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Effect of pretreatments on drying characteristics of Thompson seedless grapes

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ABSTRACT

The effect of various pretreatments on drying characteristics of Thompson seedless grapes were studied using a laboratory scale cabinet tray dryer with the controlled condition at air temperature 50^0C and at air velocity of 1.2 m/s. In various pretreatments, lye treatment and potassium metabisulphite (KMS) were used with commercial dipping oil and citric acid. Variable thermal diffusivity was calculated from experimentally estimated values of thermo-physical properties at a given moisture contents. Studies of transport properties for all pretreatments were also conducted. These parameters were correlated with the corresponding moisture content in an empirical model using a non-linear regression method. Treatments with Citric acid found to be effective, thermal diffusivity significantly decreased with a decrease in the moisture content of the grapes. The pre-drying treatments had no significant effect on the thermo-physical properties of grapes.

Key words: Drying kinetics, Grape, Pretreatment solution, Thermal diffusivity.

INTRODUCTION

Grapes (*Vitis vinifera*) are popular seasonal and perishable fruits. Preservation of grapes in the form of raisins is a traditional method commonly used to extend the shelf life of grapes. This process leads to a product that is consumed without prior rehydration and possesses good nutritional and organoleptic characteristics. Sun drying under hostile climate conditions leads to severe losses in the quantity and quality of the raisins. The basic problem in grape dehydration has been the slow rate of moisture removal from grapes during the drying process and it may be due to waxy cuticle of the grapes. Therefore, chemical dip treatments (both hot and cold) have been used to increase the drying rate of grapes which not only reduce the drying time but also improve quality of the raisins. The hot dip treatment with dipping solution causes cracking and perforation in the waxy cuticle and thus increases the drying rate over the cold dip treatment. (Riva and Peri (1986) studied the drying kinetics of different grape varieties pretreated with NaOH and ethyl oleate solutions maintained at 40^0C under sun drying and forced convective drying conditions Pangavhane *et al.* (1999) studied the effect of various pretreatments (dipping in oil- ethyl oleate, olive oil and hot NaOH solution) on drying kinetics of Thompson seedless grapes and reported that drying behavior of the pretreated grapes was in good agreement with Page's model. Kadu *et al.* (2005) studied drying behavior of some selected fruits and vegetables. The present study was undertaken to investigate effect of pretreatments and their effect on mass and thermal diffusivity of Thompson seedless grapes and organoleptic properties of raisins.

MATERIALS AND METHODS

Thompson seedless grapes from the orchards of Nashik (Maharashtra) region were used throughout experiments. The grapes were picked from the same clone vines. Moisture content, total soluble solids and titratable acidity of the grapes were determined by the AOAC methods (2002). The unit density of grapes as a function of moisture content was experimentally determined during the drying process.

Experimental setup: The cabinet tray dryer (Quality make, Mumbai) was used in this experiment. The dryers were made of steel / metal and the trays were held in a cabinet which is connected to a source of air heated by electric coils. Similar experimental setup was implemented by Chavan *et al.* (2015) in fruit leathers. The trays were made of suitably thick aluminum sheets. The air circulation was done by heavy duty blower. The air temperature ranged from 5^0C plus ambient up to 150^0C controlled by thermostat with $\pm 2^0$C accuracy. For this experiment, air temperature was kept constant at 50ºC. The air enters the bottom of the chamber below the trays and then rose through the trays of food being dried, and exits from an opening in the top of the chamber. In the practical action systems the trays were designed to force the air to follow a longer zigzag route which increases the air/ food contact time and thus improves its efficiency. Insulation (3" thick) was provided between the walls and the doors to prevent the loss of heat. The cabinet tray dryer operated on 220/230 volts single phase or 440 volts three phase.

Pretreatment: The grapes were firstly washed with tap water and then healthy berries were separated and then subjected

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to various chemical pre-treatments as given below. The pretreated berries were dehydrated in the cabinet tray drier at 50^{0}C at 1.2 m/s air velocity. The treatment details are as follows.

