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Comparison of drying processes for the production of raisins from a seedless variety of grapes

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Abstract

Drying is a very important preservation method that originates products with high nutritive value, among which the raisins, which are a very popular food product consumed worldwide.
The objectives of the present work were to dry by different processes seedless grapes from variety Crimson, which is not traditionally used for the production of raisins. Furthermore, to compare the different methods tested, some analyses were made, namely at the chemical, physical and sensorial levels.
The methodologies tested for the drying of the grapes were: direct exposure to the sun inside a solar stove and ventilated drying chambers with constant air flow at two different temperatures, 50 and 60 ºC. The technological parameter evaluated for the different dryings was the yield. At the chemical level were evaluated the moisture content, total sugars and acidity. In terms of physical properties were assessed the texture and colour, fundamental aspects for a good acceptation of dried products by the consumers. Lastly, a sensorial analysis was made to the dried products obtained, aimed at evaluating their acceptability by potential consumers.
The raisins produced by the different methods didn´t show important differences either at the chemical or at the physical levels. Still, some aspects can be pointed out: the convective drying method allowed obtaining products with less moisture and in considerably less time, reaching 14.59 % in 47 hours for the drying at 60 ºC, while in the solar stove was obtained 19.43 % of humidity during 721 hours of drying. This result is very important from the economic point of view.
Finally, at the sensory level, the tasters considers that the dried grapes produced in this work showed similar characteristics with some commercial raisins at sale in the Portuguese market.

Key Words: Drying, Grapes, Raisins, Texture, Color, Sensorial analysis.

1. Introduction

The Crimson seedless variety was developed through the program of the Agricultural Research Service of the Department of Agriculture of the United States, in Fresno, California and started being cultivated in 1989 by Ramming and Tarailo. It is a pink-red grape, seedless, with a firm texture, being a late maturation variety. This variety was very well received by the retail trade due to its good taste and exceptional shelf life [1]. The main problem associated with the production of seedless grape Crimson is the lack of coloration of the berries. The fact that the berries are small may also be a problem and the cultivation techniques for increasing the size of the berries, may further reduce the color [1].
The drying leads to a change in the food physical, chemical and biological characteristics [2]. During the drying process may occur physical changes such as shrinkage and crystallization. In some cases, reactions can occur, desirable or undesirable, altering the color, texture, odor and other properties of the food [3].
The food preservation by drying has as main objective to increase the storage stability of the product and minimize packaging and transportation costs. Drying of foods is the process of removing moisture through the simultaneous transmission of heat and moisture in food [4,5].
The solar drying of grapes originates a product with a rich color, a translucent appearance and a desirable pasty texture [3]. During drying the raisins become darker due to the accumulation of melanin brown/black pigments produced by the activity of polyphenol oxidase and non-enzymatic reactions. The golden raisins, to become clear, are dipped in hot water and treated with sulphur dioxide to prevent browning reactions [6].

The traditional method of drying in open air direct exposure to the sun has been replaced by solar drying is stoves. With this method great advantages are achieved: the problems associated with contaminants and insects are avoided and therefore the quality and security is much better, and the drying time is substantially reduced, thus improving production. Furthermore, it still uses the free of charge energy of the sun as heating source [7].
The color is widely distributed throughout nature in fruits, vegetables, seeds, roots, etc.. and is directly related with other physical, chemical and sensory quality attributes. Foods are composed of a vast amount of pigments, particularly anthocyanins, chlorophyll and carotenoids. Natural pigments have different chemical and physical properties, and most of them are sensitive to oxidation, changes in pH, light, temperature and duration of processing [9-12].
Various indicators have been tested for color changes in food systems and Hunter Lab L*a*b* (CIELab) has shown to give a good description of the visual deterioration of color, providing useful information for the control of fruit quality and products derived from fruits such as raisins [13]. The Hunter color space dimension L* represents brightness, ranging from black (0) to white (100), the dimensions a* and b* represent color opposition parameters with a* ranging from green (-a) to red (+a) and b* ranging from blue (-b) to yellow (+b) [14].
The texture results from complex interactions between the different components of the food, and the changes that occur in the texture of food during food processing are related to changes in the macro-structure of the cells [15]. The textural properties as well as the appearance and flavor are the most influential organoleptic attributes for quality, and that establish the acceptability of food by consumers. In this respect, there has been great interest in developing methods to predict and control the texture of the food, particularly with regard to the effects of processing such as drying. The analysis of the instrumental texture profile analysis (TPA) is one of the methods for determining the texture of food by simulation or imitation of repeated biting or chewing food [16].
Sensory analysis is the identification, scientific measurement, analysis and interpretation of the properties of a product, as they are perceived through the five senses: sight, smell, taste, touch and hearing [17]. Sensory properties of food are very important, in addition to the physical-chemical and microbiological properties, because they determine the acceptability of the product by the consumer [18]. At the level of the food industry sensory analysis results are used to make important decisions both at technical and commercial levels [19].
The annual statistical report of the Institute of Vine and Wine in 2012 states that the country with the largest wine-growing area in the world in 2011 was Spain, with 1032 mha. After Spain, follow France (807 mha), Italy (776 mha), China (560 mha), Turkey (500 mha), USA (405 mha), Portugal (240 mha), Argentina (218 mha) Romania (204 mha), Chile (202 mha), Australia (174 mha), South Africa (131 mha) [8].
The Thompson seedless variety represents approximately 95% of world production of raisins, being followed by Fiesta (3%) and Zante Currant (1.5%) [6].
The main objective of the present work was to find an alternative variety of grapes convenient for the production of raisins, the Crimson variety, and evaluate the final products obtained through different drying methodologies.

