Central composite rotatable design approach to optimize ‘Italia’ raisin drying conditions

Ana Cecília Poloni Rybka*¹, Sérgio Tonetto de Freitas¹, Acácio Figueiredo Netto², Aline Camarão Telles Biasoto¹

¹Embrapa Semiárido, Petrolina, PE, Brasil
²Universidade Federal do Vale do São Francisco, Petrolina, PE, Brasil
*Autor correspondente, e-mail: ana.rybka@embrapa.br

Abstract

Considering its high demand and limited production, raisin represents an important alternative to diversify grape processed products around the world. The aim of this study was to determine the best combination between drying temperature and time required to reach the highest consumer acceptance of ‘Italia’ raisin produced in the semi-arid climate in Brazil. The drying conditions were combinations between drying temperatures of 50, 56, 70, 84 and 90°C and drying times of 16, 22, 35, 48 and 54 hours, following a central composite rotational design (CCRD). The best combination between drying temperature and time was estimated to be 70°C for 35 hours (h), based on overall consumer acceptance. According to the statistical analysis used, drying at 70 °C for 35h and at 59 ºC for 28h results in equal overall consumer acceptance, being the second option the more economical. Taste and texture, raisin chroma values and pH were more positively correlated to overall acceptance. The results indicate that drying at 59ºC for 28 h is the most efficient drying condition for raisins from ‘Italia’ grapes grown in Brazilian semi-arid condition. This study uses a new approach based on the central composite rotatable design to determine the most efficient drying temperature and time for ‘Italia’ raisins.

Keywords: consumer, sensory quality, temperature, time, Vitis vinifera

Uso do delineamento completo central rotacional para otimizar condições de secagem de passas ‘Italia’

Resumo

Dada a sua alta demanda e produção limitada, uvas passas representam uma importante alternativa para diversificar produtos processados de uva em todo o mundo. O objetivo deste estudo foi determinar a melhor combinação entre a temperatura de secagem e tempo necessário para atingir a maior aceitação do consumidor de passas de uva ‘Itália’, produzida no clima semiárido do Brasil. As condições de secagem foram combinações entre temperaturas de 50, 56, 70, 84, 90 ºC e tempo de 16, 22, 35, 48, 54 h, seguindo um delineamento completo central rotacional (DCCR). A melhor combinação entre a temperatura e tempo foi a 70 ºC durante 35h com base na aceitação global do consumidor. Pela análise estatística utilizada, a secagem a 70 ºC durante 35h e a 59 ºC por 28h resulta em aceitação global do consumidor semelhante, demonstrando que a segunda opção poderia ser mais econômica. O sabor e a textura, os valores de croma e o pH foram mais positivamente correlacionados à aceitação global. Os resultados indicam que a secagem a 59 ºC por 28 h é a condição de secagem mais eficiente para passas de uva ‘Itália’ produzida no clima semiárido do Brasil. Este estudo utiliza uma nova abordagem baseada no delineamento completo central rotacional para determinar a temperatura e tempo de secagem mais eficientes para produção de passas ‘Itália’.

Palavras chave: consumidor, qualidade sensorial, temperatura, tempo, Vitis vinifera
Introduction

The world grape production has reached 69 million tons in 2011 with about 2% used for raisin production (FAO, 2015). The largest raisin producing countries are Turkey and United States. Combined, these countries account for about 80% of global raisin production (FAO, 2015). The increasing demand for convenient foods has stimulated raisin production in other grape growing countries. In Brazil, grapes have been produced under different environmental conditions, which determine the typical quality of the fruit and processed products (Pereira et al., 2011). In the Northeast semi-arid region, high light intensity, low relative humidity and high temperatures are environmental factors that can potentially contribute to high raisin quality. However, raisin production under such conditions remains to be investigated for ‘Italia’ grapes, which is one of the most cultivated grape varieties in the Brazilian semi-arid region.

Dried fruit and vegetables have almost unlimited shelf-life in proper packages and substantially lower transportation, handling and storage costs when compared to products of other preservation methods (Sharma & Adulse, 2007; Michalczyk et al., 2009).

