10^{-3} n=0.9538	0.9774	2.1910×10^{-3}	0.2519
3	Modified Page	k= 9.110×10^{-4} n=0.9538	0.9774	2.1910×10^{-3}	0.2519
4	Henderson and Pabis	a= 0.9419 k= 8.451×10^{-4}	0.9825	1.694×10^{-3}	0.1949
5	Exponential	k= 9.026×10^{-4}	0.9786	2.228×10^{-3}	0.2585
6	Exponential two term	a= 0.0584 k= 1.450×10^{-2}	0.9818	1.712×10^{-3}	0.1969
7	Modified Page equation-II	K= 0.6830 L= 27.1308 n= 0.9538	0.9774	2.191×10^{-3}	0.2519

Table 3: Evaluation of thin layer-drying model of grape pre-treated with Treatment-(T_2) and dried by solar drying

Sl. No.	Model name	Model Parameters	R^2	MSE	χ^2
1	Newton	k=1.281×10^{-3}	0.9865	1.513×10-3	0.1529
2	Page	k=2.076×10^{-3} n=0.9297	0.9867	1.373×10^{-3}	0.1373
3	Modified Page	k=01.302×10^{-3} n=0.9297	0.9867	01.373×10^{-3}	0.1373
4	Henderson and Pabis	a= 0.9501 k=1.208×10^{-3}	0.9890	1.154×10^{-3}	0.1154
5	Exponential	k=1.281×10^{-3}	0.9865	1.513×10^{-3}	0.1529
6	Exponential two term	a= 0.0734 k=1.608×10^{-2}	0.9902	1.045×10^{-3}	0.1045
7	Modified Page equation-II	K= 0.2081 L=11.9139 n=0.9297	0.9867	1.373×10^{-3}	0.1373

k = 8.451×10^{-4} for Treatment-1 and a = 0.0734, k = 1.608 × 10^{-2} for Treatment-2. Yaldiz *et al*. 2001 reported the two-term drying model was well fitted to the solar drying of grape.

Effective moisture diffusivity of grapes dried by solar drying

Fig. 8 shows Ln (MR) versus time (minute) for solar drying of grape and pre-treated with Teatment-1 and Treatment-2. The graph shows the straight line curve. The straight line equation $y = mx + c$ where the m is the slope of line. Effective diffusivity (D_{eff}) at time for treated grape which was calculated by equation (5). Effective Diffusivity (D_{eff}) at time (t) for treated Grape dried by solar drying for Teatment-T_1 and Treatment-T_2 was 7.6 × 10^{-9} m^2/s and 1.27 × 10^{-8} m^2/s respectively. The generally, effective diffusivity is used to explain the mechanism of moisture movement during drying and complexity of the process (Kashaninejad *et al*. 2007; Falade and Solademi, 2010). Similar kind of results have been observed for grape treated with 4% potassium carbonate plus 1% olive oil was ranged from 1.048 × 10^{-10} m^2/s to 6.919×10^{-10} m^2/s (Doymaz and Altiner, 2012) also this values lie within the general range of 10^{-12} to10^{-8} m^2/s for the food material.

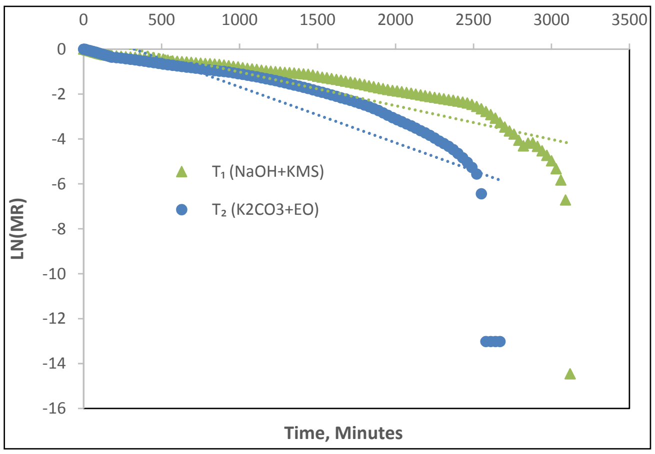


Fig. 8: LN (MR) versus Time (Minutes) Treatment-1 and Treatment -2 pre-treated Grapes dried with solar drying Method

Quality composition of dried grapes

Table 4 shows the various quality parameters (a) moisture, (b) TSS, (c) pH, (d) titratable acidity, (e) reducing sugar, (f) total sugar, (h) yellowness index of grapes before drying fresh samples and after drying Treated grapes (T1 and T2) by solar drying.

