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The influence of ethanol on the convective drying and on the nutritional quality of dekopon slices

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Abstract

Dekopon or Hallabong (Citrus reticulate "Shiranui") is a hybrid fruit that belongs to the citrus fruits. The scientific and commercial interests in dekopon is due to its nutritional composition. The objective of the study was to verify the influence of ethanol as a pretreatment in reducing drying time as well as maintaining nutritional quality (vitamin C, total phenolic compounds, and antioxidant activity) of dekopon slices. The drying with ethanol at 70 °C promoted the greatest reduction in drying time, but the processed pretreated samples at 50 °C presented the highest level of nutritional quality parameters.

Keywords: *drying time; vitamin C; phenolic compounds; antioxidant activity.*

1. Introduction

The vitamin C, consisting of ascorbic and dehydroascorbic acid, is widely found in fruits and foods, being characterized by its instability to technological processes [1, 2]. There are also other health-promoting substances, such as phenolic compounds, which are secondary metabolism in plants that have been identified as major antioxidants in fruits [3]. Those compounds are present in the fresh form of fruits and vegetables, especially in citrus fruits. Dekopon (*Citrus reticulata* "Shinarui") is among the citrus fruits. It is a cross between Kiyomi (*Citrus uses Marcov*. x *Citrus sinensis Osbeck*) and Ponkan (*Citrus reticulata Blanco*). The commercial value of dekopon is due to its sweet taste and pleasant aroma [4, 5].

Generally, fruits and vegetables in their fresh form show high moisture content and water activity, providing high degradation rates which may cause significant postharvest losses. To minimize these effects, various processing techniques can be used, as drying. Convective drying is a simple but time consumer process with consequent high energy demand. High temperatures reduce the drying time, but could carry out to food quality and nutritional composition reduction [6]. In order to minimize the negative effects of drying, some pretreatments such as ultrasound [7], osmotic dehydration [8] and ethanol application in the environment and on the surface of the samples are commonly used [9, 10].

The aims of this work were to (i) investigate the effects of the immersion of the samples in ethanol on drying time, (ii) examine the influence of ethanol and drying temperature on phenolic compounds content, vitamin C and antioxidant activity.

2. Materials and Methods

2.1. Sample preparation

Dekopon (*Citrus reticulata "Shinarui"*) were selected based on uniform maturation characteristic with peel color. The fruits were washed and sanitized with sodium hypochlorite solution [11] and stored at 7 °C (±2 °C) until the beginning of each experiment. The moisture content of the fresh dekopon (method 934.06, AOAC (2005)) was 5.92±0.01 kg H_2O kg^{-1} d.b.

For the experiments, the samples were peeled manually, eliminating the edges of the fruit. Samples were sliced with the aid of a stainless steel knife and a cutter so as to standardize the size of the slices. After cutting, the dekopon slices presented standardized dimensions 3.27±0.32 mm x 60.54±1.12 mm (thickness x diameter) and were measured using a digital caliper (Western, DC-60 model, Zhejiang, China).

2.2. Convective drying

The convective drying was performed in a tunnel dryer (Eco Engenharia Educacional, MD018 model, Brazil) The mass variation of samples during the drying was monitored using a digital balance (Marte Científica, AD33000 model, Brazil) (accuracy± 0.01 g) coupled to the sample holder allowing to obtain the kinetics of drying. In each experiment, 145.113±5.862 g of fresh fruits (totaling five slices) were dried. The process was performed until an average final moisture content of 0.235±0.054 kg H_2O kg^{-1} d.b.

The drying process followed a 2x2 factorial design to study the effects of air temperature variation (50 and 70 °C) [11] and the immersion or not of the samples in ethanol, as a pretreatment. Air velocity was keep at 2.00 m s^{-1} [12]. Pretreatment samples were completely immersed in 95% ethanol in a petri dish for 10 s [13] in a ratio sample/ethanol of 1:1 (weight/weight) approximately. The moisture content of the dried dekopon was determined according to the AOAC (2005). The water activity (a_w) determination was performed in a hygrometer (Aqualab, 3-TE model, Decagon Devices, Inc., Pullman, WA, USA).

2.3. Quality analysis

The total phenolic compounds were quantified using an adaptation of the method of Folin-Ciocalteau. Quantification was performed by spectrophotometer reading at 750 nm and the results expressed in mg of gallic acid.100 g^{-1} dry matter [14].

The ascorbic acid (vitamin C) determination was performed by the colorimetric method, 2,4 dinitrofenilhidrazina [15] and the results expressed as % retention of ascorbic acid in the dry product, according to Eq. 1

$$\%\text{retetntion} = \left(\frac{\text{g ascorbic ácid in the dehydrated sample}}{\text{g ascorbic ácid in the fresh sample}} \right) * 100 \quad (1)$$

The total antioxidant activity (AAT) by DPPH (2,2-diphenyl-1-picrylhydrazyl) [16]. The results are expressed as % sequestration. The percentage of sequestration expresses the ability of the food to inhibit the action of the reactive species present in the DPPH radical.

2.4. Statistical analysis

All analytical determinations were performed in triplicate. Parameter values are expressed as the means±standard deviation. The results were analyzed using analysis of variance

(ANOVA) and the Tukey test at 5% significance to compare the mean values using Statistic (Statsoft, Tulsa, USA).

3. Materials and Methods

3.1. Convective drying

The Fig. 1 shows the evolution of drying of dekopon slices treated and unpretreated with ethanol, at 50 and 70 °C. The drying time for the pretreated fruits to reach a final moisture content of 0.235±0.051 kg H_2O kg^{-1} d.b was 300.33±0.95 and 1193.33±0.64 min for 70 and 50 °C respectively. For the untreated samples the total drying time was 343.33±0.91 and 1540.00±0.83 min for 70 and 50 °C respectively.

