

RESEARCH PAPER

## Effect of Pre-treatments and Convective Hot Air Drying of Grapes on its Quality

Kunal Umakant Yadav and Shrikant Baslingappa Swami\*

Department of Post-Harvest Engineering, Post-Graduate Institute of Post-Harvest Technology and Management, Killa-Roha. Dist: Raigad (Maharashtra State) (Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli-Campus Roha), India

\*Corresponding author: swami\_shrikant1975@yahoo.co.in

Paper No.: 330

Received: 17-10-2025

Revised: 20-11-2025

Accepted: 01-12-2025

### 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<sub>1</sub> = 2.5% NaOH for 3 sec followed by 2% KMS for 2 minutes and Treatment T<sub>2</sub> = 2.5% potassium carbonate + 2% ethyl oleate solution for 5 minutes and dried by convective hot air drying at 45°C. 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, the Logarithmic, Henderson and Pabis model was well fitted to the experimental data with  $r^2 = 0.999$  and  $0.988$ ;  $MSE = 7.5 \times 10^{-5}$  and  $9.1 \times 10^{-4}$ ;  $\chi^2 = 0.016$  and  $0.152$  for Treatment-1 and 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 nutritional analysis of grape raisins indicated that for the best Treatment-2 moisture content was grape raisins 14.57%, TSS 73.67° B, Titrable acidity 2.58 %, pH 4.63, Reducing sugar 63.29 %, Total sugar 64.82 %, Non-reducing sugar 1.53, Ascorbic acid 20.98 mg, yellowness 35.21 and hardness. The sensory score for best treatment was colour 7.47, flavour 7.47, texture 7.42 and taste 7.70.

**Keywords:** Convective Drying, Moisture Ratio, Chemical Properties, Drying Behaviour

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).

Grapes are using as fresh fruit (Table purpose grape) and processed fruit such as jam, grape juice, jelly,

molasses, and raisins. Grapes, considered as a rich source of polyphenolic compounds, have tremendous potential for use in the development of such products (Threlfall *et al.* 2005).

Pre-treatment is a necessary step in raisin production in order to ensure the increased rate of water removal during the drying process. A faster water removal rate decreases the rate of browning and helps to produce more desirable raisins. Food products

**How to cite this article:** Yadav, K.U. and Swami, S.B. (2025). Effect of Pre-treatments and Convective Hot Air Drying of Grapes on its Quality. *Int. J. Food Ferment. Technol.*, 15(02): 363-378.

**Source of Support:** None; **Conflict of Interest:** None



generally undergo some pre-treatment before drying with intention of some changes either physical or chemical changes which help to enhance mass transport and hence the drying rate as well as quality of the dried products. Pre-treating helps keep light-coloured fruits from darkening during drying and storage and it speeds the drying of fruits with tough skins (Lokhande *et al.* 2016).

Grapes dipping in hot water or the use of chemicals such as sulphur, sodium hydroxide (NaOH), and ethyl or methyl oleate emulsions are some pre-treatments widely used for grape drying to increase the drying rate or improve the colour quality of the raisins produced (Bingol *et al.* 2012).

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).

Grapes dipping in hot water or the use of chemicals such as sulphur, caustic and ethyl or methyl oleate emulsions are some of pre-treatments widely used before the grape drying. The aim of using those pre-treatment solutions is to increase drying rates and to produce raisins of the desired quality level. Grapes were surface treated by dipping in ethyl oleate, which greatly increases the drying rate by altering the waxy layer structure at the grape surface, thus reducing the internal resistance to water diffusion (Di Matteo *et al.* 2000; Doymaz, 1998; Petrucci *et al.* 1973; Ponting and McBean, 1970; Riva and Peri, 1986).

Drying process is one of the thermal processes that are time and energy consuming in the industry. That's why new methods are aimed to decrease drying time and energy consumption without reduction in quality. Drying conditions or the drying equipment's can be modified to increase overall efficiencies. Hybrid drying techniques can also be used, such as convective hot air drying (Raghavan *et al.* 2005).

Hot air dryer deliver far more rapid drying, providing uniformity and hygiene to the products which are inevitable for industrial food drying processes. Grape

drying to produce raisins is a very slow process, due to the peculiar structure of grape peel. Grapes are covered naturally with a thin-layer of wax; hence, it is necessary to increase water transport from grape berries during drying process. Peel removal or cracking has been carried out by using either chemical or physical pre-treatments. As a consequence, the drying time of pre-treated grapes is up to four times shorter than the drying time of untreated grapes. (Senadeera *et al.* 2014).

Various researchers have reported the drying characteristics of grape by using convective hot air dryer (Doymaz and Pala 2002; Margaritis and Sawhney *et al.* 1999; Binghol *et al.* 2012; Doymaz, 2006; Pangavhane *et al.* 1999; Doymaz *et al.* 2012).