2. Experimental Methodology

2.1. Materials

For this work, were used about 20 kg of fresh grapes from Crimson seedless variety, provided by the company Herdade Vale da Rosa located in Ferreira do Alentejo, Portugal. On the day of reception was made the preparation of the Crimson grapes for drying: were chosen grape berries with similar dimensions and that showed no signs of deterioration, separating them from the stalk.

2.2. Drying procedures

Three experiments were produced, with different drying conditions: solar stove and ventilated chamber with convective air at 50 and 60 ºC. The solar greenhouse used has an aluminum frame and horticultural glass. This has a ventilator to promote a more effective extraction of air, running at different speeds of rotation. To control the temperature and humidity inside the greenhouse was allotted a thermohygrometer (Lufft - Opus 10) therein. Thus, conditions of temperature and relative humidity inside the greenhouse were recorded at 10-minute intervals throughout the drying process. The convective chambers used a constant air flow of 0.5 m/s and were programmed for constant temperatures of 50 ºC and 60 ºC in each experiment.

In all cases the drying proceeded until the sample reaches a moisture content less than 18% as recommended by the CODEX STAN 67-1981: Codex Standard for Raisins [16].

The following equation was used to calculate the drying yields:

$$\text{Yield} = \frac{\text{mass after drying}}{\text{mass of fresh grapes}} * 100 \;\; \text{expressed in \%} \qquad (1)$$

2.3. Chemical analyses

Moisture determination was made by the difference of the original mass of the sample and the final mass after heating to constant mass. The moisture content of the grapes was assessed every two hours until the samples reached humidity below 18%. For this determination was used a Mettler Toledo HG53 Halogen Moisture Analyses. The conditions of use were as follows: heat source: halogen lamp; drying temperature: 120 °C; speed of drying 3 (intermediate).

For the determination of acidity, the sample preparation followed the Portuguese Standard NP-783, 1985 [20] and the acidity determination was carried out according to the NP-1421, 1977 [21].

For the determination of total sugars the sample was prepared by the same procedure as for acidity. Total sugars were determined by refractometry and the Brix graduation was measured using a refractometer Atago 3T. The results were expressed according to the following equation:

$$[\text{Total sugars}] = \frac{°\,\text{Brix} * \frac{\text{dilution volume(ml)}}{100}}{\text{sample mass (g)} * \left(1 - \frac{H}{100}\right)} \quad in \quad \frac{g\ sucrose}{g\ dry\ solids} \qquad (2)$$

where H is the moisture in percentage.

In all cases three replicates were made.

2.4. Color measurement

The color of grapes dried by different methods was determined with a colorimeter (Chroma Meter - CR-400, Konica Minolta) in the Hunter Lab color space and for each experiment were examined 20 samples.