The objective of this study was to determine the best combination between drying temperature and time required to reach the highest consumer acceptance of ‘Italia’ raisins produced in the semi-arid climate in Brazil, aiming to provide an alternative processing to one of the most produced grapes in this climate.

Material and Methods

Grape cultivar Italia was harvested from a commercial vineyard located at the São Francisco Valley in Petrolina, PE, Brazil. After harvest, the berries were manually destemmed, randomly mixed and sanitized with 2.5% chlorine for 20 minutes, followed by wash in running deionized water.

The study followed a central composite rotatable design (CCRD) with the independent variables drying temperature and time to establish a model and determine the optimal drying conditions (Brito & Narain, 2003; Rodrigues & Iemma, 2009). The assays were accomplished according to a complete factorial design with central points (level 0) and axial points (levels ±1.41) addition. Values are presented at Tables 2 and 3. Each independent variable was composed by five coded levels. Coded levels and real levels are $X_1$: drying temperature (50, 56, 70, 84 and 90ºC) and $X_2$: drying time (16, 22, 35, 48 and 54h). A total of 11 assays composed by combinations among four factorial, three central and four axial variables were accomplished. Each combination was composed by 1.3 kg of fruit. Grape drying was accomplished in a continuous flow fixed bed dryer (Sulab, Brazil) at a constant air velocity of 3.0 m s$^{-1}$ for each combination between drying temperature and drying time. The dryer system...
consisted of vertical air flow through trays and was arranged as an open system (Azoubel et al., 2010). Air temperature was controlled by a digital thermostat. The air velocity was monitored using an anemometer (AIRFLOW, model LCS 6000, UK). At harvest, samples were subjected to physico-chemical analysis and after drying, samples were subjected to physico-chemical and sensory analysis.

Consumer’s acceptability analysis was carried out by 50 raisin consumers that evaluated each of the following quality parameters: overall acceptance, visual appearance, aroma, flavor and texture of the samples. Consumer’s acceptability of the 11 ‘Italia’ raisin samples was accomplished using the traditional nine points hedonic scale where: 1, dislike extremely; 2, dislike very much; 3, dislike moderately; 4, dislike slightly; 5, neither like nor dislike; 6, like slightly; 7, like moderately; 8, like very much; 9, like extremely. In order to avoid sensory fatigue among consumers, the 11 raisin samples were evaluated in two distinct tasting sessions carried out on two successive days. The effects of the presentation order and first-order carry-over of the samples were controlled using the crossover design proposed by Wakeling & MacFie (1995). The best combination between drying temperature and time was calculated as the combination that resulted in the highest overall consumer acceptance. The most efficient combination between drying temperature and time was calculated as the lowest temperature and shortest time that resulted in overall acceptance statistically equal to the best combination between drying temperature and time (Figure1).

For physico-chemical analysis, color was determined with a digital colorimeter Colortec PCM (Accuracy Microsensors INC., Pittsford, NY, USA). The readings were recorded and the results presented as lightness ($L^*$) with values ranging from 0 = black to 100 = white, Chroma ($C^*$) representing the color intensity or saturation, and hue angle ($h^\circ$) which is the actual color recognized by the human eye. Firmness measurements were accomplished at the equator region of each berry with a texture analyzer model TA.XT. Plus (Extralab Brasil, SP, Brazil). The results obtained represent the resistance force required to compress 20% of the berry volume. Soluble solids and pH were analyzed by dissolving 10 g of dried raisin on 100 ml of deionized water at 80°C for 2 h (Feldberg et al., 2008). Soluble solids (SS) content was determined in the dissolved raisin solution with a digital refractometer Abbe Marck II (Reichert Jung, Depew, NY, EUA). The pH was also determined in the dissolved raisin solution with a pH meter (Hanna Instruments, Woonsocket, RI, USA). The SS content and pH were calculated and expressed on the dried raisin weight basis. Total polyphenol content was determined using the Folin & Ciocalteu (1927) method with the modifications described by Larrauri et al. (1997). Berry weight was determined gravimetrically using a semi-analytical balance. Berry length and width were determined with a caliper rule.

