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ORIGINAL ARTICLE

Drying of 'Perlette' grape under different physical treatment for raisin making

Abhay Kumar Thakur · V. K. Saharan · R. K. Gupta

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Abstract Experiments were conducted to evaluate the suitability of grape (*Vitis vinifera* L) cv. 'Perlette' for raisin preparation with different physical treatments. The treatments consisted of whole berries, half cut berries and berries with superficial abrasion of peel/waxy cuticle. The effectiveness of these treatments on drying characteristics and quality of the prepared raisin were studied. The half cut berries took less time to dry as compared to scratchy surfaced berries and whole berries. Drying of berries was carried out at 60 °C in an air circulatory tray dryer with loading capacity of 6.0 kg/m^2. Initial moisture content of berries was 67% (wb) with varying total soluble solids of 15–18% which was dried to moisture content of around 15% (wb). Empirical/semi-theoretical/mathematical models, commonly describing thin-layer drying of various biological materials have been investigated to illustrate the drying characteristics of the physically treated berries. A non-linear regression analysis using a standard statistical program was used to evaluate the constants of mathematical models to describe appropriately the drying behaviour. The results as indicated that the abrasion method is effective for faster drying as against the chemical method; however this treatment gave comparatively darker raisin which was less attractive.

Keywords 'Perlette' grape · Physical treatment · Drying · Raisins · Mathematical modeling · Quality evaluation

Grape (*Vitis vinifera* L) cultivation is one of the remunerative farm enterprises in India. The country has the distinction of achieving the highest productivity in grapes in the world; with an average yield of 30 t/ha (Shikamany 2001). Grape is grown under sub-tropical, hot tropical and mild tropical climatic regions in the country. Raisins are the second most important product of the grapevine, wine being the first (Shanmugavelue 1989). The quality of raisin depends on the size of the berries, the uniformity and brilliance of the berry colour, the condition of berry surface, the texture of the skin and chemical composition of pulp and the presence of foreign matter. The bulk of the world's raisins are dried in outdoor yards by spreading clusters on tamped earth floors that are well exposed to sunshine. After 7–8 days, the clusters are turned by hand to complete drying. These are called natural raisins. Many modifications of drying and processing of raisins are being practiced to improve the quality. The yield and quality of final dried product depend on the Brix of the fresh grape berry taken for drying. Bhutani et al. (1980) found that drying berries proceeded at a faster rate in a cross-flow dehydrator than under sun drying. Treatment of berries with alkali reduced the drying time. Raisins of fairly good quality were produced in cross-flow dehydrator when the berries were treated with alkali followed by oiling and sulfuring. Barbulescu et al. (1988) found that the performance of 'Perlette' is high yielding but has low sugar accumulation compared to Black *Kismis* and White *Kismis* varieties. Sandhu (1992) reported about the raisins obtained from 'Perlette' variety of grape by soda dip treatment. Ograno-leptic evaluation revealed that when raisin obtained under forced air drying, colour was retained during the process of drying due to SO_2 absorption during drying. Berries dried at room temperature had brown colour and had poor acceptability. Pangavhane et al. (1999) reported that hot dipping pre-treatment reduces the drying time of berries and changes its drying characteristics as compared to untreated

A. K. Thakur (✉) · V. K. Saharan · R. K. Gupta
Horticultural Crop Processing Division,
Central Institute of Post-harvest Engineering and Technology,
Abohar 152116, India
e-mail: akthakur_ciphet@rediffmail.com

berries. Further, Pangavhane et al. (2002) found that drying of grapes under shade and sun took 15 and 7 days, respectively, while solar dryer took only 4 days and produced better quality raisins. An investigation was carried out by Gowda (2000) on various pretreatment combinations for raisin making from 'Arkavati' hybrid and 'Thompson seedless' varieties. The treatment combination consisting of lye-treatment + dipping oil + sulfuring + shade drying or lye treatment + sulfuring + dipping oil + shade drying was found to be the best for producing good quality raisins. Marisa et al. (2000) described an alternative physical method for enhancing the drying rate of seedless grapes. It consisted of superficial abrasion of grape peel using an inert abrasive material. The effectiveness of this novel process was compared to that of traditional ethyl oleate dipping process by analysing not only their respective drying times, but also the peel surfaces by scanning electron microscopy. The abrasion method was found to be as effective as the traditional method and gave a darker final product, which was less attractive to consumers. It would overcome pretreatments thus avoiding the use of chemical additives and permit safer raisins to be produced. The effects of different dipping solutions on hot air drying of grapes were studied by Doymaz and Mehmet (2002). Colour analysis of grapes showed that the best results were obtained in grapes which were pretreated with an alkaline emulsion of ethyl oleate and dried with air at 60 °C. The drying rates of grapes were modeled by the Page's and Exponential equations. Grapes with sour taste and low soluble solids content were used for preparation of raisin, jam, spread, sweet *chutney* and canned grapes (Prabhakara Rao et al. 2009). Partially dehydrated grapes used for jam and grape pulp were used for making spread and *chutney.*