2.5. Texture profile analysis

For the evaluation of the textural parameters was used a texturometer (TAXT Plus from Micro Systems) to obtain the texture profiles (TPA), as exemplified in Figure 1. In this case, 10 TPA's were obtained for each drying experiment. The attributes of texture: hardness, elasticity, cohesiveness and chewiness were calculated by the following equations, taking into account the definitions of the TPA in Figure 1 [22]:

$$\text{Hardness (N)} = F1 \qquad (3)$$

$$\text{Springiness (\%)} = \Delta T2/\Delta T1 * 100 \qquad (4)$$

$$\text{Cohesiveness} = A2/A1 \qquad (5)$$

$$\text{Chewiness (N)} = F1 * \Delta T2/\Delta T1 * A2/A1 \qquad (6)$$

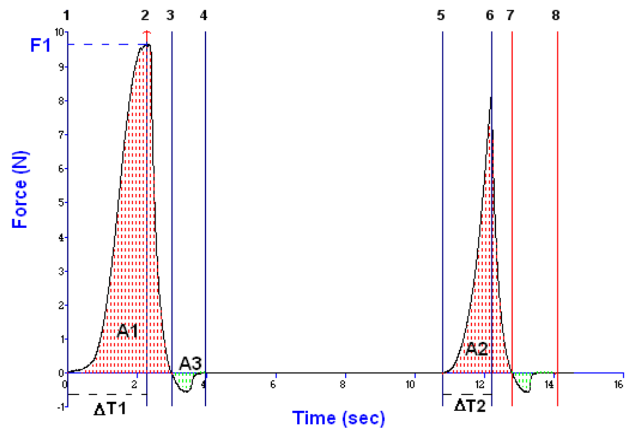

Figure 1 – Texture profile analysis (TPA). F1 is the maximum force; A1, A2 and A3 are the areas; ΔT1 and ΔT2 are time intervals.

2.6. Sensory analysis

For sensory evaluation were performed two separate tests: test for descriptive sensory profile and evidence of discriminatory sorting by preference between samples.
Initially tests were applied on sensory characteristics of raisins, through a descriptive analysis of the product with a panel of fifteen judges (untrained consumers), 6 men and 9 women aged between 22 and 55 years. The sensory attributes evaluated were color tone, color uniformity, sweetness, acidity, hardness, elasticity and overall assessment. This test was applied to the raisins obtained by three different methods and also to two varieties of raisins acquired in a commercial market: black sultanas from brand Auchan and seedless raisins from brand Ferbar. For a better characterization of the sensory profile of the dried products under study, the scales in descriptive terms were converted into numerical scale. Therefore, for the sensory attribute "sweetness" the scale was defined as: 1=very low, 2=low, 3=medium, 4=high, 5=very high. This scale was also used for the remaining attributes except the global assessment, for which was used the following scale: 1=very poor, 2=poor, 3=sufficient, 4=good, 5=very good.
In the second phase, the same panel made a proof of preference ordering. For this were used the samples dried in the chamber at 50 and 60 °C and the two commercial varieties, because the sample dried in in the solar stove was deteriorated due to its higher moisture content. In this test were evaluated the following parameters: color, texture, sweetness and overall assessment. The samples were presented to the panelists in random order, which ordered them according to their preference for each attribute evaluated.

2.7. Statistical analysis

In order to understand if the results obtained are statistically different a statistical analysis was applied. The Tukey HSD test was used with $P < 0.05$. Tukey's test also known as the Tukey HSD (Honestly Significant Difference) is a statistical test to find the results that are different from other representatively and consists of a single multi-step process for comparison, together with an analysis of variance (ANOVA). The test identifies where the difference between two values is better than the standard error which could be expected. For statistical analysis was used the statistical software V 6.1 Satsoft. This methodology was used for the result of color and texture. For the results of the sensorial analysis interpretation of the results was made by means of the Friedman test, calculating the least significant difference, considering a confidence interval of 90%.

3. Results and Discussion

3.1. Evaluation of drying processes

The initial moisture of the fresh grapes averaged 70%, and along drying the evolution of moisture was monitored to ensure that the final product had moisture content below 18%, to ensure the microbiological quality. As can be seen from Table 1, the solar drying method lasted 721h, being this related to the weather conditions during the drying period, which began on September 15, being a late period for the best use of sunlight as energy source. The fastest drying occurred at 60 °C, 47 h, approximately half when compared with drying at 50 °C which lasted for 100.5 h.

Table 1 – Drying parameters and yields.