1. Moisture content

Table 4 (a) shows the moisture content of grapes before drying and after drying. The moisture content of grapes before drying was 405.27% (db) for Treatment-1 and Treatment-2 and the moisture content ranged after drying from 14.56±4.06 to 14.54±3.80 % (db) in both T_1 and T_2. The moisture content was 14.56% (db) in Treatment-1and 14.54 % (db) in Treatment-2.

The moisture content at Treatment-1 and Treatment-2 are significantly different at p≤0.05. Irrespective of pre-treatment methods and conditions of the drying, moisture content of grapes decreases after drying. Lowest changes of moisture content was observed in Treatment T_1 than Treatment T_2 drying of grapes followed by solar drying. The decreases in moisture content of grapes after solar drying was significant at p≤0.05.

Adsule and Banerjee (2003), Winkler *et al.* (1962), Gowda *et al.* (1997) reported the desirable moisture content for grape raisins are 15.00 to 16.50%; 10 to 15 % and 14.1 to 14.9% respectively.

2. Total soluble solids

Table 4 (b) shows the total soluble solids of grapes before drying and after drying. The total soluble solids of grapes before drying was 19.90.492°B and the TSS in-creased after drying from 72 to 74 °B in both Teatment-1and Treatment-2. The TSS was 71.33±1.15^{0}B in Treatment-1 and 73.88±0.20^0 B in Treatment-2. The total soluble solids at Treatment-1 and Treatment-2 are significantly different at p≤0.05. Irrespective pre-treatment solution and conditions of the drying, TSS of grapes increases after drying. The increases in total soluble solids of grapes after solar drying might be attributed due to concentration of fruit flavours and mass/solids during drying. TSS was increased more in Treatment-2.

Mane *et al.* (2003) reported that TSS of grape raisins was 79.8 for Manikchaman variety.

3. Titratable acidity

Table 4 (c) shows the titratable acidity of grapes before drying and after drying. The titratable acidity of grapes before drying was 0.670.17 and the titratable acidity increases after drying from 2.50 to 2.63 % in both Teatment-1and Treatment-2. The titratable acidity was 2.60±0.04 % for Treatment-1 and 2.52±0.04% for Treatment-2. The total soluble solids at Treatment-1 and Treatment-2 are significantly different at p≤0.05. Irrespective of pre-treatment methods and conditions of the drying, titratable acidity of grapes increases after drying. Lowest changes of titratable acidity was observed in Treatment-2 as compared to Treatment-1.

Gowda *et al.* (1997); Dan *et al.* (1977) reported that acidity of grape raisins were in the range from 1.92 to 2.53% and 1.22 to 2.27% respectively.

4. pH

Table 4 (d) shows the pH of grapes before drying and after drying. The pH of grapes before drying was 4.3±

0.173 and observed that pH was no more changes after drying. It was 3.90 to 4.20 in both Teatment-1and Treatment-2. The pH was 3.97 ± 0.12 in Treatment-1and 4.13 ±0.21 in treatment-2 solution. The increases in pH of grapes after drying might be attributed due to the effect of air on solid content. Lowest changes of pH was observed in both pre-treatment solution of grapes followed by solar drying. The pH at Treatment 1 and Treatment-2 are significantly different at $p \le 0.05$.

Doneche (1990) observed that pH range 2.8 to 6 of raisin prepared by different pre-treatments from Thompson seedless cultivar. Tupe (2007) observed that pH of raisins prepared by different pre-treatments ranged from 2.00 to 4.65 in Thompson seedless.