T_1: 0.3% lye-treatment (90^{0}C for 5 sec) + 4% KMS (RT for 5 min)

T_2: 0.3% lye-treatment (90^{0}C for 5 sec) + 2% dipping oil (RT for 5 min) + 4% KMS (RT for 5 min)

T_3: 0.3% lye-treatment (90^{0}C for 5 sec) +3% citric acid (RT for 5min.) + 4% KMS (RT for 5 min)

T_4: 0.5% olive oil + 6% Potassium carbonate (K_2CO_3 at 50^{0}C for 3 min)

(RT: room temperature)

Drying: The pre-treated berries were placed in a single layer over the aluminum trays and inserted into the dryer cabinet. Drying runs were carried out at a constant temperature of 50^{0}C, and air velocity of 1.2 m/s. The grapes were dried from an initial moisture ratio (3.25) to final moisture ratio (0.17). In order to determine equilibrium moisture content, drying runs were conducted until changes in sample mass were less than 1g. Similar study was conducted by Sakhale and Pawar (2011) on mango slices.

Sensory quality: The sensory evaluation of raisins was carried out for each pretreatment to determine organoleptic quality of the prepared raisins. A categorical rating of the sample was made. After drying and before carrying out the sensory evaluation, the samples were again washed in tap water and dried at room temperature. The organoleptic evaluation was performed by a trained panel of 10 judges on 9 point Hedonic scale (1- extremely dislike, 9- extremely like) suggested by Amerine *et al.* (1965). The effect of various pretreatments on quality and appearance of grape raisins has also been shown photographically in Plate 1.

Determination of transport and thermo-physical properties

Thermal diffusivity: The thermal diffusivity of the grapes was determined by following expression given by Kostaropoulos and Saravacos (1997).

$$\alpha = \frac{K}{\rho Cp}$$

where α is the thermal diffusivity in $m^2 s^{-1}$ and kg, e_g and Cp_g are thermal conductivities in $Wm^{-1}K^{-1}$, density in kgm^3 and specific heat in $J\,kg^{-1}K^{-1}$, respectively, for grapes/raisins. Thermal conductivity and specific heat of the grapes were determined using Eqs. (1) and (2), respectively (Vagenas *et al.*,1990). The density of the grapes was measured at given moisture contents and to calculate the corresponding thermal diffusivities.

$$K = 0.069 + 0.404 \left[\frac{m}{1+m}\right] \quad (1)$$

Where k is thermal conductivity in $Wm^{-1}K^{-1}$ and m is the moisture content in g [water] g^{-1} [dry matter].

$$Cp = 1400 + 2782 \left[\frac{m}{1+m}\right] \quad (2)$$

Where Cp is specific heat in $J\,kg^{-1}K^{-1}$

Moisture ratio (MR): Calculation of the average dimensionless moisture ratio (MR) which is equal to (m (t)-me)/ (mi–me); mi and me are the initial and equilibrium moisture contents (dry basis), respectively, m (t) is the moisture contents at time t (Iguaz *et al.* 2003).

