Biological Forum – An International Journal 14(4a): 155-160(2022)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Effects of Pretreatments and Drying Methods on Drying Kinetics and Physical properties of Raisins

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(Received 17 September 2022, Accepted 07 November, 2022)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Drying is a process to convert grape berries into raisins. The waxy cuticle on the surface of grapes acts as a barrier against moisture evaporation during the drying process. Therefore, an effective pretreatment and drying method is necessary to remove the waxy layer to accelerate the drying rate. A study was conducted to standardize the effect of pretreatments *viz.*, K_2CO_3 with ethyl oleate and olive oil, hot water treatment and no dipping along with three drying methods *viz.*, cabinet tray dryer, solar tunnel dryer and open sun drying on drying time, instrumental color value (*L, *a**,*b**) and texture (N) of raisins. Grapes berries (var. Thompson seedless) pretreated with ethyl oleate 1.5% + K_2CO_3 3% and dried in cabinet tray dryer took lesser (26.08h) drying time and appeared lighter (47.04 *L**), bright green (4.03 *a**), intense yellow (27.98 *b**) and were soft (4.91 N). Sun dried raisins without pretreatment took maximum (169h) drying time, more dark (25.87 *L**), and observed to be stiff (6.44 N). The findings emphasize the pretreatment and drying method in minimizing the drying time with desirable color, nutritional qualities, organoleptic attributes. Therefore, the production of raisins using the above said treatment and drying method will have scope from both the industrial and health points of view, because of the remarkable reduction in the processing time and drying time.**

Keywords: Raisin, Drying methods, Drying time, Pretreatment, Color, Texture.

INTRODUCTION

Grape (*Vitis vinifera* L.) is one of the important ancient cosmopolitan fruit crops and its domestic cultivation began around 6000-8000 years ago. The crop has a rich cultural, economic, ecological and economic values among the fruit crops globally. Grape berries are highly nutritious and suitable for fresh consumption. Harvested fresh berries possess high moisture and sugar content and exhibit high metabolic activities *viz.* respiration and transpiration and therefore they are sensitive to microbial spoilage during storage (Xiao *et al*., 2010) if left unconsumed. Therefore, surplus quantity is dried to make raisins without compromising the nutritive value to be consumed later during off season or processed to several valued products such as wine, juice, jam, *etc*. Thus, processing and value addition is a sustainable way of using grapes round the year. Processing of surplus grapes to raisin concentrates its nutrients and enhances its storage life. Raisin is a nutrient concentrated product having carbohydrates,, crude fiber and phytochemicals with high antioxidant activity, that can be consumed directly or amenable for further processing as wine, juice and other food products to meet the global demand.

Raisin making is a skillful science, accomplished after dehydration to retain physical, chemical and biological qualities. The waxy layer on the surface of grape berries acts as barrier against moisture evaporation during drying process (Casado and Heredia 1999). Therefore, removal the wax layer is indispensable by certain treatment before drying (Esmaiili *et al*., 2004) otherwise drying process will be extended. The effective pretreatment therefore, is a prerequisite step for removal of wax layer for dehydration. Several pre-treatment methods have been used in the past for raisin making. Chemical, physical and blanching have been extensively applied to remove the wax layer on grape berries surface to enhance drying rate (Wang *et al*., 2016). Potassium carbonate (K_2CO_3) (Ponting and

Mbean 1970), sodium hydroxide (NaOH) (Pangavhane *et al*., 2000), sodium bicarbonate ($NaHCO_3$) (Doymaz, 2012), ethyl oleate and olive oil are the main constitutes of chemical agents used for pretreatment during raisin production before drying.