Grapes should have high sugar content of 20–24 °Brix for producing quality raisins. The low total soluble solids (TSS) (14–17 °Brix) and non-disappearance of seed at harvesting stage are the constraints associated in producing quality raisin from 'Perlette' grape. The drying behaviour and the quality of raisin produced from this variety by giving some physical manipulation as pre-treatments before drying are presented here.

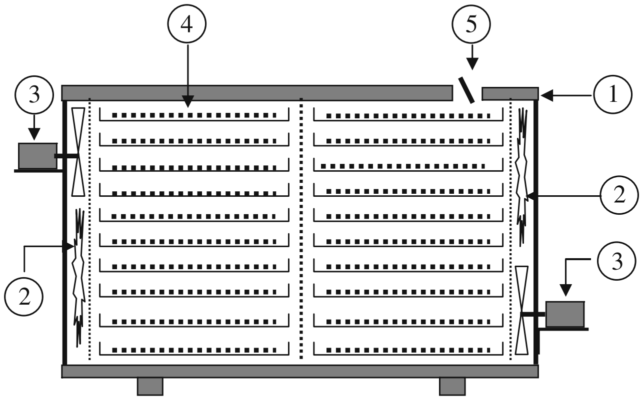
Materials and methods

Raw materials and physico-chemical characteristics Selected bunch of the 'Perlette' grape was harvested from ~25 year old well maintained vine yard located at Abohar, Punjab, India. The grapes were stored at 8–9 °C and 90–92% RH. After thorough washing, the berries were detached manually from the bunch and were used for the determination of physico-chemical characteristics and preparation of raisins. Weight of the berries (n=50) was measured by digital balance. Linear dimensions of berries (n=50) was measured with a digital vernier caliper having least count of 0.01 mm. Geometric mean diameter, sphericity and surface area were measured as suggested by McCabe and Smith (1984) for non-spherical particles. True density was determined by toluene displacement method. Porosity percentage was calculated from the difference between true density and bulk density and devided by density (Thakur 2008). Instrumental colour of the fresh grape berries in terms of L*, a*, b* values of CIE system were recorded by using a pre-calibrated handy colourimeter (NR-3000, Nippon Denshoku Ind Co Ltd, Japan). L* indicates lightness, a* chromaticity on green (−) to red (+) axis and b* chromaticity on a blue (−) to yellow (+) axis. Water activity was determined by water activity meter (ROTRONIC Probe type HygroLab3, UK) which has an operating range of humidity 0–100% RH and temperature 5–50 °C. The TSS content of grape juice was measured using hand refractometer (0–50 °Brix). Titrable acidity of filtered 'Perlette' grape juice was determined by using 0.1 N NaOH. Five ml of juice were taken in a beaker and 2–3 drops of phenolphthalein indicator were added. The juice was titrated against 0.1 N NaOH till the appearance of pink colour (Ranganna 1986). The acidity was calculated using the formula given below:

$$\text{Acidity, \%} = (\text{titer} \times \text{acid factor}) \times 100/5 \text{ ml juice}; \qquad (1)$$