Drying method	Initial moisture (%, average±st.deviation)	Final moisture (%, average±st.deviation)	Duration (h)	Yield (%)
Solar drying	70.00±1.12	19.43 ± 1.04	721.0	36
Convective drying at 50 ºC	70.00±1.12	14.52 ± 0.85	100.5	21
Convective drying at 60 ºC	70.00±1.12	14.59 ± 0.97	47.0	25

The final moisture of the raisins dried in solar greenhouse was 19.43% higher when compared with the results obtained for the convection chamber, around 15% for both temperatures, which originates a lower stability, particularly at the microbiological level. The grapes dried in the chamber had lower yields than the solar dried, as shown in Table 4, due to the lower final moisture content.

3.2. Sugars and acidity

The mean values obtained for the sugar contents were similar for the different samples, reaching about 0.30 g sucrose/g of dry matter. The results showed a high dispersion of the values obtained, indicating some heterogeneity in the raisins obtained. These values are lower than 0.67 g sucrose/g of dry matter obtained by Carranza-Concha *et al.* [23] for a variety of commercial raisins.
The solar dried sample and that dried at 60 ºC had approximately the same average acidity, 0.52 mg citric acid/g dry matter, while the raisins dried at 50 ºC had a relatively lower acidity, 0.42 mg citric acid/g dry matter. These values are higher than the value (0.30 mg citric acid/g dry matter) described by Esteban *et al.* [24] also for solar dried grapes of variety Crimson. According to the study of Rolle *et al.* [25], a variety of commercial raisins contains 0.55 mg of citric acid/g of dry matter, which is similar to the results obtained in this study.

3.3. Color

Figure 1 shows the results of evaluation of color coordinates for the different drying methods. It is noted that the values of lightness, L* were less than 50, which indicate that the raisins are dark. The a* values were positive, indicating a predominance of red coloration over the green (negative a*), and also positive values of b* indicators of the predominance of yellow coloration over the blue (negative b *).
The average values of L* were higher in grapes dried in the chamber, which means that they are lighter than those dried in the solar stove. Statistical analysis indicates that the brightness of raisins dried in the chamber are not statistically different, however these differ from the solar stove. The a* value is not statistically different for all samples and always higher than b*, indicating that the raisins tend strongly to yellow in disfavor of yellow. This difference was most marked for the value of b* of the solar stove raisins, which was considerably smaller than in the other samples.

3.4. Texture

Figure 2 shows the results obtained for the determination of hardness and springiness (elasticity) of the different raisins. Hardness is the force required to compress a food between the teeth or between the tongue and mouth, *i.e.* the force required to cause deformation [22]. As regards the comparison between the different drying systems, it is apparent that the grapes dried in a ventilated chamber at 60 °C are harder, and the remaining lots had similar hardness. The elasticity is the ability to regain shape after compression, and measures the speed of return to the initial state after removal of the force which caused the deformation [22]. It was found that the results are all statistically different, for the studied raisins. The elasticity value decreases with increasing temperature, namely raisins obtained by solar drying are less elastic than those obtained by drying in a ventilated oven at 50 °C and in turn less elastic than the grapes dried at 60 °C.

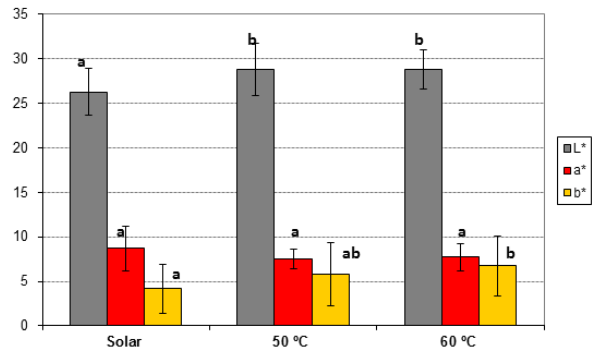

Figure 1 – Colour parameters for different dryings. The different letters indicate that the samples are statistically different according to Tukey HSD test (P <0.005).