Drying has an impact on physico-chemical quality of raisin such as color, texture, carbohydrates, acidity, anthocyanin activity, *etc*. The commonly used drying methods for grape are sun, solar, shade and mechanical drying (Wang *et al*., 2016). Natural drying of grapes under the open sun with or without cover and shade (Pangavhane and Sawhney 2002) offers economical feasibility and it is a most common method of drying. However, its inability to control the drying operation, prolonged drying time, weather uncertainties, high labor cost, requirement of large area, insect and disease infestation, contamination of dust and other foreign materials limit its application (Togrul and Pehlivan 2004). An improvement over open sun drying is solar drying, where, the commodities are dried in a chamber or in a tunnel covered with semitransparent polyethylene (Esmaiili *et al*., 2004). Mechanical drying is widely used in raisin production that offers rapid, controllable operation besides obtaining high quality of products (Wang *et al*., 2016). Therefore, a study was undertaken to evaluate solar tunnel drying and cabinet drying of grapes over sun drying in combination with different chemical pretreatments to produce raisins.

MATERIAL AND METHODS

The fresh grapes *var*. Thompson seedless having uniform bunches, size, color, maturity, free from GA_3 treatment and visible damages were harvested directly from field at Sangli, Maharashtra, packed in corrugated fiber board boxes and transported to Postharvest Technology Laboratory, Bengaluru, which is about 600 KM away in the year 2018. The materials used in the study were procured from standard laboratory supplier and local market. All other chemicals used in this experiment were of analytical grade obtained from Sigma®, Hi-Media®, SRL® and Merck®.

Fresh grapes before subjecting to pretreatments were sorted, cleaned and washed in clean running water. Each treatment was replicated four times having one kilogram sample size. Pretreatments were comprised of dipping in ethyl oleate and olive oil emulsions with 3% potassium carbonate and water blanching. Solutions of 3% K_2CO_3 +1.5 % ethyl oleate and olive were prepared using warm water at 50ºC. The grape bunches were dipped in the solutions for three minutes followed by rinsing in cold water. The water blanching was carried out by dipping the grapes bunches in hot water at 85°C for two minutes and instantly rinsed in cold water. All the samples were fumigated using sulphur dioxide in wooden fumigation chamber for 3 hours after pretreatments by burning elemental sulphur.

Cabinet tray dryer, solar tunnel dryer and open sun drying were used as drying methods. The pretreated grape bunches were dried at 60ºC using electrically operated cabinet tray dryer having 3KW, 0.5HP 1440 RPM continuous motor (Make: M/s Vijay Enterprises, Bengaluru; Model ADHS-05) The moisture content of berries was analysed constantly at two hours interval using moisture analyzer (Make: Sartorius electronic moisture analyzer, Model: MA 35) till it reached the desired level of 15-16%. Pretreated bunches were subjected to drying by placing over the ventilated steel rack under both sun drying and solar tunnel dryer. The dimension of solar tunnel dryer was 3.0 m L × 3.0 m W×2.4 m H with two fixed electric fans having 1000 CFM capacity each on either side for exhausting moist air. The temperature and relative humidity were recorded at an interval of two hours using electronic data logger (Make: Equniox, Model: EQ-172) fitted inside solar tunnel dryer. The average maximum and minimum temperature and relative humidity recorded during the experiment period were 67.5°C and 18.5°C, and 88.7% and 2.8% respectively. Under open sun drying, the pretreated grape bunches were exposed to open sun light and the maximum and minimum temperature and relative humidity recorded during the study period were 45 and 18°C and 60 and 10%, respectively.

The drying time was calculated constantly by analyzing of moisture content of berries at regular interval till the moisture level reduced below 15% on wet basis. The time interval for recording the moisture content was 2, 4 and 6 hours in cabinet tray dryer, solar tunnel dryer and open sun drying respectively. Moisture ratio (MR) of raisins during the drying was obtained using the equation (Mt/M0), where, Mt is the moisture content at time of analyzing, M0 is the initial moisture content. The moisture ratio curve was plotted between moisture ratio versus time (h) required to reduce moisture from the grapes.

The experiment was carried out in factorial completely randomized design having drying methods and pre treatments as two factors each being replicated four times. The details of factors and levels are illustrated below.