Consumer’s overall acceptance was analyzed using the response surface methodology – RSM (Khuri & Cornell, 1996). The polynomial model used was: $Y = b_0 + b_1X_1 + b_2X_2 + b_3X_1^2 + b_4X_2^2 + b_5X_1X_2$. Where $Y$ is the consumer’s overall acceptance, and $X_1$ and $X_2$ represent temperature and time, respectively, which were affected by the regression coefficients ($b_0, b_1, b_2, b_3, b_4$ and $b_5$). The RSM was used to determine the optimal combination between drying temperature and time required to reach the highest consumer’s overall acceptance (Brito & Narain, 2003; Rodrigues & Iemma, 2009). The adjusted model and its response surface were determined at $p \leq 0.05$. The validity of the model was evaluated as a function of its respective coefficient of determination ($R^2$) as well as by analysis of the lack of fitness. Calculations were performed using the Statistica 7.0 (Statsoft, Tulsa, OK, USA) software package. For comparative evaluation of samples, the results obtained by the physico-chemical analyzes and consumer test were processed using ANOVA and Tukey test ($p < 0.05$).

Results and Discussion

At harvest, ‘Italia’ grapes had average color lightness of 29.52, chroma of 5.57 and hue.
angle of 99.94, as well as berry firmness of 6.39 N, juice soluble solids content of 12.8%, juice pH of 3.69, total phenolics content of 105.46 mg 100 g\(^{-1}\), water activity of 0.98 and average berry weight of 8.85 g. After drying, the best combination between drying temperature and time was determined based on consumer’s overall acceptance results (Figure 1, Tables 3 and 4). According to our results, the highest ‘Italia’ consumer’s overall acceptance was located in the experimental central point with estimated drying temperature of 70ºC and drying time of 35h (Figure 1).

![Figure 1](image)

**Figure 1.** Consumer’s overall acceptance of ‘Italia’ raisins after drying at different temperatures (50, 56, 70, 84 and 90ºC) and times (16, 22, 35, 48 and 54h).

At the central point, increasing or decreasing drying temperature or time decreases overall consumer acceptance. The Analysis of variance (ANOVA) revealed that both drying temperature and time, individually, had a statistically significant quadratic response to overall consumer acceptance with p-values lower than 5% [Table 1]. The interaction between the drying time x temperature was not statistically significant to overall consumer acceptance.

The highest intensity for all raisin sensory attributes were obtained only with combinations between drying temperatures and times of 56ºC x 22 h, 56ºC x 48 h or 70ºC x 35 h (Table 2), whereas the lowest intensity of all raisin sensory attributes were obtained only with the combination of 50ºC x 35 h.

The color analysis revealed that the combined effect between drying temperatures x times of 84ºC x 48 h, 70ºC x 54 h, and 90ºC x 35 h resulted in the lowest lightness (L) values, indicating the darkest raisin coloration (Table 3).

Table 1. Analysis of Variance (ANOVA) for consumer’s overall acceptance of ‘Italia’ raisins dried at different temperatures and times

| Factors           | Effect  | Coefficient | Standard error | p-value   |
|-------------------|---------|-------------|----------------|-----------|
| Mean interaction  | 5.75000 | 5.75000     | 0.300249       | 0.000007**|
| Time (L)†         | -0.24762| -0.12381    | 0.367728       | 0.530569  |
| Time (Q)‡         | -1.29000| -0.64500    | 0.437684       | 0.031984* |
| Temperature (L)†  | -1.95228| -0.97614    | 0.367728       | 0.003168**|
| Temperature (Q)‡  | -2.80500| -1.40250    | 0.437684       | 0.001372**|
| Time x Temperature| -0.45500| -0.22750    | 0.520046       | 0.421647  |