5. Reducing sugar

Table 4 (e) shows the reducing sugar of grapes before drying and after drying. The reducing sugar of grapes before drying was 17.395 ± 0.716 % and the reducing sugar increased after drying from 62.50 to 64.93 % in both Teatment-1and Treatment-2. The reducing sugar was 63.03±0.46 % in treatment-1and 64.65±048 % in Treatment-2. The Reducing sugar at Treatment-1 and Treatment-2 are significantly different at $p \le 0.05$. Irrespective of pre-treatment methods and conditions of the drying, reducing sugar of grapes increases after drying. Lowest changes of reducing sugar was observed in Treatment-1 as compared to Treatment-2 of grapes followed by solar drying.

The increases in reducing sugar of grapes after solar drying might be attributed due to concentration of fruit flavours and mass/solids during drying. This increase of reducing sugar was significant at $p \le 0.05$. Gowada *et al*. 1997; Beslic *et al.* 2009 reported that reducing sugar in raisins 68% and 68.2% respectively.

6. Total sugar

Table 4 (f) shows the total sugar of grapes before drying and after drying. The total sugar of grapes before drying was 19.417± 0.087% and the total sugar increased after drying from 64.10 to 66.66 % in both Teatment-1and Treatment-2. The total sugar was 64.66±0.97 % in treatment-1and 66.13±0.46 in Treatment-2 solution. The total sugar at Treatment 1 and Treatment-2 are significantly different at $p \le 0.05$. Irrespective of pre-treatment methods and conditions of the drying, total sugar of grapes increases after drying. Lowest changes of total sugar was observed in Treatment-1 solution as compared to Treatment-2 of grapes followed by solar drying.

The increases in total sugar of grapes after solar drying might be attributed due to moisture inside the cell membrane started diffusing outward from centre to surface and sub-surface water to ambient and leaving behind solid content. With progression of drying, most of free water evaporated and only solid remained. Dan *et al*. (1977) prepared raisins from different varieties and reported the total sugars content ranging from 58.09 to 62.00 per cent. (Gowada *et al*. 1997) reported that total sugar in raisins 68.6% for Thompson seedless variety grape raisins.

7. Non-reducing sugar

Table 4 (g) shows the non-reducing sugar of grapes before drying and after drying. The non-reducing sugar of grapes before drying was 2.015 ± 0.751% and observed that non-reducing sugar was no more changes after drying. It was 0.82 to 2.49 % in both Teatment-1and Treatment-2. The non-reducing sugar was 1.64 ± 0.84 % in Treatment-1and 1.48±0.39 in Treatment-2 solution. Lowest changes of non-reducing sugar was observed in pre-treatment solution of grapes followed by solar drying. The Non-reducing sugar at Treatment-1 and Treatment-2 are significantly different at $p \le 0.05$.

Mane *et al.* (2003) reported non-reducing sugars from 3.50 to 4.80 per cent in grape raisins.

8. Ascorbic acid

Table 4 (h) shows the ascorbic acid of grapes before drying and after drying. The ascorbic acid of grapes before drying was 5.88 ± 0.740% and the ascorbic acid increased after drying from 21.00 to 21.50 % in both Teatment-1and Treatment-2. The ascorbic acid was 21.20±0.05 % in Treatment-1and 21.33±0.29 in

Treatment-2 solution. The ascorbic acid at Treatment 1 and Treatment-2 are significantly different at $p \leq 0.05$. Irrespective of pre-treatment methods and condition of the drying, ascorbic acid of grapes increases after drying. Lowest changes of ascorbic acid was observed in Treatment-1 solution as compared to Treatment-2 solution of grapes followed by solar drying.

The increases in ascorbic acid of grapes after solar drying might be attributed due to moisture inside the cell membrane started diffusing outward from centre to sur-face and sub-surface water to ambient and leaving behind solid content. With progression of drying, most of free water evaporated and only solid remained.

