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Effects of pretreatments and drying methods on nutritional and sensory quality of raisin

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Abstract
A study with three drying methods *i.e*., cabinet tray dryer, solar tunnel dryer and open sun drying methods with four pretreatments such as, ethyl oil and K_2CO_3, olive oil and K_2CO_3 and hot water blanching was undertaken to evaluate the effects of pretreatment and drying methods on nutritional quality and sensory attributes of raisins. Moisture content of grapes variety of Thompson seedless was reduced bellow 16 per cent. Raisins pretreated with ethyl oleate oil 1.5 per cent + K_2CO_3 3 per cent and dried in cabinet tray dryer had least non-enzymatic browning (0.049), highest carbohydrate (79.42 g 100 g^{-1}), minimum titratable acidity (1.80%) and crud fiber (1.11 g 100 g^{-1}) but, highest non-enzymatic browning, lover nutritional value and low sensory scores recorded for sun dried raisins without dipping pretreatment.

Keywords: raisin, pretreatment, drying methods, nutritional value, sensory attributes

Introduction
Grape (*Vitis vinifera* L.) is a nutritious fruit crop which is highly suitable for fresh consumption and development of value added products. Grape is grown in most part of the word where Italy, France, United States of America, Spain and China are the top five grape producer countries (Wang *et al*., 2016) [1]. Fresh grapes which contain about 75-80 per cent moisture are sensitive to physiological and microbial activities such as respiration, transpiration and spoilage during storage (Xiao *et al*., 2010) [2]. Grape can be consumed fresh, dried (raisin), or value added products such as wine, juice, jam, *etc*. Most of nutrients including carbohydrates, sugars, crude fiber and phytochemicals concentrate in raisins by reduction of moisture content with longer shelf life. Raisins is a popular dried fruit with high antioxidant activity which consumed directly as snack or process to wine and juice with high global demand. Raisin making or dehydration of grape is complex process compare to drying of other fruits because of presence of waxy layer on the surface of grape berries which prevents from fast moisture diffusion and extend the drying time (Casado and Heredia, 1999) [3]. Application of pre drying treatment is a key step to remove the waxy cuticle of berries before drying (Esmaiili *et al*., 2004) [4]. Chemical, physical and blanching are common methods to disturb the wax layer on grape surface to enhance drying rate (Wang *et al*., 2016) [1]. Potassium carbonate (K_2CO_3), sodium hydroxide (NaOH), sodium bicarbonate ($NaHCO_3$), ethyl oleate and olive oil are the main compounds being used as chemical pre-treatment. Apart from pretreatment, the drying method has a great effect on drying time and physico-chemical quality of raisin (Yang *et al*., 2009) [5]. Sun, solar, shade and mechanical drying are common grape drying methods all across the raisins production areas. Lack of ability to control the drying operation, prolonged drying time, weather uncertainties, high labour costs, large area requirement, insect infestation, mixing with dust and other foreign materials limits the application of natural sun drying (Toğrul and Pehlivan, 2004) [6]. The solar drying is different from sun drying in way that instead of open sun drying, the commodities are dried in a chamber or in a tunnel which is covered with semitransparent polyethylene (Esmaiili *et al*., 2004) [4]. Mechanical drying is widely used in raisin production due to its rapid, controllable, low labour, and high quality of products (Wang *et al*., 2016) [1].

Material and Methods
Raw material: The fresh grapes (*var*. Thompson seedless) with uniform bunches, size, color, maturity, free from visible damages and free from GA_3 were harvested directly from field (Sangli, Maharashtra), carefully packed in corrugated fiber board boxes and transported to Postharvest Technology Laboratory, Bengaluru. The total soluble solids content of grapes was 24°Brix and moisture content was 71-74 per cent. The average weight of grape bunches was

100-125 gram, while, the weight of individual berries ranged from 1.4 to1.8 g. Ethyl oleate oil, olive oil, and potassium carbonate used for pretreatment were procured from standard laboratory supplier and super market, respectively in Bengaluru. All other chemicals used in this experiment were of analytical grade obtained from Sigma®, Hi-Media®, SRL® and Merck®.