Mathematical models that describe drying mechanisms of grain and food provide the required temperature and moisture information (Tabatabaee *et al.* 2004). Thin-layer drying models can be categorized as theoretical, semi-theoretical and empirical models. Some semi-theoretical drying models that have been widely used in the form of models, namely, the Lewis model, the Page model, the Henderson and Pabis model and Two-term exponential model (Doymaz, 2006).

Several authors used thin-layer models to describe the drying curves of fruits and vegetables. Doymaz and Pala 2002; Sawhney *et al.* 1999 found the Page model suitable for air drying of grapes pre-treated with chemical solutions. Binghol *et al.* 2012 found the midilli model suitable for drying kinetics of grapes pre-treated with dipping solutions and dried at 60 °C air temperature. Doymaz *et al.* 2012 found the parabolic model well fitted to the convective hot air drying of grape.

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

## MATERIALS AND METHODS

### Sample preparation and Convective hot air 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 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 at temperature 45°C in the convective hot air dryer (Make M/s. Aditi Associates, India; Model: ATD-124) having capacity of 5 kW. Convective hot air drying of grape was performed at Department of Post-Harvest Engineering, Post Graduate Institute of Post-Harvest Management, Killa-Roha. There were nine numbers of trays inside the convective hot air dryer. The size of the tray was 81cm × 41cm × 3.4 cm the grapes were dried in thin layer drying. The grapes were spread on the tray in single layer. The mesh (square) size of the tray was 1×1 mm. The temperature of the drying was 45°C. The air velocity inside the dryer was 2-3 m/s.



**Fig. 1:** Experimental setup for convective hot air drying of grapes

Fig. 1 shows the convective hot air drying of pre-treated grapes with 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. The experiment was triplicated for each treatment. Moisture content versus time was calculated from the 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).

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

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).

$$\text{Moisture Ratio} = \frac{M - M_e}{M_o - M_e} \quad \dots(2)$$

Where,

MR = Moisture ratio;  $M$  = Moisture content at any time  $\theta$ , % (db);  $M_e$  = EMC, % (db);  $M_o$  = 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 <i>et al.</i> 1973
2	Page	$MR = \exp(-kt^n)$	Zhang and Litchfield, 1991
3	Modified Page equation-II	$MR = a \cdot \exp(-kt)^n$	Zhang and Litchfield, 1991
4	Exponential	$MR = \exp(-kt)$	Liu and Bakker-Arkema, 1997
5	Henderson and Pabis	$MR = a \cdot \exp(-kt)$	Henderson and Pabis, 1961
6	Logarithmic	$MR = a \cdot \exp(-kt) + C$	Zhu and Shen, 2014
7	Wang and Singh	$MR = 1 + at + bt^2$	Wang and Singh 1978
8	Two term	$MR = a \exp(-k_0t) + b \exp(-k_1t)$	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 convective hot air 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  $r^2$  (Correlation coefficient) values, lower MSE and lower  $\chi^2$  (chi-square) value.

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

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 ( $\chi^2$ ) and lower value of RMSE. The higher the  $r^2$  value and lower the chi-square ( $\chi^2$ ) 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 ( $\chi^2$ ) and root mean square error (RMSE) can be calculated as follows:

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

Where,

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

$MR_{pre,i}$  = is the  $i^{\text{th}}$  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).

$$\frac{\partial M}{\partial t} = D_{eff} \cdot \nabla^2 M \quad \dots(5)$$

Where,

$M$  = moisture content (kg water/kg dry matter);  $t$  = time (s);  $D_{eff}$  = effective moisture diffusivity, ( $m^2/s$ );  $\nabla^2$  = 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:

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

Where,

$H$  = is the half thickness of the slab  $m$ ;

$n = 1, 2, 3 \dots$  the number of terms taken into consideration.

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

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

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:

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

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°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.

Titrate 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.

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

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.

*Reducing sugars* =

$$\frac{100}{\text{Burette reading}} \times \frac{\text{Vol. prepared}}{\text{Initial Vol.}} \times \text{GV of Fehling's solution} \quad \dots(10)$$

Where,

GV = Glucose value

#### 5. Total sugars

Total sugars of fresh berries and raisins were for Treatment T<sub>1</sub> and Treatment T<sub>2</sub> 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.

$$\text{Total sugars} = \frac{\text{Factor} \times \text{Dilution}}{\text{Titre reading} \times \text{Weightn of sample}} \times 100 \quad \dots(11)$$

#### 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<sub>1</sub> and Treatment T<sub>2</sub> respectively. Determination of ascorbic acid was done by 2, 6-dichlorophenol indophenol dye method of Johnson (1948) as described by Ranganna (1986). 3% metaphosphoric acid (HPO<sub>3</sub>)

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.

$$\text{Ascorbic acid mg/100 g} = \frac{\text{Titre value} \times \text{Dye Factor} \times \text{Vol. made up}}{\text{Aliquate of extract taken for estimation} \times \text{Weightn of sample}} \quad \dots(13)$$

### 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);

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

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, flavour, 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 analysed statistically for the significance of each attributes by ANOVA.