† Linear (L); ‡ quadratic (Q); Statistical significant at p ≤ 0.01(**) or p ≤ 0.05(*).
The highest L values (whitest coloration) were obtained with the combined effect between drying temperatures and times of 56ºC x 22 h, 50ºC x 35 h. The highest chroma (C) values, that means highest color intensity or saturation, were observed with the combined effect of drying temperatures and times of 56ºC x 22 h, 50ºC x 35 h, and 70ºC x 35 h, whereas the lowest C values were observed with drying temperatures and times of 84ºC x 22 h, 84ºC x 48 h, and 90ºC x 35 h. The hue angle (h°, color definition) was higher with drying temperatures x times of 56ºC x 22 h, 56ºC x 48 h, and 50º x 35 h, whereas the lowest h° values were observed with drying temperatures x times of 84ºC x 48 h, and 90ºC x 35 h.

### Table 2. Acceptability of ‘Italia’ raisins dried at different temperatures and times.

| Drying conditions | Overall acceptance | Appearance | Aroma | Flavor | Texture |
|-------------------|--------------------|------------|-------|--------|---------|
| 56ºC x 22 h | 5.6 ab* | 6.1 a | 5.5 ab | 6.1 a | 5.7 a |
| 84ºC x 22 h | 4.0 bc | 2.8 c | 4.2 b | 4.5 ab | 4.2 abc |
| 56ºC x 48 h | 5.2 ab | 5.2 ab | 5.0 ab | 5.1 ab | 5.0 ab |
| 84ºC x 48 h | 2.4 cd | 4.9 ab | 4.7 ab | 2.1 cd | 2.4 cd |
| 70ºC x 16 h | 4.4 ab | 3.4 bc | 4.7 ab | 4.9 ab | 4.6 ab |
| 70ºC x 54 h | 4.0 bc | 3.5 bc | 5.1 ab | 3.8 bc | 3.3 bcd |
| 50ºC x 35 h | 2.3 cd | 4.2 bc | 4.2 b | 2.2 cd | 2.5 cd |
| 90ºC x 35 h | 2.0 d | 3.4 bc | 4.4 ab | 1.8 d | 2.2 d |
| 70ºC x 35 h | 5.6 ab | 5.7 a | 5.1 ab | 5.9 a | 5.3 a |
| 70ºC x 35 h | 5.1 ab | 5.2 ab | 5.0 ab | 5.0 ab | 5.2 ab |
| 70ºC x 35 h | 6.0 a | 6.2 a | 5.8 a | 6.2 a | 5.9 a |
| CV (%) | 43.0 | 44.3 | 32.6 | 46.7 | 47.4 |

*Mean intensities based on a nine point hedonic scale where 1 = dislike extremely and 9 = like extremely. *Different values in the column: means are significantly different according to Tukey’s test (p < 0.05). Mean values, n=50 consumers.

The highest raisin flesh firmness was obtained with drying temperature x times of 50ºC x 35 h, and 90ºC x 35 h, whereas the lowest firmness was obtained with 84ºC x 22 h, 56ºC x 48 h, and 70ºC x 16 h (Table 3). The highest SS content was observed in response to the combined effect of drying temperatures x time at 84ºC x 22 h, 70ºC x 16 h, 70ºC x 54 h, and 70ºC x 35 h, whereas the lowest SS contents were observed at in response to drying at 56ºC x 22 h, and 50ºC x 35 h. The highest pH values were observed in response to drying temperatures x times of 84ºC x 22 h, 56ºC x 48 h, and 70ºC x 16 h. The lowest pH values were obtained with drying temperatures x times of 70ºC x 54 h, 50ºC x 35 h, and 90ºC x 35 h. The highest total phenol content was observed with the drying temperature x time of 90ºC x 35 h, whereas the lowest total phenol contents were

### Table 3. Firmness (Firm), soluble solids (SS), pH, total phenol content (Phen), water activity (aw), berry weight (BW) and color parameters (Lightness (L), Chroma (C) and Hue angle (h°)) of ‘Italia’ raisins dried at different temperatures and times.