Pre drying treatments of grape: Grapes were cleaned by removing the dried, diseased, spoiled, immature, unwanted berries and subjected to pretreatments directly after washing in running water. Three pretreatments *viz*., dipping in ethyl oleate with potassium carbonate, olive oil emulsion with potassium carbonate and water blanching method were applied. Each treatment repeated in four replications on one kg sample size per replication. Dipping solutions of the three per cent $K_2CO_{3\ +}$ 1.5 per cent ethyl oleate oil and olive was prepared using warm water (50ºC), which was kept under continuous agitation. Washed and air dried fresh grapes were dipped in the solutions for three minutes and immediately rinsed in running cold water. The water blanching was done by dipping of the grapes bunches in hot water (85ºC) for two minutes and immediately rinsed in cold water. The temperature of water was measured by using probe thermometer to avoid overheating. Gapes were fumigated with sulphur dioxide (SO_2) using wooden fumigation chamber having dimension 1.2×0.8×0.8 meter height, width and length after dipping pretreatment. Required amount of sulphur dioxide powder (at the rate of one g kg^{-1} of grapes) was taken in glass bowl and placed at bottom center of the chamber and burnt using cotton. Immediately, the chamber was made air tight with adhesive tape to prevent the fume leakage from door and subjected for three hours of fumigation.

Drying methods: Cabinet tray dryer, solar tunnel dryer and open sun drying were used as drying methods. The pretreated grape bunches were placed in electrically operated cabinet dryer (Make: M/s. Vijay Enterprises, Bengaluru; Model ADHS-05) and dried at 60ºC. The moisture analysis was carried out continuously at two hours interval till the reach of desired level of 15-16 per cent. During drying the grape bunches were turned up frequently for uniform drying. Under solar drying, the pretreated grape bunches were placed on steel rack in solar tunnel dryer. The dimension of solar tunnel dryer was 3.0×3.0x2.4 meter, length, width and height which was installed with two electric fans for exhausting moist air. The temperature and relative humidity was recorded at an interval of two hours using electronic data logger (Make: Equniox, Model: EQ-172) inside of solar tunnel dryer. The average maximum and minimum temperature recorded was 67.5ºC and 18.5ºC, respectively while the maximum relative humidity was 88.7 per cent and minimum was 2.8 per cent. Under open sun drying, the pretreated grape bunches were placed on paper lined metal mesh racks which were exposed to open sun light. The temperature and relative humidity recorded by using same data logger. The maximum and minimum temperature and relative humidity recorded 18 - 45ºC and 10 – 60 per cent, respectively.

Analyzing of raisins nutritional compounds: Moisture content of raisins measured using Sartorius electronic moisture analyzer (Model: MA 35) and the direct reading was noted down from the instrument screen and expressed in per cent. Total soluble solids of raisins was determined using digital refractometer (Make: Erma Optical Works Ltd., Tokyo, Japan) having range of 45-92 and expressed as °B. Titratable acidity was determined by standard titration method. Total carbohydrates of raisins analyzed by phenol-sulphuric acid method according to AOAC, 2006) [7] and expressed as g 100 g^{-1}. Antioxidant activity of the raisins was determined using ferric reducing antioxidant potential (FRAP) assay and expressed in ascorbic acid equivalents in mg 100 g^{-1} (AOAC, 2006) [7]. Crude fiber content of raisin was estimated using fiber analyzer (Make: FOSS, model: FC-221) according to Ranganna, 1986 [8]. Non-enzymatic browning of raisins estimated according to Srivastava, 2002 [9] and expressed as OD value at 440 nm.

Sensory Evaluation: Sensory evaluation was done by semi trained panel of 14 members (20-30 years old) of both the gender at Department of Postharvest Technology, College of Horticulture, Bengaluru for standard sensory attributes using the 9 point Hedonic scale. The score sheet had various raisin quality attributes like color and appearance, texture, taste and overall acceptability.

Statistical analysis: The data on physico-chemical parameters of fresh grapes and raisin were analyzed by applying Factorial completely randomized design (F-CRD) using SPSS software at five per cent level of significance.