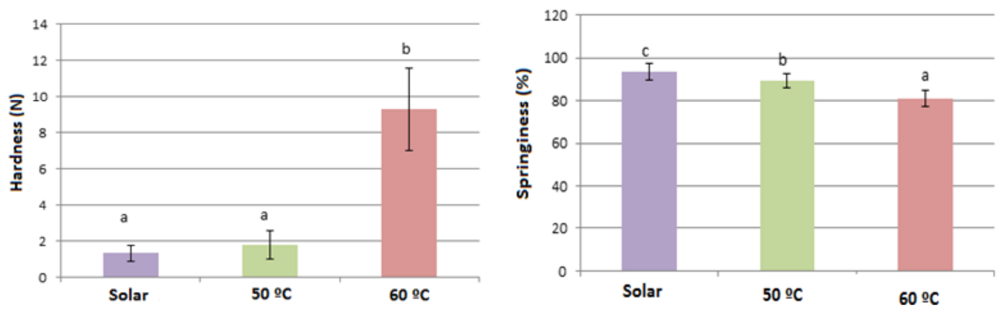

Figure 2 – Hardness (left) and springiness (right) for different dryings. The different letters indicate that the samples are statistically different according to Tukey HSD test (P <0.005).

As regards the cohesiveness, which represents the internal forces in the food, and which maintains the sample cohesive [22], it was found that the results for the samples from the solar greenhouse and from the ventilated chamber at 50 °C were similar, while the grapes dried at 60 °C were less cohesive (Figure 3). Resiliency is the strain energy per unit volume to a limit of proportionality, *i.e.* the energy used when applying a force to a material without occurring rupture, with or without any residual strain [22]. In Figure 30, it can be seen that the energy used to deform the solar dried grapes and those dried in the chamber at 50 °C is greater than the energy required to deform the raisins dried at 60 °C.
The chewiness measures the energy required to disintegrate a food as to be swallowed [22], and the results of Figure 4 indicate that in the case of grapes dried at 60 ° C this energy is higher than in the other cases. These results are derived directly from the fact that these grapes have a higher hardness than the others. Statistical analysis shows that the solar dried sample and the sample dried at 50 °C are similar.

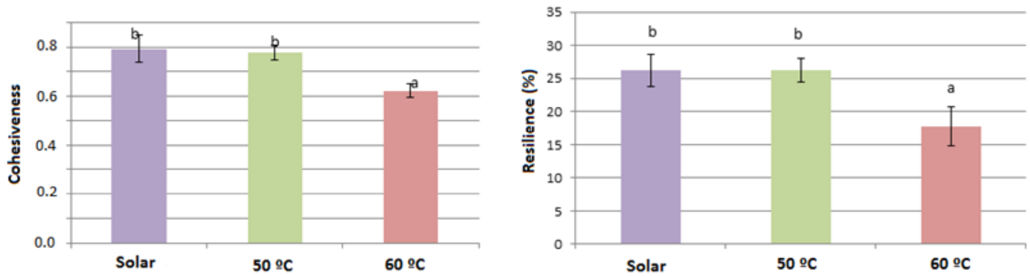

Figure 3 – Cohesiveness (left) and resilience (right) for different dryings. The different letters indicate that the samples are statistically different according to Tukey HSD test (P <0.005).

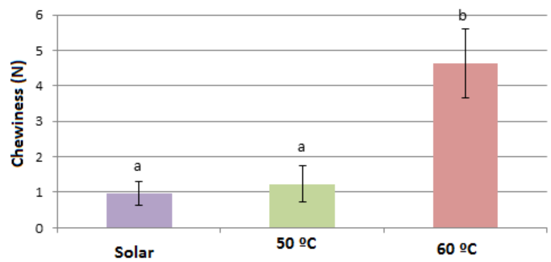

Figure 4 – Chewiness for different dryings. The different letters indicate that the samples are statistically different according to Tukey HSD test (P <0.005).

3.5. Sensory evaluation

The results of the sensory profile of the three samples of dried grapes together with two commercial brands are shown in Figure 5, as mean values for each sensory attribute and for each product tested. In most cases, there wasn't much oscillation between the values of the different samples. In terms of the overall assessment, the results obtained indicate that all samples were evaluated by the sensory panel generally as good.