Factor one: Pretreatment

T1: Ethyl Oleate 1.5% + 3% K_2CO_3 (3 minutes dipping)

T2: Olive Oil 1.5% + 3% K_2CO_3 (3 minutes dipping)

T3: Blanching (at 85°C for 2 min)

T4: Control (without dipping pre-treatment)

Factor two: Drying methods

M1: Cabinet tray dryer

M2: Solar tunnel dryer

M3: Open sun drying

The colour of fresh grapes and raisins was measured using a portable colorimeter (Lovibond LC100®, Model RM200 Portable spectrophotometer, The Tintometer Limited, Salisbury, UK). The L^* value corresponds to a dark bright scale and range from 0 to 100 (0 = black, 100 = white). The a^* and b^* are related to greenness and blueness. $+a^*$ and $-a^*$ show redness and greenness, respectively, while +*b** represents yellowness over blueness (-*b**).

Texture evaluation was carried out using a texture analyzer (TA HD plus Stable Microsystems, UK) with a 50 kg load cell. Individual raisin was compressed with a 10 mm cylindrical probe (PL/10) at a speed of 2 mm/s with automatic return to compress the raisins between parallel plates and prop. The downward distance (compression) was set at 5 mm, pre-test speed and post-test speed were 1 mm/s and 10 mm/s, respectively. The measured data was analyzed using a software program, Exponent® (Version 1.22, Stable Micro Systems, UK) and expressed as Newton (N). The data obtained were statistically analyzed by applying Factorial Completely Randomized Design (F-CRD) using SPSS® software at five per cent level of significance.

RESULTS AND DISCUSSION

The physicochemical attributes of fresh grapes berries used in the study were analyzed before the start of experiment and recorded an average berries weight (1.65 g), fruit bunch weight (125.50 g) moisture content (71-73%), water activity (0.967a_w), total soluble solids (23.58°B), titratable acidity (0.813 %), total carbohydrates (20.98 g 100 g^{-1}), crude fiber (0.9%) antioxidant activity (204.11 mg/100 g) and instrumental color values *L** (47.12), *a** (-2.84) and *b** (11.24).

The effect of different pretreatments, drying methods and their interaction differed significantly in relation to drying time (Table 1 and Fig. 1). The mean data on the effect of pretreatments on drying time reveled that the grapes pre-treated with K_2CO_3 @ 3 % and ethyl oleate @ 1.5 % took significantly minimum time (60.94h) followed by 1.5% olive oil + 3% K_2CO_3 (79.26 h) and hot water blanching (94.42 h) while, maximum (115.75h) drying time was recorded in the berries without pretreatment. The mean data on effect of different drying methods on drying time showed that the cabinet tray dryer, took significantly minimum time (40.09h) followed by solar tunnel dryer (84.88 h) whereas, significantly maximum drying time of 137.81 hours was recorded in open sun drying. The cabinet drying method has significant advantages of standard air circulation, constant temperature and continuous drying process resulting in saving 70.91 and 52.77% of drying time over solar and sun drying method among all pretreatments, respectively whereas, the solar tunnel dryer saved 38% of drying time over the open sun drying. The pretreatment involving dipping berries in potassium carbonate with ethyl oleate irrespective of all drying methods took minimum time for drying and superior over hot water blanching and control. Reduction in drying time in black grapes (25h) treated using ethyl oleate plus potassium carbonate solution has been reported (Doymaz and Pala 2002). The rapid drying in ethyl oleate or olive oil with potassium carbonate emulsion is attributed to the creation of micro cracking, elimination of waxes and lipids from skin, formation of collapsed skin on the grape berries leading to rapid moisture evaporation (Pangavhane *et al*., 2000; Gabas *et al*., 1999). The pretreatment involving dipping of grapes in olive oil with potassium carbonate emulsion could significantly reduce the drying time over hot water blanching and control in all methods of drying. The findings of Mahmutoglu *et al*. (1996) about the significant enhancement in drying rate by removing the waxy surface of grape berries using both ethyl oleate and olive oil confirms our results.