Chavan *et al*. 1992; Kulkarni *et al.* (1986) reported ascorbic acid 21.1 to 31.3 and 7.6 to 15.5 mg per 100 g of raisins prepared by various methods.

9. Colour

Table 4 (i) shows the yellowness index of grapes before drying and after drying. The yellowness of grapes before drying was 81.35 ± 0.99 and the yellowness' decreases after drying from 66.38 to 67.45 in Teatment-1. The yellowness index increases 85.83 to 86.26 in Treatment-2. The yellowness index was 68.26±2.39 in Treatment-1 and 86.15± 0.28 in Treatment-2. The colour (yellowness) at Treatment -1 and Treatment-2 are significantly different at $p \leq 0.05$. Increases in yellowness index was observed in Treatment-2 solution of grapes followed by solar drying.

Doymaz (2002) reported that colour L, a and b values of grapes raisins was in the range of 17.37-22.31, 3.84-4.55 and 4.28-5.27, respectively and yellowness index was 35.20 to 33.74.

Matteo *et al*. (2000) reported that colour L, a and b value of grapes raisins was 41.8±6.8. 2.5±0.2 and 13.8±0.9, respectively and yellowness index was 47.16.

10 Hardness

Table 4 (j) shows the hardness of grapes before and after drying. The hardness of grapes before drying from 0.60 to 0.64 N and hardness increases after drying from 5.03 to 10.51 N in both Teatment-1and Treatment-2. The hardness was 5.58 ± 0.88 N in Treatment-1and 8.57 ± 1.68 N in Treatment-2. Hardness of the grapes raisins increased with increase in rate of drying in Treatment T_2 that has the case hardening effect on the grapes the hardness increased for Treatment T_2. Xiao *et al*. (2010) reported that hardness of fresh grape was 0.62 ± 0.14 and grape raisins was 9.53 ± 0.6 N when dried at 50^0C.

Table 4: Quality parameter of grapes before and after drying

Quality parameter	Before drying	Treatment T_1 = 2.5% NaOH for 2-3 sec + 2%KMS+solar drying	Treatment T_2 = 2.5% potassium carbonate + 2% ethyle oleate+ solar drying	S.E $_m$(±)	C.D at 5 %
(a) Moisture content (%)	405.27±0.745	14.56±4.06	14.54±3.80	1.86	6.42
(b) Total soluble solids(^{0}B)	19.9 ± 0.492	71.33±1.15	73.88±0.20	0.39	1.35
(c) Titratable acidity (%)	0.678 ± 0.020	2.60±0.04	2.52±0.04	0.02	0.06
(d) pH	4.3± 0.173	3.97±0.12	4.13 ± 0.21	0.08	0.27
(e) Reducing sugar (%)	17.395± 0.716	63.03±0.46	64.65±0.48	0.27	1.06
(f) Total sugar (%)	19.417 ± 0.087	64.66±0.97	66.13±0.46	0.36	1.24
(g) Non-reducing sugar	2.015± 0.751	1.64±0.84	1.48±0.39	0.31	1.06
(h) Ascorbic acid(mg)	5.88±0.740	21.20±0.05	21.33±0.29	0.10	0.34
(i) Colour (yellowness)	81.35±0.99	68.26±2.39	86.15± 0.28	0.80	2.78
(j) Hardness (N)	0.66± 0.14	5.58 ± 0.88	8.57± 1.68	0.63	2.19

Treatment T_1

Treatment T_1

Fig. 9: Photograph of the raisins prepared from Treatment T_1 and Treatment T_2

Based on the nutritional analysis and the hardness and Yellowness index the raisins of treatment T_2 has better TSS, Titrable acidity, Reducing sugar, total sugar and ascorbic acid and better hardness and yellowness index.

Best treatment from Treatment (T_1) and Treatment (T_2)

The desirable qualities of grape raisins are the raisins should have more TSS, more Titrable acidity, more Reducing sugar, more total sugar, more ascorbic acid, more yellowness index and more hardness.

