Contents lists available at ScienceDirect

Food and Bioproducts Processing

journal homepage: www.elsevier.com/locate/fbp

Effect of drying treatments on texture and color of vegetables (pumpkin and green pepper)

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ABSTRACT

The present work evaluates the effect of different drying treatments on the color and textural attributes of green bell peppers and pumpkin, which were dried using two different methods: air drying and freeze-drying. The treatments in air drying were carried out at 30 °C and 70 °C.

From the results it is possible to conclude that the increase in drying temperature reduced drastically the hardness of green peppers and the freeze drying had an intermediate effect between vegetables dried at 30 °C and 70 °C. Moreover, the springiness was higher in dried green peppers but an opposite effect was observed on chewiness. With respect to pumpkin, any dependence between the fiber orientation and the hardness of the fresh vegetable was not found. In addition, increasing temperature from 30 °C to 70 °C particularly reduced the hardness and the chewiness of dried product and maintained cohesiveness and springiness approximately constant.

Regarding the color, it was possible to conclude that air drying at 30 °C produced small changes in color of green pepper whereas air drying at 70 °C and freeze drying originated more intense color changes. The increase of temperature on air drying augmented the color saturation of dried pumpkin while decreased the hue angle by a linear relationship. In addition, the chroma of dried pumpkin decreased significantly with the freeze drying, while the hue angle was maintained constant as compared with the fresh vegetable.

Keywords: Green pepper; Pumpkin; Hardness; Texture; Color; Air drying; Freeze drying

1. Introduction

Portuguese cuisine is rich in using fresh vegetables, such as pumpkin (*Cucurbita maxima* L.) and green pepper (*Capsicum annuum* L.), on soups, salads, sauces, packet food, desserts and many convenience foods. However, their processed form is scarce in the market. Therefore, the drying, which is one of the oldest methods for food preservation, may represent a possible method to commercialize these vegetables.

The chemical composition, associated to the antioxidants and vitamins, makes these two vegetables important in the diet, either for their nutritional value or health protective functions. The bright orange color indicates that the pumpkin is high in β-carotene, an important caratenoid precursor to vitamin A in the human body (Weinstein et al., 2004). During the last few years bell pepper has gained consumer interest due to their vitamin and antioxidant contents (Penchaiyaa et al., 2009; Simonne et al., 1997; Vega-Gálvez et al., 2008). Bell peppers present different nutritional compositions, depending on the variety and stage of maturity, but are naturally also rich in ascorbic acid, provitamin A carotenoids and minerals that have an important health-protecting effect (Faustino et al., 2007).

Bell peppers, like other vegetables, are quite perishable, originating high losses due to storage problems and marketing, among others. An alternative to the consumption of fresh vegetables is their dried form, which allows their use during the off-season. The most popular drying process uses convection through hot air, but high temperatures can change the composition and the nutritional value as well as physical properties, density, porosity, mechanical properties and organoleptic quality of the products. Despite the high costs

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Received 16 August 2010; Received in revised form 14 December 2010; Accepted 5 January 2011

doi:10.1016/j.fbp.2011.01.003

and time consuming of freeze drying, this process generates minor changes in color, flavor, chemical composition and texture (Nawirska et al., 2009). For a consumer, the color of a product is a primary perceived characteristic that plays an important role on food. Apart from the perceived primary characteristics, texture and flavor play also an important role on the acceptability of foods by the consumers. Texture is the result of complex interactions among food components at a microstructural level and at higher structural levels as, for instance, the structure of the tissue (cellular orientation, porosity) and the different types of tissues or organs that constitute food materials (Aguilera and Stanleym, 1999; Mayor et al., 2007).

Hence, it is crucial to determine and control the color and texture of the processed foods. The changes of color can be related with the degradation of carotenoids during processing that have important antioxidant properties (Gonçalves et al., 2007). In what concerns texture, this implies knowledge about changes in the mechanical properties because they are related with the textural and sensorial characteristics of the food. Several authors have studied the changes of the mechanical properties of food during convective drying and, in general, they found that a soft product (fresh) is transformed into a rigid product (dried). Alternatively it changed from a predominantly plastic behavior to a more elastic behavior (Telis et al., 2005). The fresh pumpkin has values ranging from 0.96 to 2.53 for apparent modulus of elasticity, 250–630 kPa for failure stress, 0.42–0.71 for failure strain and 85–285 kJ/m^3 for toughness and their failure mode is fiber debonding (Mayor et al., 2007).