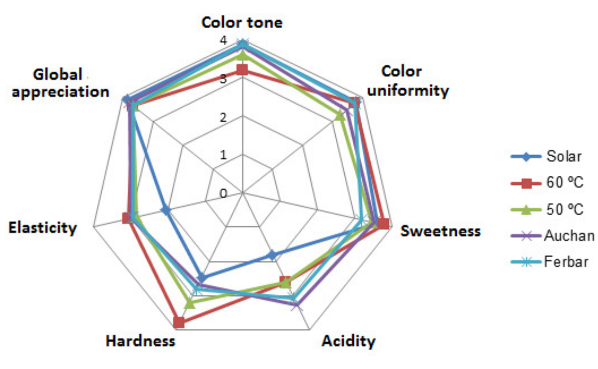

Figure 5 – Sensory profile of the dried samples and also some commercial raisins.

The solar sample was characterized as good (level 4) with regard to attributes color and sweetness and slightly good (level 2) in relation to the attributes acidity, elasticity and hardness. This sample was further characterized as the less acidic, hard and elastic of all samples analyzed. As for the sample dried at 50 °C the tasters felt that the color tone and overall assessment were considered good, while the remaining parameters were considered reasonable. Regarding the raisins dried in at 60 °C the examination by the panel of tasters showed that their tone, acidity and elasticity were considered reasonable and the remaining attributes, including global assessment, were good. In terms of flavor as well as sweetness,

the tasters found great similarity between all samples. However, with regard to acidity the panel identified differences, in the following order from the less to the most acidic: solar dried, dried at 50 °C, dried at 60 °C, and finally the commercial brands. Regarding the color parameter, the sample dried at 60 °C was the one with the lowest rating in relation to tonality, and the remaining samples were considered good. Furthermore, the sample dried in solar greenhouse was considered darker than the other samples, dried in the chamber. However, relating the uniformity of color, the sample that was dried at 50 °C showed lower values. As to texture, the panel found the sample dried at 60 °C harder, being this in accordance with the instrumental determinations observed. The sample that was dried in the sun showed the lower hardness and elasticity compared with the others.
In discriminant analysis for ordering test was intended to assess whether there would be differences in preference by the panel of judges in relation to the following attributes: sweetness, color, texture and overall enjoyment. Table 2 presents the overall results of sorting by preference of each attribute for the dried as well as commercial samples. The sample corresponding to the solar dried pear was not evaluated due to microbiological deterioration.

Table 2 – Sum of the overall results of the ordering proof.

Samples	Color	Texture	Sweetness	Global appreciation
50 ºC	30	37	39	35
60 ºC	32	40	43	38
Auchan	42	35	31	41
Ferbar	46	38	37	36

After statistical analysis of the results obtained it was found that for the attribute color there are at least two samples which are statistically different with a confidence level of 90% (Table 3). However, for the remaining attributes (sweetness, texture and overall enjoyment) there was no difference in preference between the samples, meaning that the dried samples do not differ from the commercial brands neither among themselves.

Table 3 – Calculated and estimated values of Friedman.

	Color	Texture	Sweetness	Global appreciation
Fr calculated	7,16	0,52	3,00	0,84
Fr Tabulated	6,25			

Regarding the attribute color, where there were significant differences between samples as evaluated sensorially, was still calculated the minimum difference of significance with a confidence level of 90%, to analyze the similarity or difference between the samples. The results showed that the samples dried at 50 and 60 °C as well as Auchan are similar to each other, as regards the choice of the panel. Furthermore, the two commercial brands also have similarities as seen by the taste panel.

3. Conclusions

The results obtained during the present study allowed concluding that the drying process in a ventilated chamber was faster and resulted in a lower moisture content when compared with the solar stove drying.
With regard to the acidity, the sample dried at 50 °C showed the lowest value. However, the sugar contents of all samples were similar.
Regarding the color of raisins, it can be said that they are dark, tending to a reddish and yellowish coloration (brown). In the evaluation of the texture, the grapes dried at 60 °C proved to be the toughest, the less cohesive the most difficult to chew and less resilient. The solar dried sample displayed the higher elasticity.
In the sensory profile, all samples from the grape of variety Crimson had an acceptance by panelists similar to that observed for the commercial samples tested. According to the sensory test of ordering only in the color parameter was identified a differentiation between

samples. One can thus conclude that samples resulting from drying at 50 °C and 60 °C are very similar compared to the commercial ones analyzed.
In short, the raisins produced from the grape variety Crimson dried in a ventilated chamber showed good chemical, physical and sensory properties, and can be a good way to use grapes that may not meet the conditions required for marketing in the fresh state.

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