Treatments combination details

M_1T_1: Ethyl oleate oil 1.5% + K_2CO_3 3% (3 min. dip) + Cabinet tray dryer at 60°C

M_1T_2: Olive oil 1.5% + K_2CO_3 3% (3 min. dip) + Cabinet tray dryer at 60°C

M_1T_3: Hot water blanching (2 min @ 85°C) + Cabinet tray dryer at 60°C

M_1T_4: Control (No dipping pre-treatment) + Cabinet tray dryer at 60°C

M_2T_1: Ethyl oleate oil 1.5% + K_2CO_3 3% ((3 min. dip) + Solar tunnel dryer

M_2T_2: Olive oil 1.5% + K_2CO_3 3% (3 min. dip) + Solar tunnel dryer

M_2T_3: Hot water blanching (2 min. @ 85°C) + Solar tunnel dryer

M_2T_4: Control (No dipping pre-treatment) + Solar tunnel dryer

M_3T_1: Ethyl oleate oil 1.5% + K_2CO_3 3% (3 min. dip) + Open sun drying

M_3T_2: Olive oil 1.5% + K_2CO_3 3% (3 min. dip) + Open sun drying

M_3T_3: Hot water blanching (2 min. @ 85°C) + Open sun drying

M_3T_4: Control (No dipping pretreatment) + Open sun drying

Result and Discussion

Total soluble solid of raisins: The TSS of fresh grapes variety of Thompson seedless which was used in this experiment was 23.58 °B. Regarding the pretreatment effects, the TSS of raisins ranged from 80.64 to 79.41 for T_1 and T_4, respectively (Fig.1). The similar finding was recorded for raisins which pretreated in soda dip and Golden Bleach method by Mandal and Thakur (2015). The lowest TSS in T_3 and T_4 is possibly due to highest moisture content, leading to dilution of solids and non-enzymatic browning and enzymatic browning. Among different drying methods, the TSS of raisins recorded 80.35, 79.74 and 79.75 in cabinet tray dryer, solar tunnel dryer and open sun drying, respectively which were not significantly different from each other. The significant difference registered for the interaction effects between pretreatments and drying methods. The dipping pretreatments by ethyl oleate oil in cabinet tray dryer (T_1M_1) had superior TSS (Fig.1) which was in agreement with finding of Jadhav *et al*. (2010) [10]. Cabinet tray dryer helps in quick removal of moisture from berries with enhanced quality retention, while ethyl oleate facilitates moisture removal and glassy appearance.

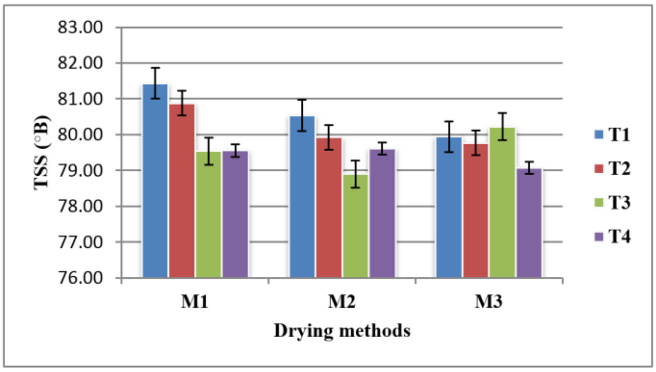

Fig 1: Effect of different pretreatments, drying methods and their interaction on total soluble solids of raisins.

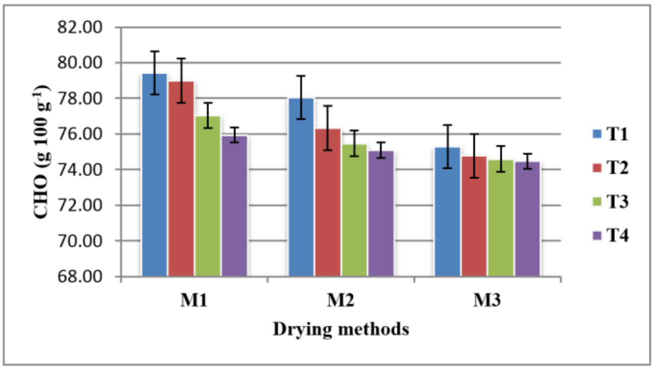

Fig 2: Effect of different pretreatments, drying methods and their interaction on total carbohydrates of raisins.