| Drying conditions | Firm (N) | SS (%) | pH | Phen (mg 100g⁻¹) | aw | BW (g) | L | C | h° |
|-------------------|---------|-------|----|-----------------|----|-------|----|----|----|
| 56ºC x 22 h | 31.5c | 30.3e | 4.08cde | 134.2g | 0.85a | 3.67b | 29.9a | 11.7ab | 77.1a |
| 84ºC x 22 h | 0.8e | 78.6a | 4.19ab | 830.3d | 0.41cd | 1.82c | 23.5c | 8.0ef | 61.6ab |
| 56ºC x 48 h | 4.2e | 59.6d | 4.14abc | 273.7f | 0.45c | 1.68cd | 24.6c | 8.0ef | 61.6ab |
| 84ºC x 48 h | 25.5cd | 67.6c | 4.00e | 2194.8b | 0.34d | 1.17c | 19.8d | 7.0f | 36.2e |
| 70ºC x 16 h | 0.8e | 73.0abc | 4.24a | 303.0f | 0.45c | 1.81c | 26.2b | 10.9bc | 67.8abc |
| 70ºC x 54 h | 50.2b | 76.0abc | 4.14abc | 273.7f | 0.45c | 1.68cd | 24.6c | 8.0ef | 61.6ab |
| 70ºC x 35 h | 68.9a | 69.6c | 3.78fg | 2811.4a | 0.40cd | 1.37ed | 22.4c | 10.9bc | 67.8abc |
| 70ºC x 35 h | 21.0d | 72.6abc | 4.05cd | 522.4e | 0.35d | 1.43cd | 23.4c | 12.3a | 52.0d |
| 70ºC x 35 h | 25.4d | 71.6abc | 4.11bcd | 438.0e | 0.38d | 1.73cd | 21.6c | 11.4abc | 50.0d |
| 70ºC x 35 h | 29.0c | 72.6abc | 4.02cd | 438.8e | 0.38d | 1.68cd | 19.9c | 11.8ab | 50.4d |
| CV (%) | 12.8 | 4.5 | 1.0 | 5.5 | 6.09 | 8.1 | 2.37 | 5.19 | 5.98 |

*Mean values within each column followed by different letters are significantly different according to Tukey’s test (p < 0.05).
observed with drying temperatures x times of 56°C x 48 h, and 70°C x 16 h. The highest water activity was observed with drying temperature x time of 56°C x 22 h and the lowest water activity was observed with drying temperatures x times of 84°C x 48h, 70°C x 35 h and 70°C x 54 h. The highest average berry weight was observed with drying temperature x time of 50°C x 35 h, whereas the lowest average berry weights were observed with drying temperatures of 84°C x 48 h, 70°C x 54 h, 90°C x 35 h, 70°C x 35 h.

‘Italia’ raisin consumer acceptance

The processing quality of raisins is determined by genotype, as well as growing and drying conditions (Angulo et al., 2007; Meng et al., 2011). During the drying process, temperature and time are the most important factors affecting raisin processing quality (Mousa & Farid, 2002, Clary et al., 2005; Zhang et al., 2005). Accordingly, our study shows that both drying temperature and time had statistical significant effect on consumer’s overall acceptance of raisins, which was the parameter used to determine the most efficient combination between drying temperature x time. The highest overall acceptance of ‘Italia’ raisins was located in the experimental central point with drying temperature of 70°C and drying time of 35 hours (Figure 1). At the central point, increasing or decreasing drying temperature and time is increased, the overall acceptance of ‘Italia’ raisins decreases. The most efficient drying conditions was determined as described by Rodrigues and lemma (2009), which determines the lowest drying temperature and time required to reach the consumer’s overall acceptance similar to the central point. The most efficient drying condition was estimated as 59°C for 28 h. This drying condition represents lower processing cost required to reach the highest consumer’s overall acceptance. After estimating the most efficient drying condition, the study was repeated to validate the results.

Sensory quality and physico-chemical attributes influencing overall consumer’s acceptance

The Pearson’s correlation analysis of consumer’s overall acceptance and physico-chemical attributes are presented on Table 4. Our results show that consumer overall acceptance was more correlated to consumer flavor acceptability ($R^2=+0.99$) and texture ($R^2=+0.98$) than to appearance ($R^2=+0.63$) and aroma ($R^2=+0.79$). Accordingly, other studies have shown that sensory attributes, such as flavor, have a strong influence on consumer overall acceptance (Chauvin et al., 2009; Oupadissakoon et al., 2010).