## RESULTS AND DISCUSSION

Fig. 2 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% ethyle oleate) dried by convective hot air dryer at 45°C. The grapes were dried from average initial

moisture content of 476.78% (db) to 14.87% (db) for Treatment  $T_1$  and 405.27% (db) to 14.57% (db) for Treatment  $T_2$ . It took around 106.5 h and 78.5h time to dry the product with pre-treated with Treatment  $T_1$  and Treatment  $T_2$ , respectively. The drying took place in falling rate period for the both treatments. Similar behaviour had been observed in the literature for grape pre-treated with potassium carbonate plus olive oil (Doymaz and Altmer, 2012).

Fig. 3 shows the drying rate (g water removed/100 g of bone dry material /min) with respect to moisture content % (db) of grapes dried by convective hot air drying at 45°C. The initial drying rate of treated grapes decreases from 0.0491 g to  $4.77 \times 10^{-3}$  g and 0.0710 g to  $7.41 \times 10^{-3}$  g for Treatment  $T_1$  and Treatment  $T_2$ , respectively. The drying rate was higher for Treatment  $T_1$  than Treatment  $T_2$ .

Fig. 4 shows variation in moisture ratio with respect to time in minute. During the drying experiment moisture ratio decreases from 1 to  $6.1 \times 10^{-7}$  and 1 to  $2.09 \times 10^{-6}$  for the pre-treatment solution Treatment  $T_1$  and Treatment  $T_2$ , respectively. Similar curve was observed for black grapes pre-treated with ethyl oleate plus potassium carbonate solution by researcher (Doymaz, 2006 and Pangavhane *et al.* 1999).

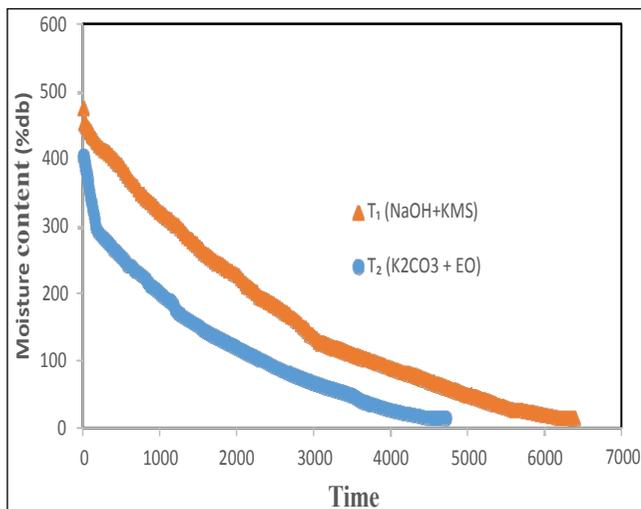


Fig. 2: Moisture content % (db) versus time (min) convective hot air drying for grape at 45°C

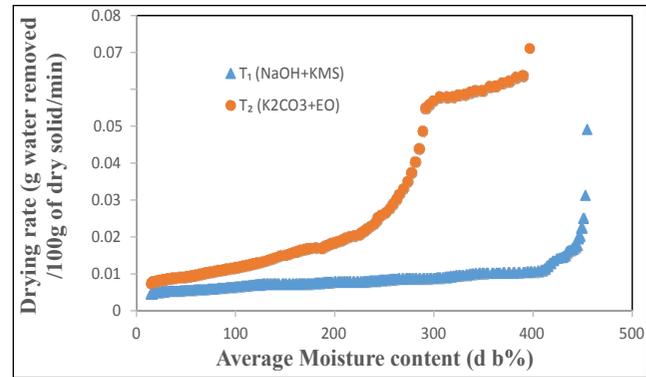


Fig. 3: Drying rate (g water removed/100 g of bone dry material/min) versus moisture content % (db) of grape dried by convective hot air drying at 45°C

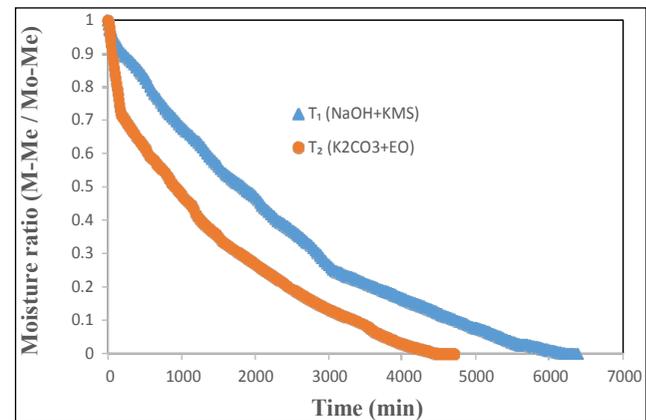


Fig. 4: Variation in moisture ratio with respect to time, min for grape during convective hot air drying

### 1. Evaluation of thin layer-drying model for grape for Treatment $T_1$ dried by convective hot air drying at 45°C

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

Out of eight drying model fitted to the drying data for Treatment  $T_1$  and Treatment  $T_2$ . Non-linear regression analysis indicated that only five models have been fitted well to the experimental data. Among the models fitted to the experimental data to Treatment  $T_1$  and Treatment  $T_2$ , the Logarithmic drying model was well fitted to the experimental data with  $r^2 = 0.9992$ ,  $MSE = 7.507 \times 10^{-5}$ , chi square ( $\chi^2$ ) = 0.0167; and  $r^2 = 0.9880$ ;  $MSE = 9.106 \times 10^{-4}$ ; chi square

$(\chi^2) = 0.1520$  for Treatment-( $T_1$ ) and Treatment-( $T_2$ ), respectively.