Total carbohydrates

The total carbohydrate of fresh grapes, which was used in this experiment was 20.98 g 100 g^{-1}. The total carbohydrates in different pretreated raisins ranged between 77.59 - 75.17 per cent. Dipping pretreatment of raisins in both ethyl oleate and olive oil with potassium carbonate were found superior in respect of total carbohydrates. Lower total carbohydrates were recorded in raisins which pretreated by hot water blanching and without pretreatment (control). The variation may be due to enzymatic and non-enzymatic browning reactions. This result is confirmation with the findings of Adiletta *et al*. (2015) [11]. which reported that, non-enzymatic browning reactions reduced the rate of sugars in Regina and Red Globe grapes during drying under ventilated chamber (50°C). Among different drying methods, the total carbohydrates ranged 77.85, 76.23 and 74.79 in raisins which prepared under cabinet tray dryer, solar tunnel dryer and open sun drying, respectively. The maximum carbohydrates observed in raisins which dehydrated in cabinet tray dryer which took least drying time and least discoloration but, minimum content of carbohydrates was recorded in sun dried raisins which took maximum drying duration and highest non-enzymatic browning. The lower carbohydrates in solar and sun dried raisins are possibly due to enzymatic and non-enzymatic browning reactions which promoted in higher drying period and prolonged drying condition.

Titratable acidity

The titratable acidity of fresh grapes which was used for raisin making was 0.81 per cent. Titratable acidity of raisins ranged from 1.95 to 2.78 (%) regarding different pretreatments which is applied in this experiment. The raisins which prepared without dipping pretreatment were recorded significantly higher titratable acidity as compared to raisins dipped in ethyl oleate and olive oil with potassium carbonate emulsion (Fig.3). Lower titratable acidity in T_1 (1.5% Ethyl Oleate Oil + 3% K_2CO_3) and T_2 (1.5% Olive Oil + 3% K_2CO_3) is may be due to the use of 3 per cent potassium carbonate emulsion with ethyl oleate or olive oil, which is basic in nature and neutralized the acidity of raisins. This result is in agreement with findings of Mandal and Thakur (2015) [12]. where the acidity of raisins reduced in 0.3 per cent lye solution compare to other pretreatment. It was seen that, titratable acidity is inversely proportionate to the total soluble solids present in raisins in all pretreatment and drying methods. The acidity of raisins was influenced with different drying system. The highest (2.50 %) acidity was found in open sun dried raisins but minimum (2.07%) was recorded in raisins prepared under in cabinet tray dryer.

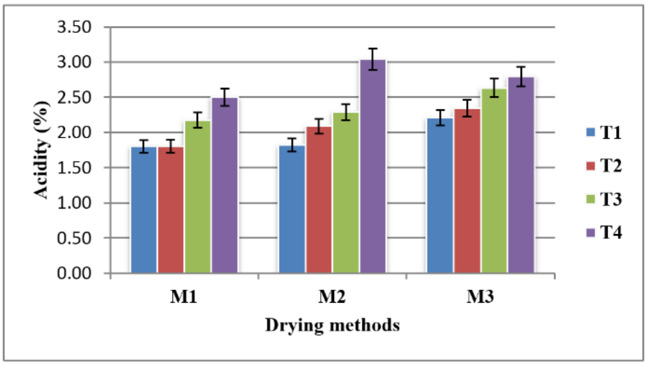

Fig 3: Effect of different pretreatments, drying methods and their interaction on titratable acidity of raisins.