The color analysis showed that lightness (L) was poorly correlated to overall acceptance ($R^2=+0.11$). Increasing temperature and time resulted in darker raisin coloration. The low correlation between L and overall acceptance is possibly due to the fact that raisin darkening increased overall acceptance up to an optimal

| Table 4. Pearson correlation coefficients ($R^2$) between consumer’s overall acceptance and sensory or physico-chemical attributes of ‘Italia’ raisins dried at different temperatures and times. |
|---------------------------------|-----------------|-----------------|
| Sensory attributes         | $R^2$ | p-value |
| Appearance                  | +0.63 | 0.0800 |
| Aroma                       | +0.79 | 0.0040 |
| Flavor                      | +0.99 | 0.0001 |
| Texture                     | +0.98 | 0.0001 |
| Physico-chemical attributes | $R^2$ | p-value |
| Lightness (L)               | +0.11 | 0.66 |
| Chroma (C)                  | +0.60 | 0.17 |
| Hue angle (h°)              | +0.35 | 0.34 |
| Firmness                    | -0.56 | 0.05 |
| Soluble solids              | +0.10 | 0.77 |
| pH                          | +0.63 | 0.03 |
| Total phenol content        | -0.68 | 0.02 |
| Water activity              | +0.02 | 0.95 |
| Berry weight                | -0.10 | 0.77 |
darkening. Further increase in drying temperature and time resulted in undesirable darkening, reducing overall acceptance. Accordingly, in the central point (70°C and 35 hours) samples reached the highest overall acceptance and with intermediate L values. Among color parameters, the C values showed the highest correlation ($R^2=+0.60$) to overall acceptance, suggesting that color intensity had an important contribution to the acceptability of raisin visual appearance. Higher C values resulted in higher appearance acceptability and consequently higher overall acceptance. The $h^o$ values showed an intermediate correlation ($R^2=+0.35$) to overall consumer acceptance compared to L or C values, suggesting that increasing $h^o$ increases overall acceptance, but too high $h^o$ values reduced overall consumer acceptance of 'Italia' raisins by consumers.

Flesh firmness of 'Italia' raisins was negatively correlated to consumer’s overall acceptance ($R^2=-0.56$), showing that with a flesh firmness increase, the overall acceptance was reduced. Flesh firmness is an important component of texture, which explains its high contribution to the final overall acceptance of 'Italia' raisins. The soluble solids content showed a positive correlation to overall acceptance, which is expected since sugars positively influence consumer likeness of different kind of foods (Crisosto et al., 2004; Crisosto et al., 2005). The pH showed a positive high correlation to overall acceptance, suggesting that the increasing pH resulted in higher consumer acceptance of 'Italia' raisins. Other studies have also showed that increasing pH (decreasing acidity) is associated to higher consumer likeness of fruits and processed products (Harker et al., 2008; Iglesias & Echeverría, 2009). The combined perception of sweetness and sourness (acidity) has also been reported to strongly affect consumer likeness (Crisosto et al., 2004). In addition to sugar and acid contents, phenols can also determine consumer flavor acceptability and overall acceptance (Lesschaeve & Noble, 2005; Chiremba et al., 2009). Our results show that total phenol content is negatively correlated to overall consumer acceptance. Accordingly, bitterness and the mouthfeel sensation of astringency are elicited primarily by phenols (Lesschaeve & Noble, 2005; Del Llauy et al., 2008). Therefore, increasing phenolic concentration during the drying process possibly increased bitterness and astringency, decreasing consumer’s overall acceptance of 'Italia' raisins.

Conclusions

‘Italia’ grapes dried at 59°C for 28 h was the most efficient processing to reach the highest overall consumer acceptance.