Table 1: Effect of different pretreatments, drying methods and their interaction on drying time of raisins.

Pretreatments (Factor – T)		Drying time (hours)			
		Drying methods (Factor – M)			
		M_1	**M_2**	**M_3**	**Mean**
T_1 -Ethyl Oleate 1.5% + K_2CO_3 3% (3 Minutes Dip)		26.08	48.25	108.50	**60.94**
T_2 - Olive Oil 1.5% + K_2CO_3 3% (3 Minutes Dip)		34.03	71.50	132.25	**79.26**
T_3 - Hot Water Blanching (2 Minutes @ 85°C)		46.50	95.25	141.50	**94.42**
T_4 - Control (No Dipping Pre-treatment)		53.75	124.50	169.00	**115.75**
Mean		**40.09**	**84.88**	**137.81**	-
	Pretreatments (T)	**Drying methods(M)**		**Interaction(T×M)**	
S Em ±	0.53	0.46		0.92	
CD @ 5%	1.53	1.32		2.65	

M_1: Cabinet tray dryer; M_2: Solar tunnel dryer; M_3: Open sun drying

The moisture ratio curves have shown that moisture ratio of samples during drying decreased with the increase in drying time and the pretreatments shortened the drying time significantly compared to the untreated samples in all methods of drying (Fig. 1). In cabinet tray dryer, the moisture content of pretreated samples (ethyl oleate + K_2CO_3) decreased rapidly from 71±3% (MR = 1) to 16±2% (MR = 0.2) in 26 h, whereas, untreated grapes showed a moisture loss from initial value 71±30% (MR = 1) up to 18±2% (MR = 0.28) in 56 h. Similar trends of moisture loss were observed in the pretreatment samples with olive oil and hot water blanching indicating a rapid rate of moisture loss compared to control. Generally, the pretreatments effect found to be similar among all drying methods, except the drying time which was minimum in cabinet tray dryer followed by solar tunnel dryer and open sun drying (Misha *et al*., 2013).

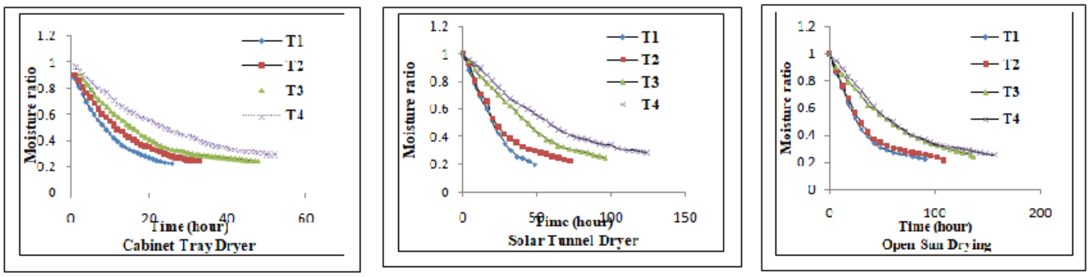

Fig. 1. Moisture ratio curve for raisins dried in cabinet tray dryer, solar tunnel dryer and open sun drying by different pretreatments T1: Ethyl Oleate 1.5% + 3% K_2CO_3 (3minutes dipping); T2: Olive Oil 1.5% + 3% K_2CO_3(3 minutes dipping); T3: Blanching (at 85°C for 2 minutes); T4: Control (without dipping pre-treatment).

The *L**, *a** and *b** values of fresh grape berries were 47.12, -2.82, 11.24 respectively. Statistically significant differences for raisin color among the pretreatments, drying methods and their interaction were observed.