**Table 2:** Model parameters,  $R^2$ , RMSE and Chi square ( $\chi^2$ ) values of grape pre-treated with Treatment ( $T_1$ ) and dried by the convective hot air drying at  $45^\circ\text{C}$

Sl. No.	Model name	Model Parameters	$R^2$	MSE	$(\chi^2)$
1	Newton	$k = 4.293 \times 10^{-4}$	0.9905	$1.267 \times 10^{-3}$	0.2852
2	Page	$k = 1.006 \times 10^{-4}$ $n = 1.18$	0.9952	$5.327 \times 10^{-4}$	0.1193
3	Henderson and Pabis	$a = 1.0231$ $k = 4.395 \times 10^{-4}$	0.9892	$1.200 \times 10^{-3}$	0.2689
4	Exponential	$k = 4.293 \times 10^{-4}$	0.9905	$1.267 \times 10^{-3}$	0.2852
5	Logarithmic	$a = 1.1658$ $k = 3.008 \times 10^{-4}$ $c = -0.1821$	0.9992	$7.507 \times 10^{-5}$	0.0167

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  $r^2$ ,  $\chi^2$  and RMSE of grape at convective hot air drying. In convective hot air drying and pre-treated with Treatment  $T_1$  and Treatment  $T_2$  case  $r^2$  values for the model were equal to 0.999 and 0.988 indicating a good fit.

**Table 3:** Model parameters,  $R^2$ , RMSE and Chi square ( $\chi^2$ ) values of grape pre-treated with Treatment ( $T_2$ ) and dried by the convective hot air drying at  $45^\circ\text{C}$

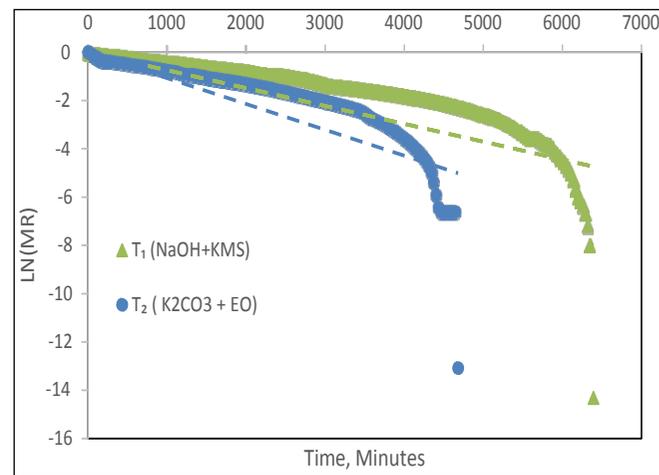
Sl. No.	Model name	Model Parameters	$R^2$	MSE	$(\chi^2)$
1	Newton	$k = 7.482 \times 10^{-4}$	0.9808	$2.804 \times 10^{-3}$	0.4740
2	Page	$k = 3.451 \times 10^{-3}$ $n = 0.7949$	0.9814	$1.507 \times 10^{-3}$	0.2532
3	Henderson and Pabis	$a = 0.8869$ $k = 6.556 \times 10^{-4}$	0.9859	$1.099 \times 10^{-3}$	0.1847
4	Exponential	$k = 7.482 \times 10^{-4}$	0.9808	$2.804 \times 10^{-3}$	0.4740
5	Logarithmic	$a = 0.9283$ $k = 5.540 \times 10^{-4}$ $c = -0.0585$	0.9880	$9.106 \times 10^{-4}$	0.1520

The model parameters like 'a' and 'k' are the characteristics constant's, 'k' is diffusivity (diffusion coefficient and it is temperature dependent). The

model parameter i.e.  $a = 1.1658$ ,  $k = 3 \times 10^{-4}$ ,  $c = -0.1821$  for Treatment  $T_1$  and  $a = 0.928$ ,  $k = 5.540 \times 10^{-4}$ ,  $c = -0.058$  for Treatment  $T_2$ . Doymaz, (2006) had found page model to fit well to the behaviour black grape dried under convective hot air drying, Doymaz and Altiner *et al.* (2012) found the parabolic model well fitted to the convective hot air drying of grape.