where, acid factor for grapes is 0.0075

Pre-treatment and drying procedure The 'Perlette' grape berries of uniform size, shape, colour, and bloom were selected for the raisin preparation. The physical treatments given to the berries included: whole (T1), whole with superficial abrasion (minor scratchy surface) of peel (T2) and half cut berries (T3). Superficial abrasion on the surface of berries was given by abrasive surface created inside the stainless steel container in which the berries were churned for 2–3 min. Half-cut berries were obtained by cutting the berries into two halves with stainless steel knife. The physically treated samples were subjected to air drying separately at 60 °C. The dryer (Narang Scientific Works Pvt Ltd, New Delhi, India) used for drying of berries was commercial model air circulation tray-dryer equipped with 10 number of heating elements (0.5 kW each) and two propeller fan of 1.5 kW each to create sufficient air circulation within the drying chamber. An opening of 0.21 m×0.01 m with control flap is provided at one side of the top surface of dryer to exhaust moist air (Fig. 1). The samples were put in a single layer on the trays (6.0 kg/m^2) and the observations on the loss of moisture were recorded at every 1 h interval. The drying of sample was continued until the sample was dried to desired moisture content (~ 15% w.b). The moisture contents of berries before and after drying



1- Insulated cabinet, 2- Heating coil, 3- Air circulation fan
4- Materials holding trays, 5- Air exhaust baffle

Fig. 1 Line diagram of air circulation tray dryer

were determined by static air oven drying at 80 °C till the constant weight reached (27 h). The drying ratio (DR) and drying yield (DY) were evaluated according to the method suggested by Von Loesecke (1998).

Selection of appropriate model equation for drying The drying curves were fitted with 4 different moisture ratio equations used by several authors (Table 1). The final moisture content reached at the end of drying was approximated as equilibrium moisture content (M_e) for calculation of moisture ratio and further applying to drying models (Chhinman 1984; Li and Morey 1987). The accuracy of the model equation was decided on the basis of coefficient of determination (r^2), root mean square error (RMSE), mean square of deviation (χ^2) and sum of the residual mean square (s^2). To calculate the coefficients of each model and to select the best model for describing the drying curves of the selected temperature range, the Marquardt-Levenberg nonlinear optimization method was applied, using statistical package for social science (SPSS 8.0). The instantaneous drying rates (g of water/100 g dry solid) and average moisture content were computed.

Storage and quality evaluation of raisin The raisins prepared by different physical treatment were stored separately for 4 months in air tight high density plastic containers at room condition (28–42 °C, 50–85% RH). Moisture content, TSS, acidity, ascorbic acid, reducing sugar (Ranganna 1986), water activity and instrumental colour were determined just after drying and at interval of 30 and 120 days. The raisins were diluted in distilled water to make the syrup (1:10) for the measurement of TSS, acidity, ascorbic acid and reducing sugar. Moisture content, water activity and colour of the raisins were measured directly.

Results and discussion

Physico-chemical properties The 'Perlette' grape is considered to be of medium quality. The phisico-chemical characteristics of berries are given in Table 2. Observed dimension of berries suggests that it may be considered as almost spherical. The peel and seed contents were in the range of 11–14% and remaining was the pulp and juice. The TSS and acidity increased and decreased, respectively as the berries matured on the vines. The acidity of the berries harvested in first week of June was slightly higher than those harvested in second week. The bulk density of berries was found 37.8% less than the true density.

Drying characteristics The moisture content of berries decreased continuously with time of convective drying. The moisture loss and drying time relation was non-linear, initially higher moisture loss was observed due to release of free moisture as compared to the later part of drying (Fig. 2). The whole grape berries (T1) took maximum time for drying and this is due to the fact that the waxy cuticle created hindrance in removal of moisture from pulp. The berries with superficial abrasion of surface (T2) dried comparatively faster than the whole berries (T1). Minimum drying time was taken by the half cut berries (T3); this was due to more open surface exposed to the drying air temperature. However, the raisin produced from T2 and T3 were comparatively sticky because during drying, small amount of juice was squeezed out to the surface due to heating. Kataria and Shaikh (2007) have found that the basic problem in grape drying has been the slow rate of moisture removal during drying due to the waxy cuticle of grapes that controls the rate of moisture diffusion through

Table 1 Mathematical models applied to the drying curves

Model name	Model equation	References
Newton	MR = exp (-kt)	Brooker et al. (1974), Lui and Bakker-Arkema (1997)
Page	MR = exp (-kt^n)	Brooker et al. (1974), Lopez et al. (2000)
Henderson and Pebis	MR = a exp (-kt)	Chhinman (1984)
Midilli-Kucuk	MR = a exp (-kt^n)+bt	Midilli and Kucuk (2003)

a, b & n are model coefficients; k is the drying rate constant (h^{-1})

