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# Optical and mechanical properties of cocona chips as affected by the drying process

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ABSTRACT

The effect of the application of a pre-osmotic treatment to obtain hot air dried cocona (*Solanum sessiliofurum Dunal*) chips was studied. The drying kinetics and the optical and mechanical properties of cocona chips obtained by the combined method of osmotic dehydration and hot air drying (OD + HAD) and by only hot air drying (HAD) were compared. Samples were dried by hot air at 60 °C. For the combined method, they were pre-dried to a moisture content of 75 $g_{water}$/100 g, immersed in a 55 °Brix sucrose solution at 25 °C for 48 min. The pre-osmodehydration applied did not influence the subsequent hot air drying kinetics, resulting in a final product with 0.055 ± 0.005 $g_{water}/g_{cocona.}$ The optical properties of OD + HAD chips were more favorable, exhibiting a smaller color change with respect to the fresh fruit (±15 units) than the HAD samples (±23 units). On the other hand, the OD + HAD chips presented more fracture peaks than HAD ones, this related with a structure with a higher degree of crispness, a very desirable property for a chip product.


## 1. Introduction

*Solanum sessiliflorum Dunal*, known as cocona or topiro, is an exotic fruit which is native to tropical America and distributed around the Amazon basin of Brazil, Colombia, Peru, Ecuador and Venezuela (Pereira da Silva et al., 2011). The interest in the trade and consumption of tropical fruits has increased significantly in recent years due to their sensory properties and a growing recognition of their therapeutic and nutritional value (Bicas et al., 2011). Recent studies into the nutritional and functional properties, in different ecotypes of cocona, have emphasized its attractive characteristics (Yuyama et al., 2007; Murillo et al., 2010; Contreras Calderón et al., 2011). However, due to its high degree of acidity and astringency this exotic fruit is not consumed fresh and its use is limited to the elaboration of traditional, home-made products, such as juices, jams or candies. The cocona is little known because its production is small scale, which is due to its great variability, poor dissemination, logistical problems and gaps in basic research and technology. For these reasons, it seems essential to evaluate how the quality properties of cocona are affected by the different processing methods.

Dehydration is a technique that is widely applied in the preservation of fruit and vegetables. This technology has been used since ancient times to stabilize and increase the shelf-life of food products. It relies on reducing the water activity ($a_w$) in the food, slowing down degradation processes, especially those caused by chemical and microbiological agents. Dehydration causes an appreciable change in the geometric properties with a consequent reduction in the weight and volume of the product, which facilitates transport and storage. At the same time, it causes a number of changes related to the nutritional, sensory, optical and textural properties that can sometimes become undesirable (Fito et al., 2001; Bennett et al., 2011). For dehydrated fruit pieces, the optical and textural properties greatly influence the quality and, thus, consumer-acceptance. Both color changes that occur due to enzymatic browning phenomena and structural changes in the fruit

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tissues caused by water loss during drying depend on the method used and the conditions in which the process takes place (Torreggiani and Bertolo, 2001).

The dehydration technique most commonly used on food products is hot air drying (Krokida et al., 2003). Using this technique, a simultaneous mass and heat transfer occurs (Nguyen and Price, 2007). Hot air drying (HAD) produces stable dehydrated products, but unfortunately their final quality is drastically reduced when compared to the fresh fruit due to the high temperatures and times involved in the process (Ratti, 2001). To avoid this problem, different combined drying methods may be considered. In this sense, the application of osmotic dehydration (OD) prior to using HAD to obtain dried fruit has been investigated (Alvarez et al., 1995; Rodriguez et al., 2003; García et al., 2007; Rózek et al., 2010). These authors have observed an improvement in the quality of the dried products as well as a reduction in the process drying time. During OD, the cellular tissue is immersed in a concentrated sugar or salt solution to promote the loss of water (Fito and Chiralt, 2003). In addition to mass transfer, structural changes occur as a result of the deformation and breakage of the cellular element. This causes changes in the macroscopic properties of the sample, such as in the optical and mechanical properties, which are related to the appearance (Chiralt and Talens, 2005). However, unlike other drying processes, in the case of osmotic dehydration the damage to the flavor and color of the fruit caused by enzymatic browning phenomena is minimal (Uddin et al., 2004). Nevertheless, as prolonged immersion times are required to achieve adequate levels of osmotic dehydration, it is a good candidate for combining with hot air drying.