References

Angulo, O., Fidelibus, M.W., Heymann, H. 2007. Grape cultivar and drying method affect sensory characteristics and consumer preference of raisins. Journal of the Science of Food and Agriculture 87: 865-870.

Azoubel, P.M., Baima, M.A.M., Amorim, M.R., Oliveira, S.S.B. 2010. Effect of ultrasound on banana cv Pacovan drying kinetics. Journal of Food Engineering 97: 194-198.

Bennett, L.E., Jegasothy, H., Konczak, I., Frank, D., Sudharmarajan, S., Clingeleffer, P.R. 2011. Total polyphenolics and anti-oxidant properties of selected dried fruits and relationships to drying conditions. Journal of Functional Foods 3: 115-124.

Brito, E.S., Narain, N. 2003. Effect of pH and distillate volume on monitoring aroma quality of bittersweet chocolate. Food Quality and Preferences 14: 219-226.

Chauvin, M.A., Whiting, M., Ross, C.F. 2009. The influence of harvest time on sensory properties and consumer acceptance of sweet cherries. Horticulture Technology 19: 748-754.

Chiremba, C., Taylor, J.R.N., Duodu, K.G. 2009. Phenolic content, antioxidant activity, and consumer acceptability of sorghum cookies. Cereal Chemistry 86: 590-594.

Clary, C.D., Mejia-Meza, E., Wang, S., Petrucci, V.E. 2007. Improving grape quality using microwave vacuum drying associated with temperature control. Journal of Food Science 72: 23-28.

Clary, C.D., Wang, S.J., Petrucci, V.E. 2005. Fixed and incremental levels of microwave power application on drying grapes under vacuum. Journal of Food Science 70: 344-349.

Crisosto, C.H., Garner, D., Crisosto, G.M., Boweman, E. 2004. Increasing Blackamber' plum (Prunus salicina Lindell) consumer acceptance. Postharvest Biology and Technology 24: 237-244.
Crisosto, C.H., Garner, D., Crisosto, G.M. 2005. Relationship between ripe soluble solids concentration (RSSC) and consumer acceptance of high and low acid melting flesh peach and nectarine (Prunus persica [L.] Batsch) cultivars. Postharvest Biology and Technology 38: 239-246.

Del Llauudy, M.C., Canals, R., Canals, J.M., Zamora, F. 2008. Influence of ripening stage and maceration length on the contribution of grape skins, seeds and stems to phenolic composition and astringency in wine-simulated macerations. European Food Research and Technology 226: 337-344.

Doymaz, I. 2006. Drying kinetics of black grapes treated with different solutions. Journal of Food Engineering 76: 212-217.

Esmaili, M., Sotudeh-Gharebagh, R., Cronin, K., Mousavi, M.A.E., Rezazadeh, G. 2007. Grape drying: A review. Food Reviews International 23: 257-280.

FAS, Foreign Agricultural Service. 2015. World raisin situation and outlook. http://www.fas.usda.gov/data/raisins-world-markets-and-trade <Access on Jun 4th 2015>

FAO. Food and Agricultural Organization of United Nations: Economic And Social Department: The Statistical Division. 2015. http://faostat.fao.org/ <Access on Jun 4th 2015>

Feldberg, N.P., Mota, R.V., Simões, W.L., Regina, M.A. 2008. Viabilidade da utilização de descartes de produção de uvas sem sementes para elaboração de passas. Revista Brasileira de Fruticultura 30: 846-849.

Folin, O., Ciocalteu, V. 1927. On tyrosine and tryptophane determinations in proteins. Journal of Biological Chemistry 73: 627–650.

Harker, F.R., Kupferman, E.M., Marin, A.B., Gunson, F.A., Triggs, C.M. 2008. Eating quality standards for apples based on consumer preferences. Postharvest Biology and Technology 50: 70-78.

Iglesias, I., Echeverria, G. 2009. Differential effect of cultivar and harvest data on nectarine colour, quality and consumer acceptance. Scientia Horticulturae 120: 41-50.

Jaiswal, V., DerMarderosian, A., Porter, J.R. 2010. Anthocyanins and polyphenol oxidase from fried arils of pomegranate. Food Chemistry 118: 11-16.

