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# Effects of drying and pretreatment on the nutritional and functional quality of raisins

*J. Carranza-Concha, M. Benlloch, M.M. Camacho, N. Martínez-Navarrete**

*Department of Food Technology, Universidad Politécnica de Valencia, Camino de Vera 14, 46022 Valencia, Spain*

ABSTRACT

The close relationship between the consumption of fruits and health status stems from the nutritional and non-nutritional compounds found in fruits which play a key role in the prevention of different diseases. However, fruit processing and storage greatly affect fruit compounds. The aim of the present work was to study the influence of processing on the stability of macro and micronutrients present in grapes, with a view to recommending products that provide the highest nutritional quality and the best health conditions. The study focused on fruit dehydration treatments. Conventional and microwave-assisted air-drying processes were used to obtain raisins. Dehydration caused a decrease of all grape compounds studied excluding total phenols. Moreover, compared to conventional processing, microwave-assisted drying produced greater losses of ascorbic acid in the grape and increased pectin solubilization with a consequent change in texture. However the microwave-dehydrated samples showed higher antioxidant activity.



*Keywords:* Microwave; Air drying; NaOH pretreatment; Total phenols; Antioxidant activity; Tartaric acid

## 1. Introduction

Traditionally raisins are obtained by sun drying of the fruit for eight to ten days, which substantially reduces water content. This drying method is cheap, but there is a risk of damage due to dust and insect infection (Pangavhane and Sawhney, 2002). An alternative to this is artificial drying. Convective drying is one of the oldest dehydration methods in which hot air passes through the fruit removing the water from the surface. This creates a diffusion gradient in the food that moves the water from the interior to the outer surface (Gowen et al., 2006). However, this process decreases the quality of the final product (Erenturk et al., 2005). Moreover, dehydration causes damages in texture, color, taste and nutritional value of food due to the high temperatures and long drying times required in the process. According to Tarhan (2006), the dehydration of grapes affects their content of polyphenols, ascorbic acid and antioxidant activity. That is why efforts should be made to reduce drying times and decrease the temperatures used in the drying processes and, in this way, obtain better quality products. This has led to the development of less invasive technologies to reduce the moisture content of food. An example is the use of microwave energy alone or combined with hot air (Contreras et al., 2005, 2007; Gowen et al., 2006).

Microwave drying is a technique that allows rapid dehydration and can be applied to certain foods, particularly fruits and vegetables (Zhang et al., 2006). The great interest in this technology is due to the high capacity of penetration of these waves, that heat not only on the surface but also inside the food. This speeds up the drying process and can improve the quality of the final product compared to other dehydration techniques like hot air drying (Contreras et al., 2005, 2007, 2008). Moreover, in microwave drying, heat is generated in the wet but not in the dry food areas, so that food areas with no water are not unnecessarily heated, which avoids the negative effects of heat on product quality (Bilbao, 2002; Martin, 2002). By contrast, microwave drying systems have the drawback that it is very difficult to know the distribution of the energy field, because it is modified by the introduction of a load in the system (Zhang et al., 2006). The combined use of microwaves and hot air drying improves final product quality (Ahrne et al., 2003; Contreras et al., 2005; Funebo et al., 2002; Piotrowski et al., 2004; Prothon et al., 2001; Raghavan and Silveira, 2001; Torringa et al., 2001). On the other hand,

* *Corresponding author*. Tel.: +34 963879362; fax: +34 96387369.
E-mail address: nmartin@tal.upv.es (N. Martínez-Navarrete).
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the skin of some fruits such as grapes is covered by a waxy coating that reduces permeability and therefore hinders the loss of water (Tarhan, 2006). That is why prior to artificial drying other chemical and physical pre-treatments are used to enhance permeability by increasing the drying rate, while preserving the physical, chemical, nutritional and organoleptic qualities of the final product. The more extended chemical pre-treatments to reduce drying times of grapes consist on dipping the berries in NaOH (Berna et al., 1991; Femenia et al., 1998) or $K_2CO_3$ (Rocha et al., 1993) solutions, which induces breakage of the skin favoring the mass transfer. Also the use of oil emulsions has been described in order to eliminate the waxy coating (Eissen et al., 1985; Aguilera et al., 1987).

The present work studies the changes in the nutritional and functional value of grapes as a result of convective and microwave-assisted hot air drying, with and without NaOH pretreatment to produce raisins

## 2. Materials and methods

### 2.1. Raw material

Grapes (Vitis vinifera) selected from the Imperial seedless and Thompson seedless varieties and purchased in supermarkets in the city of Valencia were used for the experiments. The grapes were stored in a refrigerator before handling (up to 12 h), rinsed with distilled water and dried with paper towels; the berries were then separated from the bunch and dry-treated. Additionally, commercial raisins were purchased at a local supermarket and compared with the raisins obtained experimentally in the laboratory.