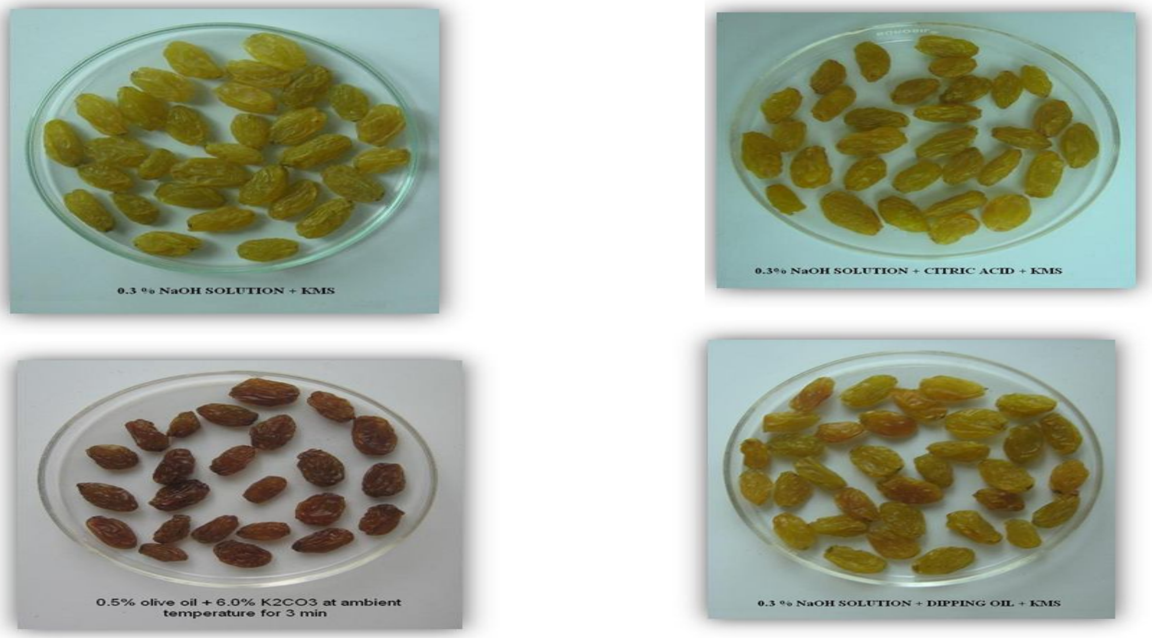

Plate 1. Effect of various pretreatment on quality of grape raisins

The value of Pages constants k and N were determined at a drying air temperature of 50^{0}C for each pretreatment experimentally from normalized drying curves which were evaluated based on coefficient of determination (R^2). Pages models given by,

$$MR = exp(-kt^N)$$

Tulasidas *et al.* (1993) tested Pages models as a single-layer drying model for describing the drying curve of grapes.

Unit density: In order to determine thermal diffusivity and dimensionless times, unit (particle) density of the grapes ($ñ_s$) is required as an input variable. The unit density is a function of moisture content (dry basis) of the grapes as measured by non-linear regression for the grapes/raisins during the drying process. Based on a non-linear relationship (Gabas *et al.* 1999) between unit density of grapes and the moisture content, solid density (e_s) was also determined as the equation constant by 1483.6 kgm^3.

$$\rho g = \rho s\left[\frac{1}{1+m}\right] + \rho\left[\frac{m}{1+m}\right]$$

A coefficient of determination (R^2) of 0.94 indicated a high degree of correlation when ρ_w =998.2 (kgm^{-3}) was used. The variation of solid density with temperature is assumed to be negligible. The values of 992.2, 988.1, 983.2 and 977.8 (kgm^{-3}) were used as water density to calculate the unit density of the grapes at 40, 50, 60 and 70^{0}C, respectively (Barbosa-Canovas and Vega-Mercado, 1996; Esmaiilia *et al.* 2007).

RESULTS AND DISCUSSION

The data obtained during the course of investigation are presented and discussed in detail. The results recorded for different parameters of physicochemical study such as % Dry matter, TSS, Titrable acidity, Unit density, Equivalent radius of berries, Thermal conductivity and specific heat of the raisins are presented in Table 1. The data presented in Table 2 shows that each pretreatment had different drying time. Treatment T_1 had shortest drying time followed by T_3 and T_4 while treatment T_4 had longest drying time. This may be due to pretreatment of grapes with lye solution. Lye solution containing NaOH might have removed some part of the surface wax from the skin and produced micro cracks on skin which facilitated into increased moisture evaporation. Whereas in treatment T_4, NaOH solution was not used, such micro cracks were not formed and therefore resulted into longer drying time. Pages constant k, N is different for different pretreatments and coefficient of determination (R^2) indicates that Pages model fit well with experimental data. Similar results were observed by Pangavhane *et al.* (1999) that Pages constant k, N are different for different pretreatments.

Table 1 Physico-chemical properties of the grapes

Specification	Range
Dry matter (%)	22.86±1.32
Total soluble sugar (%)	19±3
Titratable acidity	0.45±0.17
Unit density (kgm^{-3})	1105±10
Equivalent radius of berries (m)	.006657±0002
Thermal conductivity (Wm^{-1}K^{-1})	0.37±0.38
Specific heat (J kg^{-1}K^{-1})	3525±39

Table 2 Results of nonlinear regression analysis using Page's model for total drying time

Pretreatment run	Drying time (hrs)	K(hr^{-1})	N	R^2
T_1	18	0.02	2.45	0.986
T_2	29	0.13	1.46	0.9974
T_3	25	0.021	1.52	0.9978
T_4	38	0.1	1.45	0.9975

Fig 1 shows the variation of moisture ratio with drying time. As shown in the graph, at 50^{0}C, the pretreatment one had shortened the drying time significantly compared to the other pretreatment. The drying rate was dependent on both the pretreatment conditions and the operating conditions. All curves shown in Fig-1, 2 and 3) exhibited a similar trend i.e. moisture ratio decreased with increase in drying time. Effects of pretreatment on drying time were also observed by Pangavhane *et al.* (1999) and Esmaiilia *et al.* (2007).