Crude fiber

The crude fiber in raisins prepared by different pretreatment ranged from 1.14 to 1.76 g 100 $^{-1}$g (fig. 4). The similar result (1.18%) was reported by Kumar (2009) [13] for Thompson seedless raisins. The lower crude fiber in raisins, pretreated by ethyl oleate and olive oil with potassium carbonate emulsion is possibly due to destruction of fiber content in cell wall of grapes skin by potassium carbonate to develop cracking in the surface of berries. This result was supported by Camire and Dougherty (2003) [14]. which reported that, insoluble fiber in raisins is affected by dipping lye pretreatment.

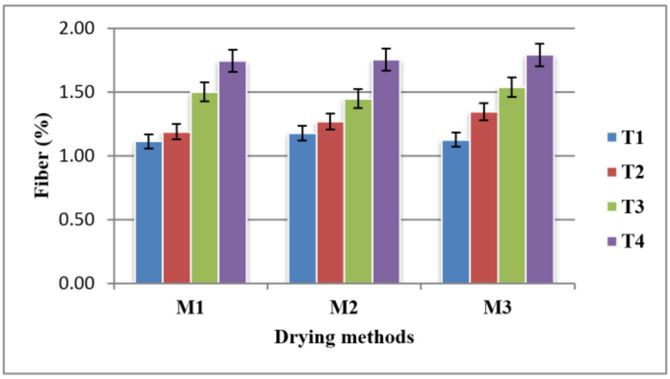

Fig 4: Effect of different pretreatments, drying methods and their interaction on crude fiber of raisins.

Total antioxidant activity of raisins

The total antioxidant activity of raisins ranged from 431.01 to 330.63mg $100g^{-1}$ in T_1 (1.5% Ethyl Oleate Oil + 3% K_2CO_3) and control treatment, respectively (Fig. 5). Breksa *et al.* (2010) [15] also reported that Golden, Thompson seedless raisins treated with sulphur dioxide had significantly higher phenolic compound than dipped in hot water or sun-dried Thompson seedless raisins. Raisins which prepared under different drying methodology showed variation in total antioxidant activity. The total antioxidant activity ranged from 328.06 in sun dried raisins to 349.81 in cabinet dried raisins. This result is supported by Kaliora *et al.* (2009) [16] that revealed which golden color Thompson seedless raisins have significantly higher antioxidant activity as well as higher total phenolic contents than sun-dried Thompson seedless raisins. The variation possibly could be because of enzymatic activity which is reduced phenolic content and antioxidant activity in sun dried raisins (Breksa *et al.*, 2010) [15].

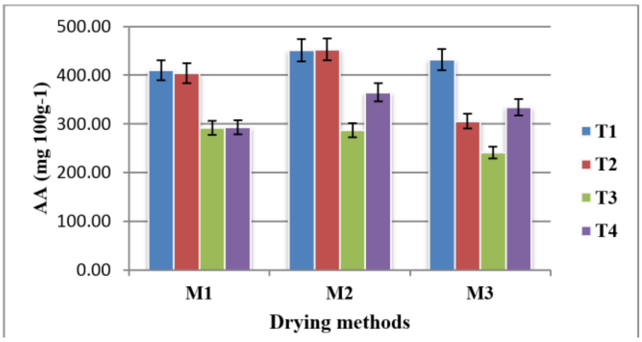

Fig 5: Effect of different pretreatments, drying methods and their interaction on antioxidant activity of raisins.

Non- enzymatic browning (NEB)

The NEB of raisins significantly affected by dipping pretreatments which ranged from 0.18 in T_1 to 0.71 OD at 440nm in T_4 (Fig 6). The dipping pretreatments of grapes in ethyl oleate and olive oil with potassium carbonate in all methods of drying were having lower non-enzymatic browning (NEB) and superior color than hot water blanching. This result is support by Doreyappa *et al.* (1998) [17]. was reported that NEB of raisins was affected by pretreatment and showed that Golden bleach hot dip pretreatment had lower browning values. The non-enzymatic browning (OD values at 440 nm) in different drying methods were 0.29, 0.30 and 0.59 in cabinet, solar and sun drying, respectively. Higher NEB values in sun and solar dried raisins is may be due to drying at inconsistent temperature and slow drying rate, which is not a rapid drying process led to more browning in raisins. With respect to interaction effects of pretreatments and drying methods the non-enzymatic browning of raisins ranged from 0.05 (M_1T_1) to 0.84 (M_3T_4). The similar finding reported by Burcak and Amet, (2015) [18]. where alcohol soluble color of raisins was more in natural sun drying than raisins pretreated with sodium hydroxide and dried in solar tunnel dryer.