1. Colour

Table 5 (a) shows sensory score for colour ranged from 6.42 to 8.2, the higher score 8.2 for control Treatment T_2. The colour of control Treatment highly accepted by the sensory panelist. The sensory values for colour were non-significant at $p \leq 0.05$.

2. Flavour

Table 5 (b) shows sensory score for flavour ranged from 6.90 to 7.90, the higher score 7.90 for Treatment-2. The flavour of Treatment-2 highly accepted by the sensory panelist. The sensory values for flavour were non-significant at $p \leq 0.05$.

3. Texture

Table 5 (c) shows sensory score for texture ranged from 7.06 to 8.22, the higher score 8.22 for Treatment-2. The texture of Treatment-2 highly accepted by the sensory panelist. The sensory values for texture were non-significant at $p \leq 0.05$.

4. Taste

Table 5 (d) shows sensory score for taste ranged from 6.85 to 8.08, the higher score 8.08 for Treatment-2. The taste of Treatment-2 highly accepted by the sensory panelist. The sensory values for taste were non-significant at $p \leq 0.05$.

5. Overall acceptability

Table 5 (e) shows sensory score for Overall acceptability ranged from 6.95 to 8.15, the higher score 8.15 for Treatment-2. The Overall acceptability of Treatment-2 highly accepted by the sensory panelist. The sensory values for Overall acceptability were non-significant at $p \leq 0.05$.

From the data of quality analysis of dried grapes (i.e. acidity, pH, TSS, reducing sugars, total sugars, non-reducing sugar, ascorbic acid, hardness, colour (yellowness), drying time) for treatment T_1 and Treatment T_2 showed that Treatment T_2 had highest retention of quality parameter as compare to Treatments T_1. The best sensory score of the product have been obtained from sensory analysis which was grapes pretreated with Treatment T_2 and dried

Table 5: Sensory score of grapes pretreated with Treatment T_1 and T_2 and dried by solar drying

Parameter	Control	Treatment 1	Treatment 2	SEm(±)	CD 5% @ p≤0.05
Colour (a)	7.12	6.42	8.2	3.18	9.12
Flavour (b)	7.45	6.90	7.90	2.90	8.57
Texture (c)	8.0	7.06	8.22	2.40	6.86
Taste (d)	7.25	6.85	8.08	2.49	7.13
Overall acceptability (e)	7.49	6.95	8.15	2.20	6.32

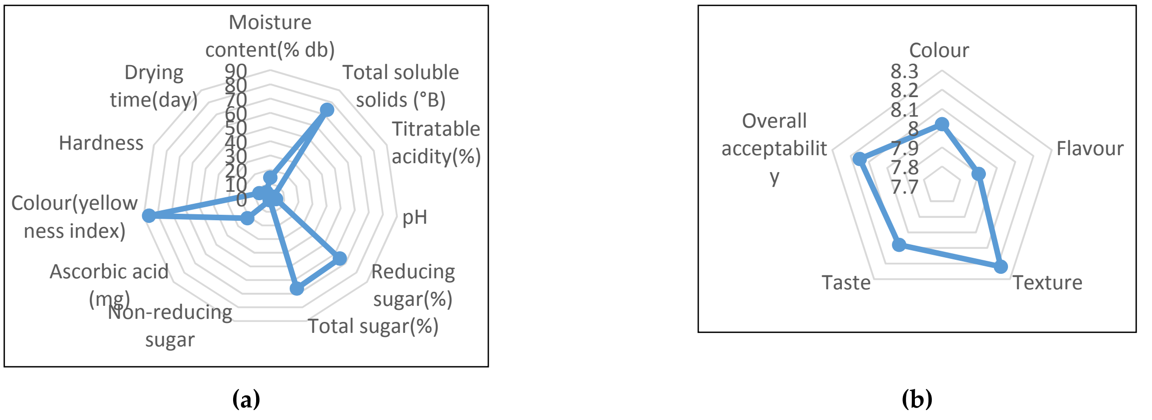


Fig. 8: (a) Quality analysis and **(b)** sensory analysis of grapes pretreated with Treatment T_2 and dried by solar drying

by solar drying had achieved the highest colour 8.02, flavour 7.9, texture 8.22 and taste 8.08 .From the both quality properties, colour measurement and the sensory analysis the best product i.e. grapes pretreated with Treatment T_2 and dried by solar drying satisfactorily retains parameter with desirable quality.