Table 2 Physico-chemical characteristics of the 'Perlette' grape

Peel thickness, mm (n=20)	0.0227±0.05
Number of seeds (n=10)	2.9±0.738 (Range 2–4)
Seed: Pulp: Peel ratio (n=10)	0.095±0.035 : 1.879±0.315 : 0.133±0.044
Major axis diameter, mm (n=50)	16.41±1.133
Minor axis diameter, mm (n=50)	15.59±1.065
Weight of single berry, g (n=50)	2.392±0.547
Bulk density, kg/m^3	606
True density, kg/m^3	974
Moisture content of berry,% (wb)	67.0
Firmness, g (n=50)	295±41.63
Total soluble solids, º Brix	14–17
Acidity,%	1.075 (1st week harvested)
	0.760 (2nd week harvested)
Viscosity of fresh juice, Kreb unit, Cp, g	42, 66, 38
Instrumental colour (n=10), L*, a*, b*	47.773±1.405, −6.186±1.398, 13.879±1.791
Acid (tartaric), mg/100 ml juice	10.51
Water activity of fresh berry at 41.58 °C	0.923

berries. They suggested a maximum permissible drying temperature for grape as 65 °C. The process of convective drying of grape may be considered as diffusion controlled action as the rate of moisture removal goes on decreasing (Fig. 2). The highest value of overall drying rate was obtained in half cut berries (Table 3) followed by superficially abraised and whole berries. The moisture solid relationship in pulpy fruits is more complex than other organic materials like grains due to the presence of sugar.

Mathematical modeling of drying The moisture content data of the treated samples were fitted to the more useful moisture ratio (MR) expressions; that is (M-Me)/(Mo-Me) and then non-linear curve fitting computations with drying time were performed on the four statistical drying models, which are commonly used for the representation of drying

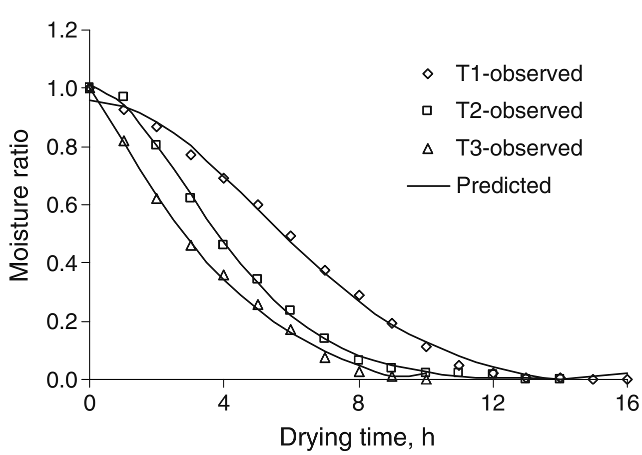


Fig. 2 Effect of treatments on moisture ratios of 'Perlette' grape as described by Midilli-Kucuk model; T1: Whole berry, T2: Whole berry with superficial abrasion, T3: Half cut berry. Symbols are observed values and solid lines are predicted

of most of biological materials (Table 1). The results of non-linear statistical analysis of these models are given in Table 4 for all the treatment. The acceptability of the model equation is based on the value of coefficient of determination (r^2), which should be close to one and lower value of residual mean square (s^2) should be near to zero. It can be seen from Table 4 that the appropriate model to describe the thin layer drying curves for the physically treated berries is the Midilli and Kucuk (2003) model. The coefficient of determination value ranged from 0.997 to 0.999 and lower values of residual mean square error from 0.00021 to 0.00049 indicating a very good fit of the model equation with the experimental values of moisture content during drying. The performance of the model is shown in Fig. 1. The Page's model can also be used for describing the drying behaviour of grape berries but the performance of Midilli and Kucuk model is relatively better than the Page's model.