**Effective moisture diffusivity**

Fig. 5 shows Ln (MR) versus time (minute) for convective hot air drying of and pre-treated grape with Treatment  $T_1$  and Treatment  $T_2$ . 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 drying by convective hot air for Treatment- $T_1$  and Treatment- $T_2$  was  $3.55 \times 10^{-9} \text{ m}^2/\text{s}$  and  $5.58 \times 10^{-9} \text{ m}^2/\text{s}$  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  $1.048 \times 10^{-10} \text{ m}^2/\text{s}$  to  $6.919 \times 10^{-10} \text{ m}^2/\text{s}$  (Doymaz and Altiner, 2012) also this values lie within the general range of  $10^{-12}$  to  $10^{-8} \text{ m}^2/\text{s}$  for the food material.



**Fig. 5:** Ln (MR) versus Time (Minutes) for pre-treated grapes for Treatment  $T_1$  and Treatment  $T_2$  dried with convective hot air drying at  $45^\circ\text{C}$

### 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 ( $T_1$  and  $T_2$ ) by convective hot air 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) and the moisture content ranged after drying from  $14.85 \pm 0.51$  to  $14.57 \pm 1.46$  % (db) in both  $T_1$  and  $T_2$ . The moisture content was 14.85 % (db) in Treatment-1 and 14.57 % (db) in Treatment-2. The moisture content at Treatment 1 and Treatment-2 are significantly different at  $p \leq 0.05$ . 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  $T_2$  than Treatment  $T_1$  drying of grapes followed by convective hot air drying at  $45^\circ \text{C}$ .

The decreases in moisture content of grapes after convective hot air drying was significant at  $p \leq 0.05$ .

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  $19.90.492^\circ \text{B}$  and the TSS increased after drying from  $72 \pm 0$  to  $73.67 \pm 0.58$   $^\circ \text{B}$  in both Treatment-1 and Treatment-2. The TSS was  $72^\circ \text{B}$  in Treatment-1 and  $73.67^\circ \text{B}$  in Treatment-2. The total soluble solids at Treatment-1 and Treatment-2 are significantly different at  $p \leq 0.05$ . Irrespective pre-treatment solution and conditions of the drying, TSS of grapes increases after drying. TSS was increased more in treatment-2.

As the grapes are pre-treated with Treatment-1 and Treatment-2 followed by convective drying the TSS increases from 72 to  $73.67^\circ \text{B}$ . The increases in total soluble solid of grapes after convective hot air 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.

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  $2.41 \pm 0.04$  to  $2.58 \pm 0.03$  % in both Treatment-1 and Treatment-2. Average titratable acidity was 2.41 % for Treatment-1 and 2.58% for Treatment-2. The total soluble solids at Treatment-1 and Treatment-2 are significantly different at  $p \leq 0.05$ . Irrespective of pre-treatment methods and conditions of the drying, titratable acidity of grapes increases after drying. Lowest changes of titratable acidity was observed Treatment-1 solution as compared to treatment-2 solution.

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  $4.3 \pm 0.173$  and observed that pH was increases after drying. It was  $4.63 \pm 0.12$  to  $4.87 \pm 0.06$  in both Treatment-1 and Treatment-2. The pH was  $4.87 \pm 0.06$  in Treatment-1 and  $4.63 \pm 0.12$  in Treatment-2 solution. The increases in pH of grape after convective hot air drying might be attributed due to the effect of hot air on solid content. Lowest changes of pH was observed in both pre-treatment solution of grapes followed by

convective hot air drying. The pH at Treatment 1 and Treatment-2 are significantly different at  $p \leq 0.05$ .

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  $17.395 \pm 0.716$  % and the reducing sugar increased after drying from  $60.73 \pm 0.14$  to  $63.29 \pm 0.00$  % in both Treatment-1 and Treatment-2. The reducing sugar was 60.73 % in treatment-1 and 63.29 in Treatment-2. The Reducing sugar at Treatment-1 and Treatment-2 are significantly different at  $p \leq 0.05$ . 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 solution of grapes followed by convective hot air drying compared with Treatment  $T_2$ .

The increases in reducing sugar of grapes after convective hot air drying might be attributed due to concentration of fruit flavours and mass/solids during drying. This increase of reducing sugar was significant at  $p \leq 0.05$ . 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  $19.417 \pm 0.087$  % and the total sugar increased after drying from  $63.03 \pm 0.92$  to  $64.82 \pm 0.26$  % in both Treatment-1 and Treatment-2. The total sugar was 63.03 % in Treatment-1 and 64.82 in Treatment-2. The total sugar at Treatment-1 and Treatment-2 are significantly different at  $p \leq 0.05$ . 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-2 solution as compared to Treatment-1.

The increases in total sugar of grapes after convective hot air drying might be attributed due to moisture inside the cell membrane started diffusing outward from centre to surface and subsurface 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 grape raisins 68.6% for Thompson seedless variety.

### 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  $2.015 \pm 0.751$  % and observed that non-reducing sugar was increases in Treatment  $T_1$  and decreases in Treatment  $T_2$  after drying. It was  $2.31 \pm 0.80$  to  $1.53 \pm 0.26$  % in both Treatment-1 and Treatment-2. The non-reducing sugar was  $2.31 \pm 0.80$  % in Treatment-1 and  $1.53 \pm 0.26$  in Treatment-2 solution. Lowest changes of non-reducing sugar was observed in pre-treatment solution of grapes followed by convective hot air drying. The Non-reducing sugar at Treatment- 1 and Treatment-2 were significantly different at  $p \leq 0.05$ .