The present work aimed at studying the effect of freeze-drying and air drying at different temperatures on the color and texture of pumpkin and green pepper. Texture attributes (hardness, adhesiveness, springiness, cohesiveness, and chewiness) were estimated after measurements made with a texturometer.

2. Experimental

2.1. Drying procedures

Pumpkin and green bell pepper were purchased in a local market, washed and cut to samples of approximately 2 cm × 2 cm and dried in ventilated oven and freeze drier. For the drying of pumpkin only the pulp was used, whereas the bell pepper was dried with skin.

For the convective drying, an electrical stove WTB Binder with ventilation was used. The stove was operated at constant temperatures of 30 °C, 50 °C and 70 °C, and the air flow was 300 m^3/h.

For the freeze drying, the samples were frozen in a conventional kitchen freezer, and then left in the freeze-drier (model Table Top TFD5505) for 38 h at a temperature between −47 °C and −50 °C, and a pressure of 5 mTorr (0.666 Pa).

Table 1 shows the conditions of each drying trial, for comparison purposes.

2.2. Texture measurements

For determining the textural properties of pumpkin, texture profile analysis was carried out on cylindrical samples removed at 1, 3 and 4 cm of the skin and on axial and radial directions as illustrated in Fig. 1.

Measurements to the fresh green pepper were done on both sides of the pepper tissue, that is to say, from the skin (external) and the flesh (internal) sides.

Texture profile analysis (TPA) to all the samples was performed using a Texture Analyser (model TA.XT.Plus). The texture profile analysis was carried out by two compression cycles between parallel plates performed on cylindrical samples (diameter 10 mm, height 3 mm) using a flat 75 mm diameter plunger, with a 5 s of time between cycles. The parameters that have been used were the following: 5 kg force load cell and 0.5 mm s^{-1} test speed.

The textural properties: hardness, springiness, cohesiveness, and chewiness were calculated after Eqs. (1)–(4) (see Fig. 2):

$$\text{Hardness}, \quad H = F_1 \tag{1}$$

$$\text{Springiness}, \quad S = \frac{\Delta T_2}{\Delta T_1} \times 100 \tag{2}$$

$$\text{Cohesiveness}, \quad C = \frac{A_2}{A_1} \tag{3}$$

$$\text{Chewiness} = H \times S \times C \tag{4}$$

2.3. Color measurements

The color of the fresh and dried samples was assessed using a handheld tristimulus colorimeter (Chroma Meter – CR-400, Konica Minolta) calibrated with a white standard tile. A CIE standard illuminant D65 was used to determine CIE color space coordinates, $L^*a^*b^*$ values. This system is suggested by Mendoza et al. (2006) as the best color space for quantification in foods with curved surfaces. These Cartesian coordinates can be used to calculate the polar or cylindrical coordinates: $L^*H^\circ C$, with H° representing the hue angle and C the chroma, as defined by Eqs. (5) and (6):

$$\begin{cases} H^\circ = \text{arctg}(b*/a*), & \text{for } a* > 0; \quad b* > 0 \\ H^\circ = 180^\circ + \text{arctg}(b*/a*), & \text{for } a* < 0; \quad b* > 0 \\ H^\circ = 270^\circ + \text{arctg}(b*/a*), & \text{for } a* < 0; \quad b* < 0 \\ H^\circ = 360^\circ + \text{arctg}(b*/a*), & \text{for } a* > 0; \quad b* > 0 \end{cases} \tag{5}$$

$$C = \sqrt{(a*)^2 + (b*)^2} \tag{6}$$

The total color change (ΔE), was the parameter considered for the overall color difference evaluation, between a dried sample and the fresh vegetable (designated with an index 0) in Eq. (7):

$$\Delta E = \sqrt{(L_0 - L)^2 + (a_0 - a)^2 + (b_0 - b)^2} \tag{7}$$

Fresh vegetables were used as the reference and a larger ΔE denotes greater color change from the reference material.

3. Results and discussion

3.1. Texture measurements

Table 2 resumes the values of the textural properties for green bell pepper calculated from the compression TPA curves (through Eqs. (1)–(4)). The parameter hardness can be related to the force performed by mastication that takes part during