Among pretreatments, the lightness (*L**) values of raisins ranged from 27.79 to 41.81. The raisins pretreated with ethyl oleate and olive oil with potassium carbonate had maximum (47.04) *L** values and of superior color compared to hot water blanching and control (Table 2 and Plate 1). Higher *L** values indicate the lighter colour and least browning in raisins. The color of raisins not only depends on pretreatments but also on drying methods as the *L** values were 29.89, 32.63, and 41.49 under sun, solar and cabinet dried raisins, respectively indicating superior quality of cabinet dried raisins appearing light in colour. Similar results of production of high quality Crimson raisins using solar and cabinet dryer (Guine *et al*., 2015). The darker color in control is possibly due to enzymatic and non-enzymatic browning which are the main factors for discoloration of raisins during drying.

The mean redness (*a**) values of pre treated raisins ranged from 8.05 to 9.89 whereas, it was in the range of 7.07 to 11.77 in drying methods, The least values of a* indicate less dominance of red colour and higher the value more is the red colour. The raisins pretreated with ethyl oleate and potassium carbonate exhibiting more green colour had minimum (8.05) a* value (Venkatram *et al*., 2017), where, *a** values of raisins were affected by different pretreatments and drying methods. There was a negative correlation between lightness (**L*) and redness (**a*) values *i.e*., the raisins with dark color showed lower **L* values but, possessed higher**a* values and *vice-versa*.

Significant difference was recorded for yellowness (*b**) of raisins, where, +*b** value indicates the yellowness predominating blueness. The mean *b** values of the pretreated samples ranged from 6.77 to 20.33 and maximum *b** value (20.33) was recorded in raisins pretreated with ethyl oleate and potassium carbonate, whereas, it was minimum (6.77) in control whereas the *b** values were 9.27, 11.06 and 23.45 in raisins prepared under open sun, solar dryer and cabinet dryer, respectively. The general observation revealed that, preferred color of raisins is obtained when the raisins took minimum time for drying. The color of raisins not only depends to pretreatments but, it also depends on various drying methods. Visually the raisins pretreated with ethyl oleate and potassium carbonate emulsion were light green, golden brown and dark brown in appearance obtained from cabinet, solar tunnel and open sun drying, respectively. The variation in color parameter of raisins may be due to different enzymatic and non-enzymatic browning, rate of drying, incidence of oxidation and other factors among different drying system and different drying times and temperatures (Bai *et al*., 2013).

Table 2: Effect of different pretreatments drying methods and their interaction on color values (*L, *a**, *b**) of raisins.**

Factor- T	Factor – M (Drying methods)											
	Color value (L^*)				Color value (a^*)				Color value (b^*)			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
T_1 -	47.04	40.06	38.33	**41.81**	4.03	9.44	10.68	**8.05**	27.98	18.63	14.40	**20.33**
T_2 -	44.51	34.58	24.23	**34.44**	6.45	11.01	12.20	**9.89**	27.83	16.63	8.92	**17.79**
T_3 -	44.36	28.45	31.14	**34.65**	5.49	7.53	12.15	**8.39**	25.13	6.17	9.18	**13.49**
T_4 -	30.07	27.43	25.87	**27.79**	12.33	5.18	12.04	**9.85**	12.88	2.83	4.60	**6.77**
Mean	**41.49**	**32.63**	**29.89**	-	**7.07**	**8.29**	**11.77**	-	**23.45**	**11.06**	**9.27**	-

	(L^*)			(a^*)			(b^*)		
	(T)	(M)	T×M	(T)	(M)	T×M	(T)	(M)	T×M
S Em ±	0.63	0.55	1.09	0.51	0.44	0.88	0.52	0.45	0.91
CD @ 5%	1.81	1.57	3.14	1.45	1.26	2.51	1.50	1.30	2.60

Plate 1. Appearance of raisins pretreated with ethyl oleate and potassium carbonate (T1) and dried in Cabinet tray dryer (M1), Solar tunnel dryer (M2) and Open sun drying (M3) methods.