Mane *et al.* 2003; Beslic *et al.* 2009 reported non-reducing sugars from 3.50 to 4.80 and 3.5 to 4.8 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  $5.88 \pm 0.740$  % and the ascorbic acid increased after drying from  $20.17 \pm 0.29$  to  $20.98 \pm 0.03$  % in both Treatment-1 and Treatment-2. The ascorbic acid was 20.17 % in Treatment-1 and 20.98 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

increased after drying. Lowest changes of Ascorbic acid was observed in Treatment-1 as compared to Treatment-2 of grapes.

The increases in ascorbic acid of grapes after pre-treatment and convective hot air drying might be attributed due to moisture inside the cell membrane started diffusing outward from centre to surface and subsurface 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 (yellowness index)

Table 4 (i) shows the yellowness index of grapes before drying and after drying. The yellowness index of grapes before drying was  $81.35 \pm 0.99$  and the yellowness' decreases after drying from 75.07 to 77.47 in both Treatment-1 and Treatment-2. The yellowness was  $75.15 \pm 2.95$  in Treatment-1 solution and  $76.27 \pm 1.20$  in Treatment-2 solution. The colour (yellowness) at Treatment 1 and Treatment-2 are significantly different at  $p \leq 0.05$ . Irrespective of pre-treatment methods and conditions of the drying, yellowness of grapes decreases after drying. Lowest changes of yellowness was observed in Treatment-2 solution of grapes followed by convective hot air drying.

The decreases in yellowness of grapes after convective hot air drying might be attributed due to moisture diffusivity due to combined effect of treatment and temperature of convective hot air drying.

The colour  $L, a, b$  values for fresh grapes were reported by Lydakakis (2003) 50-55, 7.5-5.5, 18-21, respectively.

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  $41.8 \pm 6.8$ ,  $2.5 \pm 0.2$  and  $13.8 \pm 0.9$ , 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  $3.87 \pm 0.12$  to  $7.24 \pm 0.53$  % in both Treatment-1 and Treatment-2. The hardness was  $3.87 \pm 0.12$  N in Treatment-1 and  $7.24 \pm 0.53$  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  $0.62 \pm 0.14$  and grape raisins was  $9.53 \pm 0.6$  N when dried at  $50^\circ\text{C}$ .

**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 + convective hot air drying	Treatment $T_2 = 2.5\%$ potassium carbonate + 2% ethyle oleate + convective hot air drying	S.E <sub>m</sub> ( $\pm$ )	C.D <sub>5%</sub> <sup>at</sup>
(a) Moisture content (%db)	405.27 $\pm$ 0.745	14.85 $\pm$ 0.51	14.57 $\pm$ 1.46	0.514	1.778
(b) Total soluble solids °B	19.9 $\pm$ 0.492	72 $\pm$ 0.00	73.67 $\pm$ 0.58	0.192	0.666
(c) Titratable acidity (%)	0.678 $\pm$ 0.020	2.41 $\pm$ 0.04	2.58 $\pm$ 0.03	0.016	0.057
(d) pH	4.3 $\pm$ 0.173	4.87 $\pm$ 0.06	4.63 $\pm$ 0.12	0.043	0.149
(e) Reducing sugar (%)	17.395 $\pm$ 0.716	60.73 $\pm$ 0.14	63.29 $\pm$ 0.00	0.140	0.486
(f) Total sugar (%)	19.417 $\pm$ 0.087	63.03 $\pm$ 0.92	64.82 $\pm$ 0.26	0.320	1.107
(g) Non-reducing sugar	2.015 $\pm$ 0.751	2.31 $\pm$ 0.80	1.53 $\pm$ 0.26	0.281	0.971
(h) Ascorbic acid (mg)	5.88 $\pm$ 0.740	20.17 $\pm$ 0.29	20.98 $\pm$ 0.03	0.097	0.335
(i) Colour (yellowness)	81.35 $\pm$ 0.99	75.15 $\pm$ 2.95	76.27 $\pm$ 1.20	1.064	3.682
(j) Hardness	0.66 $\pm$ 0.14	3.87 $\pm$ 0.12	7.24 $\pm$ 0.53	0.183	0.632

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 6.91 to 7.41, the higher score 7.41 for Treatment  $T_2$ . The colour of Treatment  $T_2$  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 7.14 to 7.47, the higher score 7.47 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 7.22 to 8.0, the higher score 8.0 for control

Treatment. The texture of control Treatment highly accepted by the sensory panelist. The sensory values for texture were non-significant at  $p \leq 0.05$ .