Conclusions:

1. The grapes were dried from average initial moisture content of 370.57% (db) to 14.39% (db) for Treatment 1 and 405.25% (db) to 14.65% (db) for Treatment 2. It took around 6, 5 days to dry the product with pre-treated with Treatment-1and Treatment-2, respectively.
2. Among the models fitted to the experimental data to Treatment-1 and Treatment-2, the Henderson and pabis drying model was well fitted to the experimental data with $r^2 = 0.9825$, MSE = 1.712×10^{-3}, chi square (2) = 0.1949 for Treatment-1 and Exponential two term drying model was well fitted to the experimental data with $r^2 = 0.9902$, MSE= 1.045×10^{-3}, chi square (**2**) = 0.1045 for Treatment-2.
3. Effective Diffusivity (D_{eff}) at time (t) for treated Grape dried by solar drying for Teatment-T_1 and Treatment-T_2 was 7.6×10^{-9} m²/s and 1.27×10^{-8} m²/s respectively.
4. Grapes pretreated with Treatment T_2 and dried by solar drying satisfactorily retains parameter with desirable quality parameter moisture content of raisins was 14.54%, TSS 73.88 ^{0}B, Titrable acidity 2.52 %, pH 4.13, Reducing sugar 64.65 %, Total sugar 66.13 %, Non-reducing sugar 1.48 , Ascorbic acid 21.33 mg, yellowness 86.15 and hardness 8.57 for Treatment-2.

REFERENCES

A.O.A.C. (1975). Official methods of analysis, 11th Ed. Association of Official Analytical Chemists, Washington, D.C.

A.O.A.C. (1990). Official methods of analysis, 15th Ed. Association of Official Analytical Chemists, Arlington, V.A.

Adsule, P. G., and Banerjee, K. (2003). Standardisation of Quality of Indian Raisins with Reference to Codex Standards and Harmonisation of Indian Standards. Indian Food Packer, 57(4), 59-65.

Babaji, J. P. (2009). "Studies on raisin making in grape cv. thompson seedless" (Doctoral dissertation, jau, junagadh).

Beslic Z Todic S and Sivcev B, (2009). Inheritance of yield components and quality of grape in hybridization of grapevine cultivars. Acta Horticulture Vol.827: pp 501-503.

Bolin, H. R., & Sta€ord, A. E. (1980). Fatty acid esters and carbonates in grape drying. J. of Food Science, 45, 754±755.

Bolin, H. R., Petrucci, V., & Fuller, G. (1975). Characteristics of mechanically harvested raisins produced by dehydration and by ®eld drying. Journal of Food Science, 40, 1036±1038.

Chakraverty A. (1994). Post-harvest technology of cereals, pulses and oilseeds. New Delhi Oxford and IBH Publishing Co, Third Edition.

Chakraverty, A. (2005). Post-Harvest Technology of cereals, Pulses and oilseeds, 3rd Edition, oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, 54-55.

Chavan U D, Adsule R N and Kadam S S, (1992). Raisins from Gibberelic acid treated grapes. Drakshavritta, 12 (6): 75-76.

Crank J. (1975). Mathematics of diffusion, second edition, London: Oxford university press.

Dan, A., Pandey, S. N., and Anand, J. C. (1977). Studies on Raisin Production From Grapes (*Vitis vinifera*) Grown Under Delhi Conditions. Indian J. of Horti., 34(3), 215-219.

Di Matteo M, Cinquanta L, Galiero G, Crescitelli S (2000) Effect of a novel physical pretreatment process on the drying kinetics of dipping on thin-layer drying characteristics of seedless grapes. Biosyst Eng., 98, 411-421.

Doneche, B (1990): metabolism of tartaric acid of grapes by botrytis cinerea .sci.alim. 10 (3), 589-602.

