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Optimization of pretreatments for vacuum dried grapes

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Abstract
The effects of pretratments were investigated to optimize the drying time for the production of raisins by vacuum drying. Response surface methodology was used to optimize process parameters: concentration of pretreatment solutions such as potassium carbonate, olive oil, soy lecithin, sugar concentration and immersion time for the drying time of vacuum dried grapes. The optimized conditions of pretreatments were found to be 7 % potassium carbonate with 5 min immersion time, 3% olive oil with immersion time 2 min, 3% soy lecithin with immersion 4 min and 64° brix sugar concentration with immersion time 48 h. The minimum drying time of 33 h was found for the grapes treated with potassium carbonate concentration of 7 % and immersion time of 5 min.

Keywords: immersion time, optimization, pretreatment, response surface methodology, vacuum drying

Introduction
Grape is a seasonal perishable crop. It is available for 4 to 5 months in a year. It gets faster spoilage; therefore it must be utilized within a short duration i.e. four to five days. Natural drying process takes about 15 days to produce raisins.

Drying is a process for heat and mass transfer in which water moves from the internal part of drying product's surface. Heat is transferred from the surrounding air to the surface of the product due to rise in temperature and the remaining amount is utilized in evaporation of the moisture from the surface. Therefore, it may cause changes in product quality in physical structure such as shrinkage, puffing, crystallization, etc. (El-Ghetany 2006) [2].

Vacuum drying is a viable technology in which process materials are dried in a reduced pressure environment under the absence of air (oxygen), which lowers the heat needed for rapid drying. Vacuum dryers offer low temperature drying for heat sensitive materials without damaging the product's originality (Feng *et al.*, 1999, Regier *et al.*, 2004 and Moussa and Farid, 2002) [3, 9, 5]. It is faster than other drying methods. For foods and pharmaceuticals, this can be valuable, as other drying processes can degrade quality (Parikh, 2015) [7]. A controlled environment has been suitable for the material within the closed chamber, in which heat is used to speedily remove the water content inside the material for fast drying. Fresh air as per environmental temperature is blown inside the chamber to remove humid air in between energy source and product because of evaporation and moisture present. Therefore, a study was undertaken to optimize concentration of pretreatments and immersion time for grapes by vacuum drying process.

Materials and Methods
Selection of raw materials
Fresh grapes were purchased from a local market of Jabalpur, (M.P.), India. The selected grapes were graded according to size and colour to obtain uniform quality. Then, they were washed with water and unwanted material like dust, dirt, and surface adhering were removed.

Preparation of sample and solution
The cleaned and graded grapes were pretreated in different solution for different immersion time. The pretreatments were used for developing of cracks in waxy layer of grapes. Four types of solutions were used with different concentration: K_2CO_3 solution, soy lecithin solution, olive oil solution and sugar solution were prepared in distilled water and heated at 50 °C. Grapes were kept in these solutions under continuous agitation for specific immersion time. Finally the samples were weight.

Measurement of initial moisture content The moisture content of fresh samples was determined by using air oven method and calculated by using following equation (Ranganna, 2000) [8]. Cool the dried sample in desiccators and weighed. The weight of sample before and after drying was taken and loss in weight was calculated. Moisture content (*wb*) of samples was calculated by the following formula:

$$Moisture\ Content\ (\%, w.b.) = \frac{(Initial\ mass\ of\ sample, g - final\ mass\ of\ sample, g\ )X100}{Initial\ mass\ of\ sample, g}$$

Measurement of total soluble solids

The total soluble solids of prepared solution were found out by using hand refractometer, which give the reading directly in Brix. (Ranganna, 2000) [8].

Drying procedure under vacuum condition

Vacuum drying as a specific field of drying, in which products get quickly dried at low temperature under the absence of air during dehydration diminishes oxidation reaction for improvement in colour, texture and flavour of dried product. The basic principle of vacuum drying is to remove the water by means of vacuum. There are four essential elements in a vacuum drying system: a vacuum chamber, vacuum generating device, system for collecting water vapour and means for supplying heat required for vaporization of water (Brown *et al.*, 1964) [1]. Therefore grapes were dried without exposing them to high temperature. Weight loss of the dried grapes was measured at various time intervals, ranging from 30 min at the beginning of drying to achieve moisture content of 14% (wb) then drying processes were stopped. The weighed samples were spread in the form of thin layer on aluminium trays. These aluminium trays were put in vacuum dryer at a temperature of 60^{o}C. The experiments were replicated thrice, and the average of the drying time for each pre-treatment was used for statically analysis.

Statistical design

The influence of two independent variables i.e. solution concentration and immersion time on drying time for grapes was analyzed by using central composite rotatable design. All independent variables were controlled at three different levels discussed in Table-1. A second-order polynomial equation was then used to fit the measured, dependent variable (drying time) as a function of drying parameter. Response Surface Methodology (RSM) which explores the relationship between several explanatory variables and response variable was applied to the experimental data using the trial package, Design expert version 11 (Stat-ease Inc., USA). The process was optimized for minimum value of drying time conducting statistical analysis.