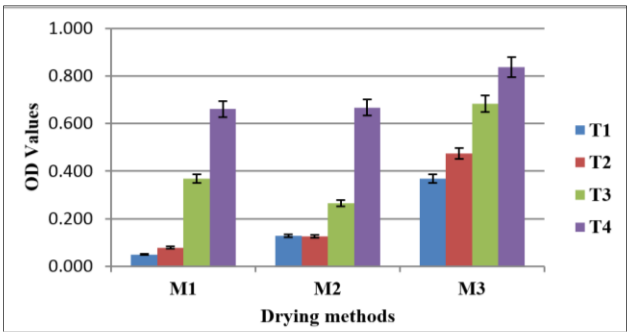

Fig 6: Effect of different pretreatments, drying methods and their interaction on non-enzymatic browning of raisins.

Sensory evaluation of raisins

The raisins pretreated by ethyl oleate oil with potassium carbonate emulsion were superior in recording bright colour and appearance than other pretreatments in all methods of drying. The raisins prepared in this method through sulphuring of grapes resulted light green, golden yellow and dark brown coloured raisins in cabinet, solar and open sun drying respectively. Raisins pretreated in olive oil with potassium carbonate emulsion had same color but little darker and oily surface than ethyl oleate dip method in all three methods of drying The hot water blanching and control were dark in color and not much attracted by sensory panel. (Fig 7). The pretreatments of raisins in ethyl oleate and olive oil with potassium carbonate have given good textured raisins in cabinet dryer than others. Most of the raisins prepared in solar tunnel dryer and open sun are little hard and not uniform texture, may be due to inconsistent *viz.* prolonged drying and more browning. Similarly Almeida *et al.* (2015) [19] reported that raisins prepared in different drying systems obtained different sensory texture scores. Ethyl oleate and olive oil with potassium carbonate dipping pretreatment had equally performed to good taste than hot water blanching in all methods of drying. The raisins which pretreated in ethyl oleate and olive oil with potassium carbonate were more attractive and obtained maximum overall acceptance than hot water blanching and control in all three methods of drying (Fig 7). The raisins which dried faster had bright color such as light green, golden brown and dark brown in cabinet, solar and open sun drying respectively which might has influenced for maximum overall acceptability. The ethyl oleate dip raisins were more attractive with acceptable texture and found highest overall acceptability score (8.5 out of 9) same treatment in solar tunnel dryer and open sun drying obtained 8.13 and 6.72 out of 9.

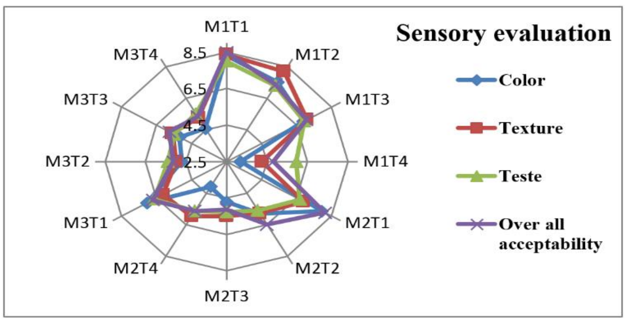

Fig 7: Effect of different pretreatments, drying methods and their interaction on sensory attributes of raisins.

Conclusion

Pretreatment and drying method are two critical factors for production of high quality raisins. The ideal combination of pretreatment (ethyl oleate oil 1.5% + K_2CO_3 3%) and drying method (cabinet tray and solar tunnel dryer) produce raisins with high nutritional quality, desirable sensory attributes, saves energy, time, labor and maintain high hygienic standards.

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