Doymaz, I. (2004). Convective air drying characteristics of thin layer carrots. Journal of Food Engineering 61(3); 359-364. 90

Doymaz, I., (2006). Drying kinetics of black grapes treated with different solutions. J. Food Eng., 76, 212-217.

Doymaz, İ., and Altıner, P. (2012). Effect of pretreatment solution on drying and color characteristics of seedless grapes. Food Science and Biotechnology, 21(1), 43-49.

Doymaz, I., and Pala, M. (2002). The effects of dipping pretreatments on air-drying rates of the seedless grapes. Journal of Food Engineering, 52(4), 413-417.

El-Sebaii, A. A., Aboul-Enein, S., Ramadan, M. R. I., & El-Gohary, H. G. (2002). Empirical correlations for drying kinetics of some fruits and vegetables. Energy, 27(9), 845-859.

Ertekin, C., and O. Yaldiz. (2004). Drying of eggplant and selection of a suitable thin layer drying model. Journal of Food Engineering 63.3: 349-359.

Fadhel, A., Kooli, S., Farhat, A., & Bellghith, A. (2005). Study of the solar drying of grapes by three different processes. Desalination, 185(1-3), 535-541.

Falade K. O. and Solademi O. J. (2010). Modelling of air drying of fresh and blanched sweet potato slices. International Journal of Food Science and Technology. 45, 278-288.

FAOSTAT (2010) Food and Agriculture Organization of the United Nations (FAO). FAOSTAT Database. www.fao.org/statistics/databases/en/

GOWDA, I. D., Singh, R., and Murthy, B. N. S. (1997). Evaluation of new grape hybrids for dehydration. Journal of Food Science and Technology-Mysore, 34(4), 286-290.

Hamdi, I., Kooli, S., Elkhadraoui, A., Azaizia, Z., Abdelhamid, F., & Guizani, A. (2018). Experimental study and numerical modeling for drying grapes under solar greenhouse. Renewable Energy, 127, 936-946.

Henderson S.M and Pabis S (1961). Grain drying theory. I. Temperature effect on drying coefficient. Journal of Agricultural Engineering Research, 6; 169-174.

Henderson, S. M. (1974). Progress in developing the thin layer drying equation. Transactions of the ASAE, 17, 1167–1172.

Kashaninejad M., Mortazavi A., Safekordi A. and Tabil L. G. (2007). Thin layer drying characteristics and modelling of pistachio nuts. Journal of Food Engineering. 78, 98-108.

King, C. J. (1977). Heat and mass transfer fundamentals applied to food engineering. Journal of Food Process Engineering, 1, 3±14.

Kulkarni A P, Khedkar D M, Maharaj R B and Patil V K, (1986). Studies on drying dehydration of Thompson Seedless grapes for raisin making. Maharashtra Journal of Horticulture, 3(1): 13-34.

Labuza, T. P., & Hyman, C. R. (1998). Moisture migration and control in multi-domain foods. Trends in Food Science & Technology, 9, 47±55.

Liu Q and Bakker-Arkema F.W. (1977). Stochastic modelling of grain drying. Part: 2 Model development. Journal of Agricultural Engineering Research, 66, 275-280.

Lopez A, Iguaz A, Esnoz A and Virseda P (2000). Thin layer drying behavior of vegetable waste from wholesale market. Drying Technology, 18 (4 and 5):995-1006.

Mahmutoğlu, T., Emir, F., & Saygi, Y. B. (1996). Solar/solar drying of differently treated grapes and storage stability of dried grapes. J. of Food Engineering, 29(3-4), 289-300.

Mane B B, Adsule R N, Charan U D and Kachare D P, (2003). Evaluation of raisin making quality of some grape varieties grown in Maharashtra. Journal of Maharashtra Agricultural University, 28 (3): 241-244.

Mazumdar B C and Majumder K, (2003). Methods on Physico-Chemical analysis of fruits. Daya Publishing House, New Delhi. pp 110-113.