Table 1: Independent variables with their range and levels for vacuum drying

Set of experiment	Independent variables	level		
		-1	0	+1
1st set: Effect of K_2CO_3 concentrations and immersion time	K_2CO_3 (%)	3	5	7
	Time (min)	1	3	5
2nd set: Effect of olive oil concentrations and immersion time	Olive oil (%)	1	2	3
	Time (s)	40	80	120
3rd set: Effect of soy lecithin concentrations and immersion time	Soy lecithin (%)	1	2	3
	Time (min)	2	3	4
4th set: Effect of sugar concentrations and immersion time	Sugar (%)	50	57	64
	Time (h)	24	36	48

Results and Discussions

Effect of different solution concentration and immersion time on drying time

The combined effect of different solution concentration and immersion time affected the drying time to achieve the final moisture content (14 %, wb) of the grapes is shown in Figure 1 to 4. These figures show that drying time was reduced with increasing pre-treatment concentration and immersion time. This may be due to the fact that pre-treatment accelerates drying rates because presence of the cuticular wax is the main barrier to the evaporation of water. Removal of the surface wax by pretreatments is effective in promoting evaporation. Dipping of grapes in pre-treatment removes part of the wax and probably destroys the cuticular structure, whereby the drying rate is increased. Dipped grapes stay yellow green. This is due to inhibition of the action of the polyphenol oxidizes by quick drying. The waxy cuticule of grape skin controls the rate of moisture diffusion through the berries and accelerate drying. Chemical treatments are applied to remove or modified this cuticle and increase grape permeability to water (Gabas *et al.*, 1999 and Pangavhane *et al.*, 1999) [4, 6]. Statistical analysis revealed that drying time was significantly affected by different solution concentration and immersion time.

The variation of drying time was studied against the variation of solution concentration and immersion time. The variation is described by a polynomial equation of second order. The multiple regression model for the drying time showed regression coefficient R^2 i.e. 0.99 and p value < 0.0001.

The polynomial equations generated by multiple regression analysis using CCRD for different combination of solution concentration and immersion time are as follows:

Drying time = 144.19 - 3.38 x (B) - 18.62 x (A) - 0.16 x (B) x (A) - 0.1 x $(B)^2$ + 0.65 x $(A)^2$

Drying time = 227.4 - 25.92 x (C) - 1.65 x (A) + 0.13 x (C) x (A) + 1.4 x $(C)^2$ + 0.003 x $(A)^2$

Drying time= 112.64 - 4.69 x (D) - 10.72 x (A) + 0.17 x (D) x (A) + 0.37 x $(D)^2$ + 0.67 x $(A)^2$

Drying time= 128.72 - 0.19 x (E) – 0.42 x (A) - 0.01 x (E) x (A) - 0.002 x $(E)^2$ + 0.004 x $(A)^2$

Where, A = Immersion time, B = Potassium Carbonate, C = Olive oil, D = Soy lecithin,

E = Sugar concentration

In figure 1, optimum potassium carbonate concentration and immersion time for minimum drying time (33 h) was observed to be 7 % and 5 min respectively. Figure 2 shows that the sample of grapes treated with 3% olive oil took minimum drying time of 61.5 h at min immersion time of 2 min. This may be due to higher concentration of solution resulted in cracks development of waxy layer of grapes by which drying rate becomes faster.

From figure 3 it can be inferred that an increase in the percentage of soy lecithin results in lesser drying time. An optimum soy lecithin (3 %) and immersion time (4 min) for minimum drying time (72 h) was observed. The influence of sugar concentration and immersion time on the drying time for grapes is shown in figure 4. The drying time for the grapes decreased from 90.9 h to 49.4 h when sugar concentration increased from 50 to 64 °Brix for any constant immersion time within the range of 24 to 48 h. An optimum sugar concentration and immersion time for minimum drying time of 50 h was observed to be 64 °Brix and 48 h respectively. Pretreated grapes with sugar solution have been beneficial for reduction in drying time and retarding enzymatic browning reaction. Moreover the drying time of the grapes drops before drying because of the osmotic pressure, whereby reducing drying time (Tsai, 1977) [10].