#### 3.4.4 Taste

Table 5 (d) shows sensory score for taste ranged from 7.25 to 7.70, the higher score 7.70 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 7.17 to 7.45, the higher score 7.45 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 by Convective hot air drying  $45^\circ\text{C}$  had achieved the highest colour 7.41, flavour 7.47, texture 7.42 and



Treatment  $T_1$

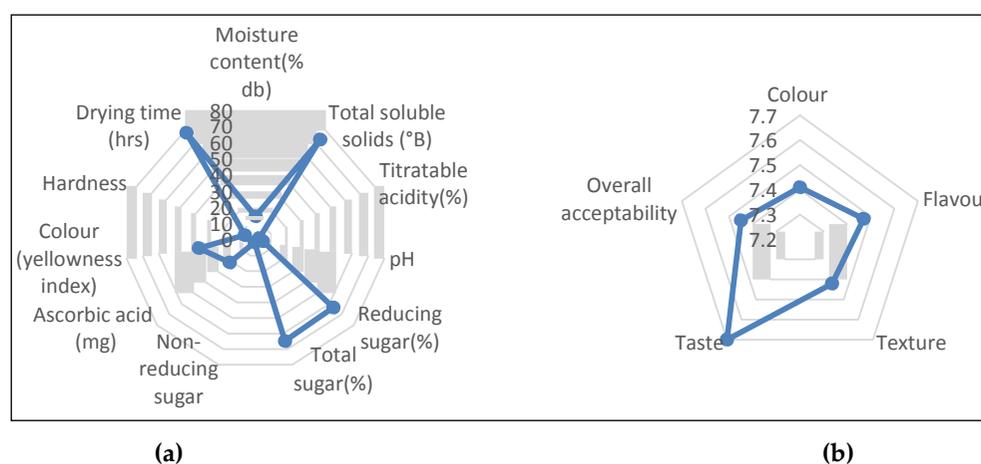


Treatment  $T_2$

Fig. 6: Photograph of the raisins prepared from Treatment  $T_1$  and Treatment  $T_2$

**Table 5:** Sensory score of grapes pretreated with Treatment T<sub>2</sub> and dried by Convective hot air drying 45°C

Parameter	Control	Treatment 1	Treatment 2	SE <sub>m</sub> (±)	CD 5% <sub>@ p&lt;0.05</sub>
Colour (a)	7.12	6.91	7.41	3.84	10.98
Flavour (b)	7.45	7.14	7.47	3.84	9.55
Texture (c)	8.0	7.22	7.42	3.61	10.33
Taste (d)	7.25	7.34	7.70	3.36	9.61
Overall acceptability (e)	7.44	7.17	7.45	3.53	10.11


**Fig. 7 (a)** quality analysis and **(b)** sensory analysis of grapes pretreated with Treatment T<sub>2</sub> and dried by Convective hot air drying 45°C

taste 7.70. From the both quality properties, colour measurement and the sensory analysis the best product i.e. grapes pretreated with Treatment T<sub>2</sub> and dried by Convective hot air drying 45°C satisfactorily retains parameter with desirable quality.

## CONCLUSION

1. The grapes were dried from average initial moisture content of 476.78% (db) to 14.87% (db) for Treatment 1 and 405.27% (db) to 14.57% (db) for Treatment 2. It took around 106.5 h (6.5 days) and 78.5h (4.5 days) time to dry the product with pre-treated with Treatment 1 and Treatment 2.
2. Among the models fitted to the experimental data to Treatment-1 and Treatment-2 solution, the Logarithmic drying model was well fitted to the experimental data with  $r^2 = 0.9992$ ,  $MSE = 7.507 \times 10^{-5}$ , chi square ( $\chi^2$ ) = 0.0167; and  $r^2 = 0.9880$ ;  $MSE = 9.106 \times 10^{-4}$ ; chi square ( $\chi^2$ ) = 0.1520 for Treatment-(T<sub>1</sub>) and Treatment-(T<sub>2</sub>), respectively.

3. Effective Diffusivity ( $D_{eff}$ ) at time (t) for treated Grape drying by Convective hot air for Treatment-T<sub>1</sub> and Treatment-T<sub>2</sub> was  $3.55 \times 10^{-9}$  m<sup>2</sup>/s and  $5.58 \times 10^{-9}$  m<sup>2</sup>/s respectively.
4. Grapes pretreated with Treatment T<sub>2</sub> and dried by convective hot air drying satisfactorily retains parameter with desirable quality parameter moisture content of raisins was 14.57%, TSS 73.67°B, Titrable acidity 2.58 %, pH 4.63, Reducing sugar 63.29 %, Total sugar 64.82 %, Non-reducing sugar 1.53, Ascorbic acid 20.98mg, yellowness 35.21 and hardness for Treatment 2.