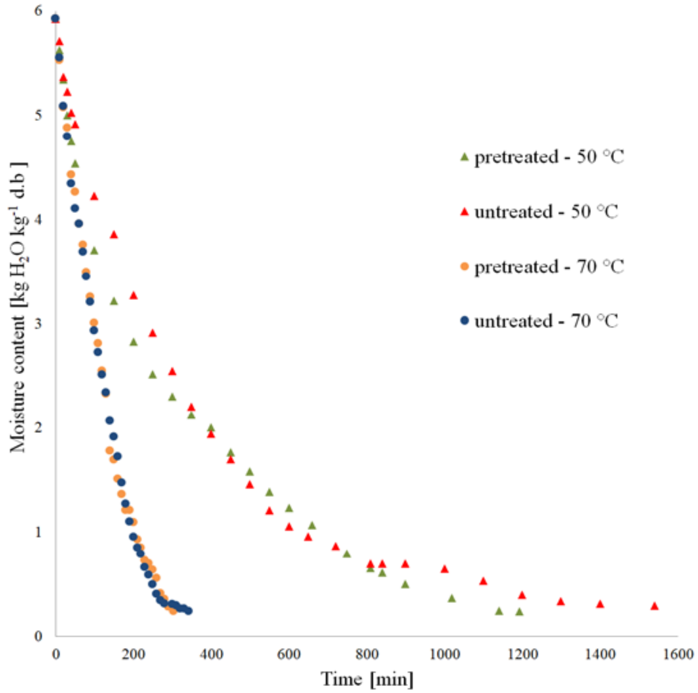

Fig. 1 Evolution of moisture content of treated ethanol immersion and untreated dekopon at 50 e 70 °C.

The experiments at 70 °C with pretreatment and without pretreatment did not obtain a significant difference between them ($p>0.05$), presenting times of 303.33±2.49[a] min and

343.33±2.65[a] min, respectively. However, these experiments differed statistically from the others ($p<0.05$), in addition, the experiments at 50 °C with pretreatment and without pretreatment showed a statistical difference between them ($p<0.05$), reaching a final processing time of 1193.33±3.46[b] min and 1540.00±1.73[c] min. These data demonstrate the effectiveness of the application of ethanol to the samples of dekopon slices as well as the increase of the drying air temperature with respect to the reduction of the total process time, which can bring benefits mainly in the energy economy. The use of ethanol in direct contact with the sample, as pretreatment to convective drying, was studied by [10] during the drying of banana having the same effect in relation to the increase of the diffusivity allowing the pretreated experiments to present a lower drying time. With the application of the ethanol under the sample, a homogeneous mixture is formed (ethanol has hydroxyl that binds with water by hydrogen bond) and this mixture presents a higher vapor pressure when compared to the solution without ethanol, justifying the reduction of the drying process [10, 11, 17]. As the temperature of the air increases, a higher rate of drying occurs due to the greater mobility that the water reaches inside the pores, reducing the internal resistance to the transport of moisture [7], and similar results are found in the literature [18, 19].

The a_w is an important parameter in food preservation and the results have proved the efficiency of the drying process in reduced the values. The fresh samples presented a_w of 0.97±0.02[a], differing from the others ($p<0.05$). The experiments at 50 °C with pretreatment, and without pretreatment, as well as those of 70 °C with pretreatment and without pretreatment, presented a_w of 0.36±0.05[b], 0.37±0.03[b], 0.38±0.05[b], and 0.360±0.021[b] ($p>0.05$), respectively, according to literature [20].

3.2. Quality analysis

The effect of air temperature drying and ethanol immersion on the phenolic content, vitamin C retention and total antioxidant activity of dekopon slices dehydrated are showed in Table 1.

Table 1. Phenolic content, vitamin C retention and total antioxidant activity in dekopon slices dehydrated

Conditions	Phenolic [mg 100 g^{-1}]	AAT [%sequestration]	Vitamin C [%retention]
50 °C, pretreated	766.67±10.25^{a}	74.80±0.12^{a}	39.09±0.91^{a}
50 °C, untreated	642.89±6.14^{b}	59.06±1.14^{b}	32.45±0.04^{b}
70 °C, pretreated	622.16±6.06^{bc}	51.71±0.59^{c}	30.71±0.03^{c}
70 °C, untreated	609.75±4.77^{c}	49.54±0.80^{d}	28.85±0.09^{d}

Different letters mean significant difference ($p<0.05$).

The reduction of bioactive compounds in foods and the degradation of phenolic are usually pointed as drying disadvantages. The lowest phenolic compounds, percentage of retention of vitamin C and total antioxidant activity were found in the experiments at 70 °C. By the drying, the polyphenols could have interactions with other compounds or have their chemical structure changed [3]. Temperature have a negative effect on phenolic [21]. The increase in temperature also brings reductions in the vitamin C, a thermosensitive compound [22]. In addition, the effect of the use of ethanol was clearly evidenced. The higher retention and antioxidant activity were found with the use of ethanol. Moreover, one can see that those indexes were more relevant at lower temperatures. For example, the antioxidant activity was 26.7% higher by the use of ethanol at 50 ºC whereas it was 4.4 % higher by the same use at 70 ºC. The alcohol causes a more intense evaporation of water, reducing the time of exposure of the sample to the drying process, minimizing the effects of temperature under the quality parameters analyzed [23].

4. Conclusions

The immersion in ethanol and the use of higher temperatures lead to shorter drying time. In addition, the quality compounds analyzed had greater preservation in the experiment at 50 °C and with application of ethanol, evidencing the importance of the use pretreatment as well as the choice of the range temperature process.

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