Khuri, A.I., Cornell, J.A. 1996. Response surfaces: designs and analyses. New York: Marcel Dekker. 517 p.

Larrauri, J.A., Ruperez, P., Saura-Calixto, F. 1997. Effect of drying temperature on the stability of polyphenols and antioxidant activity of red grape pomace peels. Journal of Agricultural and Food Chemistry 45: 1390-1393.

Lesschaeve, I., Noble, A.C. 2005. Polyphenols: factors influencing their sensory properties and their effects on food and beverage preferences. American Journal of Clinical Nutrition 81: 330-335.

Margaris, D.P., Ghiaus, A.G. 2007. Experimental study of hot air dehydration of sultana grapes. Journal of Food Engineering 79: 1115-1121.

Meng, J., Fang, Y., Zhang, A., Chen, S., Xu, T., Ren, Z., Han, G., Liu, J., Li, H., Zhang, Z., Wang, H. 2011. Phenolic content and antioxidant capacity of Chinese raisins produced in Xinjiang province. Food Research International 44: 2830-2836.

Michalczyk, M., Macura, R., Matuszak, I. 2009. The effect of air-drying, freeze-drying and storage on the quality and antioxidant activity of some selected berries. Journal of Food Processing and Preservation 33: 11-21.

Mousa, N., Farid, M. 2002. Microwave vacuum drying of banana slices. Drying Technology 20: 2055-2066.

Mwithiga, G., Olwal, J.O. 2005. The drying kinetics of kale (Brassica oleracea) in a convective hot air dryer. Journal of Food Engineering 71: 373-378.

Oupadissakoon, C., Chambers, E., Kongpensook, V., Suwonsichon, S., Yenket, R., Retiveau, A. 2010. Journal of the Science of Food and Agriculture 90: 1081-1088.

Pereira, G.E., Araújo, A.J.B., Santos, J., Vanderlinde, R., Lima, L.L.A. 2011. Chemical and aromatic characteristics of Brazilian tropical wines. Acta Horticulturae 910: 135-140.

Rahman, M.S., Guizani, N., Al-Zakwani, I. 2005. Pore formation in apple during air-drying as a function of temperature: porosity and pore-size distribution. Journal of the Science of Food and Agriculture 85: 979–989.

Ramos, I.N., Brandão, T.R.S., Silva, C.L.M. 2003. Structural changes during air drying of fruits and vegetables. Food Science and Technology International 9: 201-206.

Rodrigues M.I., Iemma A.F. 2009. Planejamento de Experimentos & Otimização de Processos. 2nd edition. Campinas, Brasil: Universidade de Campinas. 358 p.

Sharma, A.K., Adulse, P.G. 2007. Raisin production in India. Pune: NRC for grapes. p. 1-5.

Singh, S.P., Jairaj, K.S., Srikant, K. 2012. Universal drying rate constant of seedless grapes: A review. Renewable and Sustainable Energy Reviews 16:
Srikiatden, J., Roberts, J.S. 2006. Measuring moisture diffusivity of potato and carrot (core and cortex) during convective hot air and isothermal drying. *Journal of Food Engineering* 74: 143-152.

Thakur, A.K., Saharan, V.K., Gupta, R.K. 2010. Drying of ‘Perlette’ grape under different physical treatment for raisin making. *Journal of Food Science and Technology* 47: 626-631.

Wang, N., Brennan, J.G. 1992. Effect of water binding on the drying behavior of potato. In: Drying 92, Part B, ed. A.S. Mujumdar, Elsevier, Amsterdam, New York. p.1350–1359.

Wakeling, I.N., MacFie, H.J.H. 1995. Designing consumer trials balanced for first and higher orders of carry-over effect when only a subset of k samples from t may be tested. *Food Quality and Preference* 6: 299-308.

Zhang, M., Li, C.L., Ding, X.L. 2005. Effects of heating conditions on the thermal denaturation of white mushroom suitable for dehydration. *Drying Technology* 23: 1119-1125.