Fig 2 represents the graph of drying rates versus the moisture content of the grapes. Drying rate curves can be increased for pretreatment T_1, T_2, T_3 of grapes as compared to olive oil pretreated grapes due to the enhanced moisture evaporation. Similar results are reported by Pangavhane *et al.* (1999) and Esmaiilia *et al.* (2007).

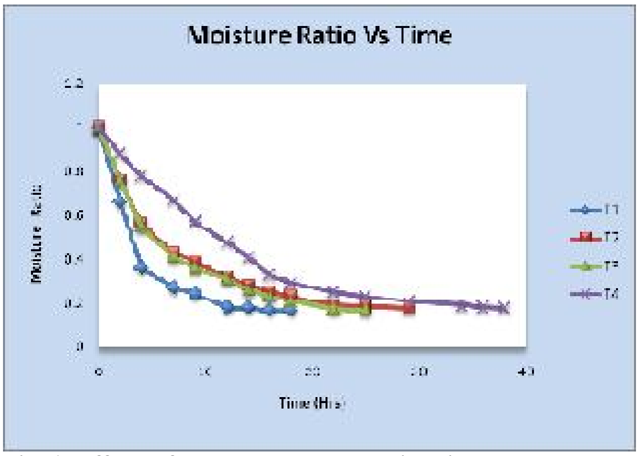

Fig. 1. Effects of pretreatments on drying time

T_1: 0.3% lye-treatment + 4% KMS T_2: 0.3% lye-treatment +2% dipping oil + 4% KMS

T_3: 0.3% lye-treatment +3% citric acid + 4% KMS T4: 0.5% olive oil + 6% K_2CO_3

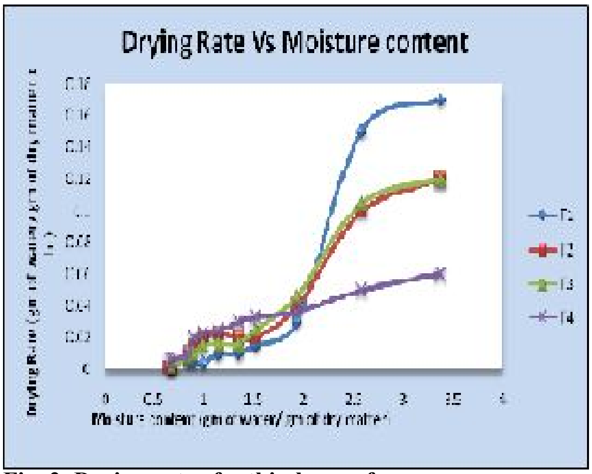

Fig. 2. Drying rate of a thin layer of grapes

T_1: 0.3% lye-treatment + 4% KMS T_2: 0.3% lye-treatment +2% dipping oil + 4% KMS
T_3: 0.3% lye-treatment +3% citric acid + 4% KMS T_4: 0.5% olive oil + 6% K_2CO_3

Fig 3 shows the variation of thermal diffusivity of the grapes during the drying process. The thermal conductivity and the specific heat were decreased during the drying process and the density was increased due to water evaporation. The decrease of thermal diffusivity during the drying process of the grapes indicated that the effect of specific heat was offset by the effect of thermal conductivity and particularly by the effect of density. There are no significant differences in the thermal diffusivities of the different pretreated grapes. This implies that the pretreatments had no significant effect on the thermo-physical properties of the grapes. Esmaiilia *et al.* (2007) also reported the similar findings.

The thermal diffusivity was significantly decreased with a decrease in the moisture content of the grapes due to a linear decrease of thermal conductivity and an increase in the grape density (Table 3).