Texture is the physical characteristic that greatly influences the sensory values and marketability of raisins. In this experiment, the texture of raisin samples was significantly affected by pretreatments and drying methods. Among the different pretreatments, the mean hardness of raisin ranged from 4.96 to 6.37 in different treatments used in our study. Hardness is the force required to compress or to cause deformation in a food object. It was evident that the raisins pretreated with K_2CO_3, ethyl oleate and olive oil required minimum work and force for compression as well as deformation and therefore, the raisins obtained were of soft texture (Alizadeh *et al*., 2010) (Table 3). The soft texture is possibly due to the occurrence of micro fissures on the cell wall of grapes by alkali emulsion K_2CO_3 having a pH of 10-11 responsible for the softness of raisins (Esmaiili *et al*., 2007) (Plate 2). From the mean data on raisin texture obtained from different the drying methods, it was apparent that the grapes dried in open sun conditions were hard (5.61 N) and less hard in cabinet dryer (5.35N) followed by solar tunnel dryer (5.39N). Prolonged drying time resulted in increased hardness because of caramelization and Maillard reactions occurred during drying and formation of hard structure (Almeida *et al*., 2013).

Table 3: Effect of different pretreatments drying methods and their interaction on texture (N) of raisins.

Factor – T (Pretreatments)		Texture (N)			
		Factor - M (Drying methods)			
		M_1	M_2	M_3	Mean
T_1 - Ethyl Oleate 1.5% + K_2CO_3 3% (3 Minutes Dip)		4.91	4.96	5.01	**4.96**
T_2 - Olive Oil 1.5% + K_2CO_3 3% (3 Minutes Dip)		4.91	4.86	5.25	**5.00**
T_3 - Hot Water Blanching (2 Minutes @ 85°C)		5.29	5.34	5.75	**5.46**
T_4 - Control (No Dipping Pre-treatment)		6.28	6.39	6.44	**6.37**
Mean		**5.35**	**5.39**	**5.61**	**-**
	Pretreatments (T)	**Drying methods(M)**		**Interaction T×M**	
S Em ±	0.03	0.02		0.05	
CD @ 5%	0.08	0.07		0.14	

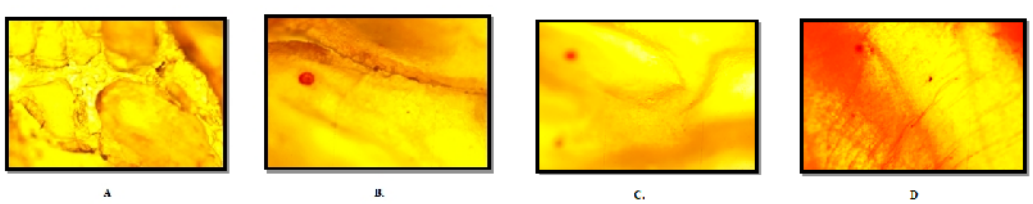

Plate 2. Effect of different pretreatments on raisins skin texture which are dried in cabinet dryer (40X). Raisins pretreated with ethyl oleate + K_2CO_3(A); Olive oil + K_2CO_3 (B); Hot water blanching (C); Without dipping Pretreatment (D).

CONCLUSION

The combination of pretreatments and drying methods are critical factors for production of good quality raisins. The raisin produced from the combination of a pretreatment *i.e.* potassium carbonate and ethyl olate and drying methods *viz*., cabinet tray dryer and solar tunnel dryer accelerated the drying rate, had appealing colour and soft texture in short period of time saving energy and manpower, acceptable sensory attributes and better marketability.

Acknowledgements. Senior author is grateful to the University Support and Workforce Development Program, International Programs in Agriculture (IPIA), Purdue University, West Lafayette, Indiana, USA for sponsoring the education programme and University of Horticultural Sciences, Bagalkot, India for providing all the support during study period.

Conflict of Interest. None.

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How to cite this article: Foshanji Ahmad Shafiq, Krishna, H.C., Sadanand K. Mushrif, Ramegowda, G.K., Bhuvaneswari S., Shankarappa T.H. and Sahel Nasir Ahmad (2022). Effects of Pretreatments and Drying Methods on Drying Kinetics and Physical properties of Raisins. *Biological Forum – An International Journal, 14*(4a): 155-160.