The aim of this work was to study the effect of osmotic dehydration combined with hot air drying on the mechanical and optical properties of cocona chips for the purposes of being able to offer a new product to consumers. A kinetic study of the drying process was assessed.

## 2. Materials and methods

### 2.1. Sample preparation and osmotic solution preparation

The cocona studied was obtained from the Center for Biological Research and Agroforestry Production (CIPAF) of the Technological University of Chocó (Colombia). The water content, °Brix and water activity of the fruit was measured as described below. The fruit pieces were peeled and cut perpendicularly to the fruit axis into 5 mm thick half slices. Food grade commercial sucrose was used to prepare the osmotic solution (OS) by mixing 55 g of sucrose with approximately 45 g of distilled water to obtain a homogeneous 55 °Brix solution.

### 2.2. Drying procedures

Dried slices of cocona, called chips in this study, were obtained by hot air drying (HAD chips) and by a combined osmotic-hot air drying procedure (OD + HAD chips). In order to optimize both processes, previous kinetic studies were conducted. In this sense, the effective diffusivity of water ($D_e$) was determined for each process. The simplified solution of Fick's Second Law (Eq. (1)), valid for an infinite plane sheet and long drying times, was used to this end. A non-linear regression method was applied to fit the data.

$$Y = \frac{\left(x_w{}^t - x_w{}^\infty\right)}{\left(x_w{}^0 - x_w{}^\infty\right)} = \frac{8}{\pi^2}\exp\frac{D_e\pi^2 t}{4l^2} \quad (1)$$

where Y is the reduced driving force, $x_w$ is the water content ($g/g_{cocona}$) with superscripts: 0 (initial condition), $t$ (at time $t$) or $e$ (at equilibrium condition); $D_e$ is the effective water diffusivity ($m^2/s$); $l$ is the slab half-thickness (m); and $t$ is the time (s).

#### 2.2.1. Osmotic dehydration kinetics

The halves of cocona slices were placed in the 55 °Brix OS, maintaining a 1:10 fruit:OS ratio. The system was kept at 25 °C and continuously stirred. Changes in the total mass weight, mass fraction of water, mass fraction of soluble solids and water activity of the samples at 0, 5, 10, 15, 20, 25, 30, 40, 60, 120, 180, 240, 300 and 360 min were analyzed, as described below.

The obtained results were used to select the osmotic dehydration time necessary to obtain samples with 0.75 g water/g sample. These pre-osmodehydrated samples were air dried, as described below.

#### 2.2.2. Hot air drying kinetics

Both fresh samples and those pre-osmodehydrated to $x_w$ 0.75 were dried at 60 °C to obtain chip samples. Air drying experiments were carried out in a perforated tray dryer (Back to Basics FD-600) with a constant air flow rate of 1.6 m/s. The samples were air dried for 0, 30, 60, 120, 180, 240 and 300 min, where constant weight was achieved. The change in the total mass of the samples was registered at each time, together with the water content (see Section 2.3.1). Furthermore, the characteristic dimensions of the cocona slice were measured to determine the percentage of shrinkage (see Section 2.3.2).

### 2.3. Analysis

#### 2.3.1. Water content, °Brix and water activity

The mass fraction of water ($x_w$) was obtained in triplicate by vacuum drying the samples in a vacuum oven (Vaciotem, J.P. Selecta) at 60 °C ± 1 °C under a pressure of <100 mm Hg until constant weight (AOAC method 934.06, 2000). The mass fraction of soluble solids in the liquid phase ($Z_s$) was obtained at 20 °C by measuring the °Brix (Refracto 30 PX, Mettler Toledo at 20 °C) of the previously homogenized samples (Ultraturrax T25, Janke & Kunkel). The mass fraction of soluble solids ($x_s$) in the sample was calculated by the following equation:

$$x_s = \frac{{}^{Q}\text{Brix}.x_w}{(100 - {}^{Q}\text{Brix})} \quad (2)$$

The water activity ($a_w$) was measured by using a water activity meter (Aqualab CX-2, Decagon Devices). Changes in the total water and soluble solids mass were calculated by means of the following equations (Igual et al., 2010):

$$\Delta M = \frac{M^t - M^0}{M^0} \quad (3)$$

$$\Delta M_w = \frac{M^t X_w{}^t - M^0 X_w{}^0}{M^0} \quad (4)$$

$$\Delta M_s = \frac{M^t X_s{}^t - M^0 X_s{}^0}{M^0} \quad (5)$$