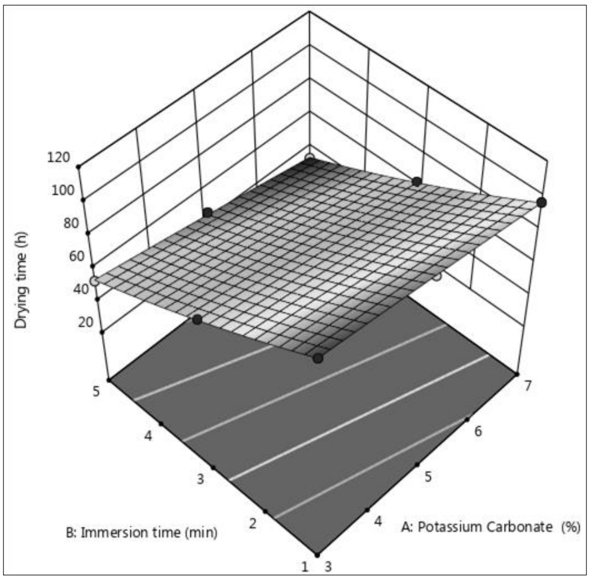

Fig 1: Effect of potassium carbonate concentration and immersion time on drying time

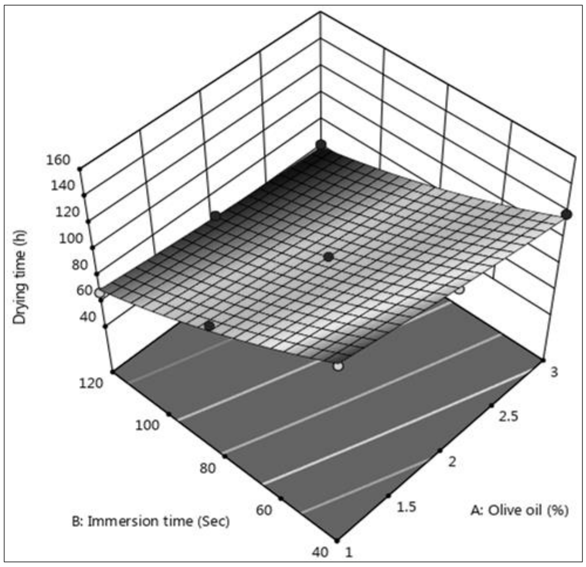

Fig 2: Effect of olive oil concentration and immersion time on drying time

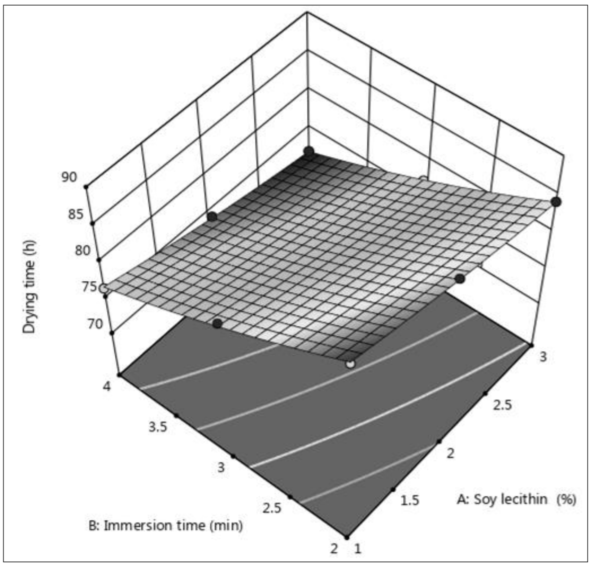

Fig 3: Effect of soy lecithin concentration and immersion time on drying time on vacuum drying

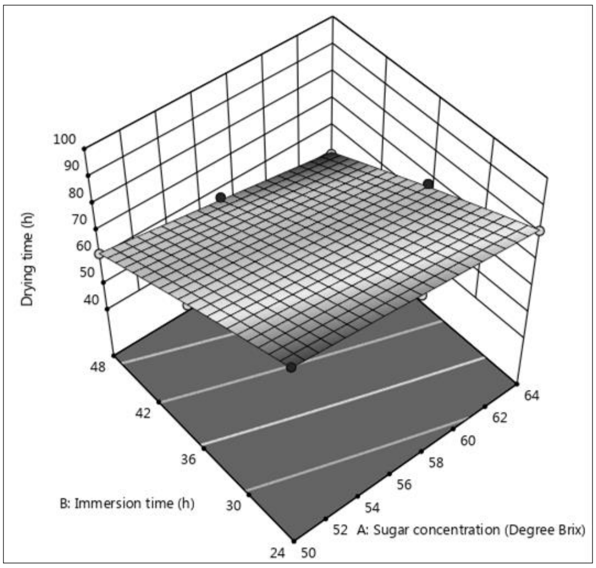

Fig 4: Effect of sugar concentration and immersion time on drying time

Conclusion

Different pretreatments and immersion time for grapes were evaluated to find out the effect of these parameters on drying time of the dehydrated grapes. Drying time reduced with increase in solution concentration and immersion time. Optimization process was employed to find out the best combination of process parameters. The study was concluded that the minimum drying time of 33 h was found for the grapes treated with potassium carbonate concentration of 7 % and immersion time of 5 min.

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