Quality characteristics of raisin The moisture content of 'Perlette' berries was initially 67% (wb) which on drying reduced to ~ 16% (wb); caused shrinkage and remarkably reduced the shape and size of the dried berries. It was thought of by giving physical treatment of cutting berries in 2 half would facilitate removal of seeds from berries during the process of drying. But this was not achieved. The light green colour of the berries turned to brown and it further accelerated till the drying process completed. The qualitative parameters of the raisin prepared by different treatments are shown in Table 5. The amount of ascorbic acid reduced in case of physically treated samples (T2 and T3) after drying. About 40% of ascorbic acid was lost in case of physically treated raisins as compared to the raisins from whole berries (T1). Also the drying yield of half cut berries

Table 3 Overall drying rate of 'Perlette' grape at 60 °C

Treatment	M_i % db	M_f % db	Drying time (t), h	dM/dt %/h	Dried wt, kg/kg	DR	DY, %
T1	203	19.0	16.0	11.5	0.28	2.53	39.5
T2	203	18.2	14.0	13.2	0.25	2.55	39.2
T3	203	17.6	10.0	18.5	0.23	2.57	38.9

M_i and M_f – Initial and final moisture content, *DR* Drying ratio, *DY* Drying yield

T1_T3: See Fig. 2

Table 4 Parameters specific to each model equation for drying of 'Perlette' grape at 60 °C

Model	Treatment	k	n	a	b	r^2	s^2
Newton	T1	0.155	–	–	–	0.912	0.01178
	T2	0.225	–	–	–	0.939	0.00822
	T3	0.284	–	–	–	0.976	0.00287
Page	T1	0.026	1.896	–	–	0.994	0.00084
	T2	0.065	1.759	–	–	0.998	0.00020
	T3	0.178	0.316	–	–	0.994	0.00072
Henderson and Pebis	T1	0.175	–	1.143	–	0.933	0.00959
	T2	0.252	–	1.144	–	0.958	0.00606
	T3	0.298	–	1.055	–	0.979	0.00270
Midilli-Kucuk	T1	0.020	1.986	0.959	−0.0017	0.997	0.00049
	T2	0.071	1.721	1.014	0.000026	0.999	0.00021
	T3	0.195	1.166	0.999	−0.00779	0.998	0.00037

a, b and n are model coefficients; k is the drying rate constant (h^{-1})

T1-T3: See Fig. 2

Table 5 Effect of physical treatment on quality of raisin prepared from 'Perlette' grape

Parameters		Days after drying								
		0			30			120		
		T1	T2	T3	T1	T2	T3	T1	T2	T3
Moisture content % (wb)		16.7	16.3	15.5	16.8	16.1	15.6	16.9	16.0	15.9
TSS,%		68.0	76.0	76.5	67.5	77.5	77.0	70.0	80.0	75.0
Acidity,%		0.42	0.43	0.46	0.41	0.45	0.40	0.46	0.54	0.48
Ascorbic.acid, mg/100g		23.0	13.9	13.8	22.4	13.3	13.9	22.2	12.3	13.8
Reducing sugar,%		36.8	37.1	34.0	37.5	37.8	34.1	34.7	39.2	37.2
Water activity, a_{-w}		0.518	0.561	0.500	0.538	0.567	0.512	0.571	0.543	0.520
Intrumental Colour	L*	15.2	18.7	18.3	15.6	18.8	17.9	16.6	14.0	15:2
	a*	8.4	8.2	8.5	8.6	7.1	8.3	4.7	6.2	5.2
	b*	4.8	6.7	5.6	4.9	6.7	5.5	−0.9	2.5	1.1

TSS: Total soluble solids, T1- T3: See Fig. 2

(T3) was slightly lower than the other 2 samples. Physical manipulation like cutting of berries did not produce a level of quality as was expected. The prepared raisin was stored up to 4 months in air tight high density plastic containers. No major change in overall quality was observed (Table 5), little variation was observed in TSS and this may be due to natural desiccation process.

Conclusion

Raisins prepared from 'Perlette' grapes may be useful in bakery, deserts preparation and confectionary industries. It may not be acceptable for direct consumption as a dry fruit. Superficial abrasion of berries enhanced the rate of drying but produced slightly sticky raisin in comparison to the whole berries drying. However, this method is suitable to produce safer raisin as against the traditional methods which involves the use of chemical additives. The idea of removal of seeds during drying by cutting the berries into 2 halves was not encouraging, as it affected the overall quality especially ascorbic acid. According to the results of non-linear regression analysis of drying data, among the 4 model equations, the Midilli and Kucuk drying model was found most suitable for describing the convective air drying of grape berries. The raisins obtained can be safely stored up to 4 months in air tight PVC or glass jars without any significant change in quality.

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