### 2.2. Processing

The two grape varieties were treated using two drying methods: microwave-assisted hot air drying (MW) and hot air drying (HA); additionally the Imperial seedless grape variety was subjected to a pretreatment to shorten drying times, which consisted of dipping the berries in a NaOH solution (0.03%) at 95 °C for 45 s. In all cases the final moisture content was set at 30% for the dehydrated grapes. Next is the description of the procedure that was followed for each of these drying treatments.

For microwave drying a total of 100 g of grapes was introduced in a laboratory dryer (Contreras et al., 2008). This device has a mechanism to control the microwave power (set at 0.2 W/g), air temperature (60 °C), air velocity (1.6 m/s) and the evolution of the mass of the product over time with the help of an analytical balance. For hot air drying a laboratory dryer with larger sample capacity was used. A total of 450 g of grapes was introduced in the dryer, which could also control temperature and air velocity (60 °C, 10 m/s) as well as the mass of the product by means of an analytical balance. The weight of the sample was recorded during the process and allowed for the calculation of the moisture content at each drying time providing the initial moisture content is known (Eq. (1)).

$$X_{wt} = \frac{M_0 \cdot X_{w0} + \Delta P}{M_t} \quad (1)$$

where $X_{wt}$, moisture content at each drying time (g of water/g of product); $M_0$, initial grape mass (g); $X_{w0}$, initial moisture content (g of water/g of product); $\Delta P = M_t - M_0$; $M_t$, grape mass at each drying time (g).

Using this equation, the drying process was stopped when the moisture content of the dried product was approximately 30%. The drying times were: HA = 50 h, MW = 7.5 h, HA + NaOH = 34 h and MW + NaOH = 4.5 h. The reduction of process time when applying microwave instead of hot air was around 85%, which agrees with data reported by Contreras et al. (2008) for apple slices and strawberry halves.

### 2.3. Sample analysis

All samples were analyzed in the moisture content (AOAC 20 013, 1997), the soluble solids of the liquid phase of the samples (°Brix) at 20 °C (refractometer Atago NAR-3T, Tokyo, Japan) and water activity ($a_w$) (dew-point hygrometer GBX FA-st lab, Lyon, France). Total acidity was measured by titration with NaOH (0.1 N) and expressed in mg of the main acid (tartaric acid, TA) (AOAC, 1997). Ascorbic acid (AA) was determined by titration according to AOAC 985.33 (1997). The total pectin content was analyzed by quantifying the galacturonic acid residues (AGU) following the procedure used by Yu et al. (1996). To determine the AGU a Thermo Spectronic UV1 spectrophotometer (Madison, USA) was used for measuring absorbance at 520 nm. The determination of phosphorus was analyzed by colorimetry, using the same spectrophotometer at 600 nm. Ca, K and Mg were calculated by high-performance anion-exchange chromatography (HPAEC), using a Metrohm chromatograph (Herisau, Switzerland) and tartaric acid as mobile phase (4 mmol/l) and dipicolinic acid (0.75 mmol/l) and a Metrosep C2-150 column (4 × 150 mm) with a particle size of 7 μm. Like the minerals, the sugars were determined by the same technique, using 0.1 N NaOH as mobile phase and a Metrosep Carb 1 column (4.6 × 250 mm) for carbohydrates with a particle size of 5 μm. In both cases the grapes were homogenized with an Ultra-Turrax T25 (Staufen, Germany) and then centrifuged at 4 °C and 10,000 rpm for 10 min. The extraction for the quantification of total phenols (TP) was carried out using the technique described by Peiró et al. (2006). The same extract obtained for TP quantification was used for the determination of antioxidant activity (AOA). The TP were quantified using the Folin–Ciocalteu test (Li et al., 2006) and expressed in mg of gallic acid/100 g fresh grape. The antioxidant activity was determined by a modification of the spectrophotometric technique developed by Re et al. (1999), using the ABTS+ radical (Sigma) generated by 2.45 mM potassium persulfate ($K_2S_2O_8$). The results were expressed as antioxidant activity equivalent to mg of Trolox (TEAC) in 100 g of fresh sample. All the experiments were replicated thrice.

## 3. Results and discussion

Tables 1 and 2 show the mean values of $a_w$ and the components analyzed in the samples of the fresh and treated grape varieties by different drying methods (MW, HA, and MW + NaOH and HA + NaOH). As expected, the decrease in moisture content caused a general increase in °Brix and, as a result, a decrease in water activity after dehydration with the drying methods under consideration.

Due to the variability in the initial composition of the fresh fruit, the gain or loss in the content of each compound was calculated in order to compare among the different dehydration treatments, taking into consideration the compound content in 100 g of fresh grapes and in the raisins referred also to 100 g of fresh grapes, according to Eq. (2) (Table 3). These data were used to calculate the percentage change in the content of