## REFERENCES

- A.O.A.C. 1975. Official methods of analysis, 11<sup>th</sup> Ed. Association of Official Analytical Chemists, Washington, D.C.
- A.O.A.C. 1990. Official methods of analysis, 15<sup>th</sup> 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*, **827**: 501-503.
- Bingol, G., Roberts, J.S., Balaban, M.O. and Devres, Y.O. 2012. Effect of dipping temperature and dipping time on drying rate and color change of grapes. *Drying Technology*, **30**(6): 597-606.
- 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, 3<sup>rd</sup> Edition, oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, pp. 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., Adsule, P.G. and Negi, S.S. 1987. Evaluation of new grape cultivars for processing. *Journal of Food Science and Technology*, **24**(4): 194-196.
- Dan, A., Pandey, S.N. and Anand, J.C. 1977. Studies on Raisin Production From Grapes (*Vitis vinifera*) Grown Under Delhi Conditions. *Indian Journal of Horticulture*, **34**(3): 215-219.
- Di Matteo, M., Cinquanta, L., Galiero, G. and Crescitelli, S. 2000. Effect of a novel physical pretreatment process on the drying kinetics of seedless grapes. *Journal of Food Engineering*, **46**(2): 83-89.
- Doneche, B 1990. Metabolism of tartaric acid of grapes by botrytis cinerea. *Sci. Alim.*, **10**(3): 589-602.
- Doreyappa Gowda, I.N., Singh, R. and Murthy, B.N.S. 1997. Evaluation of new grape hybrids for dehydration. *Journal of Food Science and Technology*, **34**(4): 286-290.
- Doymaz, II. 1998. Investigation of drying characteristics of grape and Kahramanmaras pepper. Ph.D. Thesis, Science Institute, Yildiz Technical University, Istanbul.
- Doymaz, I. 2004. Convective air drying characteristics of thin layer carrots. *Journal of Food Engineering*, **61**(3): 359-364.
- Doymaz, I. 2006. Drying kinetics of black grapes pretreated with different solutions. *Journal of Food Engineering*, **76**(2): 212-217.
- Doymaz, İ. and Altiner, 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.
- Ertekin, C. and Yaldiz, O. 2004. Drying of eggplant and selection of a suitable thin layer drying model. *Journal of Food Engineering*, **63**(3): 349-359.
- 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.
- FAO (Food and Agriculture Organization of the United Nations). 2010. Faostat.
- 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.
- Kiran Banan, L. and Hegde, A. 2006. Plaque and salivary pH changes after consumption of fresh fruit juices. *Journal of Clinical Pediatric Dentistry*, **30**(1): 9-13.
- 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.
- 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.
- Lokhande, S.M. and Sahoo, A.K. 2016. Effect of drying on grape raisin quality parameters. *International Journal of Innovative Research in Science and Engineering*, **2**(07): 86-95.
- 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.
- Lydakis, D. and Aked, J. 2003. Vapour heat treatment of Sultanina table grapes. II: Effects on post-harvest quality. *Post-harvest Biology and Technology*, **27**(2): 117-126.
- 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.

- Pangavhane, D.R., Sawhney, R.L. and Sarsavadia, P.N. 1999. Effect of various dipping pretreatment on drying kinetics of Thompson seedless grapes. *Journal of Food Engineering*, **39**(2): 211-216.
- Petrucchi, V., Canata, N., Bolin, H.R., Fuller, G. and Stafford, A.E. 1973. Use of oleic acid derivatives to accelerate drying of Thompson seedless grapes. *Journal of the American Oil Chemists' Society*, **51**: 77-80.
- Ponting, J.D. and Mc Bean, D.M. 1970. Temperature and dipping treatment effects on drying rates and drying times of grapes, prunes and other waxy fruits. *Food Technology*, **24**: 85-88.
- Raghavan, G.S.V., Rennie, T.J., Sunjka, P.S., Orsat, V., Phaphuangwittayakul, W. and Terdtoon, P. 2005. Overview of new techniques for drying biological materials with emphasis on energy aspects. *Brazilian Journal of Chemical Engineering*, **22**(2).
- 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. and Peri, C. 1986. Kinetics of sun and air drying of different varieties of seedless grapes. *Journal of Food Technology*, **21**: 199- 208.
- Sawhney, R.L., Pangavhane, D.R. and Sarsavadia, P.N. 1999. Drying kinetics of single layer Thompson seedless grapes under heated ambient air conditions. *Drying Technology*, **17**(1-2): 215-236.
- Senadeera, W., Adiletta, G., Di Matteo, M. and Russo, P. 2014. Drying kinetics, quality changes and shrinkage of two grape varieties of Italy. In Applied Mechanics and materials (Vol. 553, pp. 362-366). Trans Tech Publications.
- 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).
- Tabatabaee, R., Jayas, D.S. and White, N.D.G. 2004. Thin-layer drying and rewetting characteristics of buckwheat. *Canadian Biosystems Engineering*, **46**(3): 19-24.
- Threlfall, A.G., Pilkington, L., Milsom, K.M., Blinkhorn, A.S. and Tickle, M. 2005. General dental practitioners' views on the use of stainless steel crowns to restore primary molars. *British Dental Journal*, **199**(7): 453-455.
- Togrul, I.Y. and Pehlivan, D. 2003. Modelling of drying kinetics of single apricot. *Journal of Food Engineering*, **58**: 23-32.
- Tupe, A. 2007. Effect of pre-treatments 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.
- 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.