National Horticulture Board. (2017). Indian horticulture database—2017.

Ozdemir M and Devers Y. O (1999). The thin layer drying characteristics of hazelnuts during roasting. Journal of Food Engineering, 42; 225-233.

Peri, C., & Riva, M. (1984). Etude du s_echage des raisins 2: E€et des traitments de modi®cation de la surface sur la qualit_e du produit. Sciences des Alimentes, 4, 273±286.

Pointing, J. D., & Mc Bean, D. M. (1970). Temperature and dipping treatment effects on drying times of grapes prunes and other waxy fruits. Food Technology, 24, 1403±1406.

Ranganna S. (1986). Handbook of Analysis and Quality Control for Fruits and Vegetables products, Tata McGraw-Hill Publishing Company Limited, New Delhi.

Ranganna, S. (1978). Manual of analysis of fruit and vegetable products. Tata McGraw- Hill Publisher, New Delhi.

Rhim, j., Wu, Y., Weller, C., and Schnepf, M (1999). Physical characteristics of a composite film of soy protein isolate and propylene glycol alginate. Journal of Food Science, 64(1), 149-152

Riva, M., & Peri, C. (1986). Kinetics of sun and air drying of different varieties of seedless grapes. Journal of Food Technology, 21, 199± 208.

Rizvi, S. S. H. (1986). Thermodynamic properties of food in dehydration. In M. A. Rao, & S. S. H. Rizvi, Engineering properties of foods. New York: Marcel Dekker.

Saravacos, G. D., & Marousis, S. M. (1988). E€ect of ethyloleate on the rate of air-drying of foods. Journal of Food Engineering, 7, 263± 270.

Singh, S. P., Jairaj, K. S., and Srikant, K. (2016). Comparison of Drying Characteristics of Green and Black Seedless Grapes using Hot Air Dryer. International Journal of Science, Technology and Society, 1(2).

Sundari, A. U., Neelamegam, P., & Subramanian, C. V. (2014). Drying kinetics of muscat grapes in a solar drier with evacuated tube collector. International Journal of Engineering, TRANSACTIONS B: Applications, 27(5), 811-8.

Togrul I. Y. and Pehlivan Dursun (2003). Modelling of drying kinetics of single apricot. Journal of Food Engineering, 58: 23–32.

Tupe, A. (2007): Effect of pretretments on quality of raisins prepared from thomposon seedless grapes. M.sc (agri) thesis, submitted to PDKV, Akola (M.S)

Wang C.Y and Singh R.P (1978). A single layer drying equation for rough rice. ASAE Paper no: 78-3001, ASAE, St. Joseph, MI.

Wang, Z., Sun, J., Liao, X., Chen, F., Zhao, G., Wu, J., and Hu, X. (2007). Mathematical modelling on hot air drying of thin layer apple pomace. Food Research International, 40, 39-46.

Westerman P. W., White G. M. and Ross I. I. (1973). Relative humidity effect on the high temperature drying of shelled corn. Transactions of the ASAE. 16; 1136-1139.

Winkler, A. J. (1962). General viticulture. Univ of California Press.

Xiao, H. W., Pang, C. L., Wang, L. H., Bai, J. W., Yang, W. X., and Gao, Z. J. (2010). Drying kinetics and quality of Monukka seedless grapes dried in an air-impingement jet dryer. Biosystems Engineering, 105(2), 233-240.

Yaldiz, O., Ertekin, C., & Uzun, H. I. (2001). Mathematical modeling of thin layer solar drying of sultana grapes. Energy, 26 (5), 457-465.

Zhang Q and Litchfield J.B (1991). An optimization of intermittent corn drying in a laboratory scale thin layer dryer. Drying Technology, 9; 383-395.

Zhu A. and Shen X. (2014). The model and mass transfer characteristics of convective drying of peach slices. International Journal of Heat and Mass Transfer. 72; 45-351.

Zomorodian, A., & Dadashzadeh, M. (2009). Indirect and mixed mode solar drying mathematical models for sultana grape. Journal of Agricultural Science and Technology, 11