For deciding the quality from the consumer's acceptance point of view sensory evaluation was carried out to the raisins obtained from each run. The average sensory scores for each pretreatment are presented in Table 4. It was observed that the raisins obtained from T_1 poor in texture and taste was although drying time was less compared to other treatments, but. This might be due to crystallization of sugar which made the raisins grainy and hard. The raisins

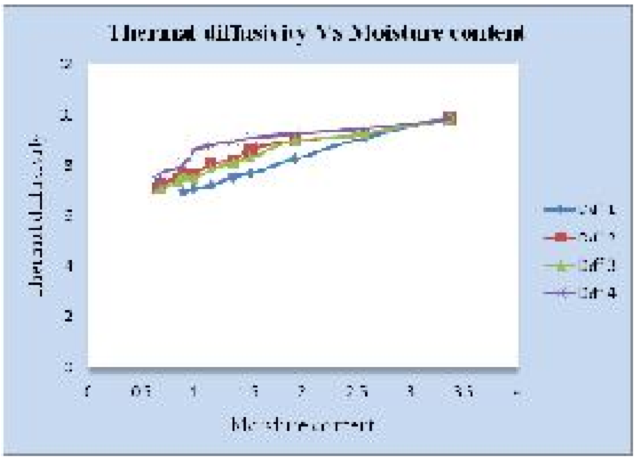

Fig-3: Thermal diffusivity of various pretreated grapes during the drying

obtained from the pretreatments T_2 and T_3 were found to be of good quality because of both citric acid and dipping oil developed soft texture and made the raisins fluffy, dry and clean. Among these two, citric acid pretreatment was found better than dipping oil pretreatment because citric acid prevented the crystallization of sugar, induced tart taste whereas dipping oil induced brown color rather than light yellow color. However, T_4 pretreatment produced raisins with oily surface. The T_3 raisins were found to be much lighter in color with better texture as compared to the raisins produced in T_1. However, the T_2 and T_4 produced raisins with a reddish brown color.

It was observed from Table 4 that the scores for organoleptic quality of raisins produced on the hedonic scale ranges between five and nine for all pretreatments. However, the raisins obtained from citric acid pretreatment achieved the highest sensory score (8.2) whereas olive oil scored the lowest (5.4). The higher score of the raisins produced in T_3 by the panelists was for their light color, fruity flavor with softer and chewier texture. Thus, the drying rate was dependent on both the pretreatment and the operating conditions. Similar findings were made by Sakhale *et al.* (2007).

The raisins prepared by applying the various pretreatments and then drying in cabinet tray dryer at 50^{0}C with constant air flow of 1.2 m/s. It showed that treatment which contained lye solution and potassium metabisulphite (KMS) induced light green colored raisins whereas olive oil and K_2CO_3 treatment produced brown colored raisins. The

Table 3: Thermo-physical properties of grapes

Moisture content (dry basis)	Thermal diffusivity ($x10^8 m^2 s^{-1}$)	Specific heat (J/ kg K)	Thermal conductivity (W/m K)	Unit density (kg/ m^3)
3.37	9.86	3542	0.38	1087
2.58	9.24	3403	0.35	1112
1.44	8.31	3041	0.30	1186
0.92	7.41	2707	0.25	1235
0.62	6.97	2462	0.22	1282

Table 4: Organoleptic characteristics of tray dried raisins

Sensory Parameter	Treatments			
	T_1	T_2	T_3	T_4
Color	9	8	9	8
Aroma	7	5	7	7
Taste	7	5	8	5
Mouth feel	6	7	9	6
Overall Acceptability	7	6	8	6
Average	7.2	6.2	8.2	5.4

KMS prevented the browning and helped to maintain light yellow color of the raisins. In absence of KMS, browning took place and hence led to develop the brown color than light green color. The use of weak acids reduced the degree of non-enzymic browning by decreasing the pH. Hence raisins obtained by using citric acid also possessed light green color. The raisins prepared from dipping oil treated grapes were light brown in color because dipping oil led to the development of brown color rather than greenish one. The results are in agreement with the findings reported by Femenia *et al.* (1998).

CONCLUSION

Combination of hot and cold pretreatments improves organoleptic properties and reduces drying time of raisins. Pretreatment of grapes with 3% sodium hydroxide solution at 100^{0}C for 30 sec followed by a citric acid (3%) solution for 5 min at room temperature (RT), and in a potassium metabisulphite (4%) solution for 5 min at RT was found to be effective. Thermal diffusivity of the grapes varies with the moisture content of the grapes. The pre-drying treatments had no significant effect on the thermo-physical properties (i.e. thermal conductivity, Specific heat and particle density) of the grapes.

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