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Effect of multi-flash drying and microwave vacuum drying on the microstructure and texture of pumpkin slices

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ABSTRACT

The influence of different drying methods on the microstructure, porosity, and texture of pumpkins slices was assessed, aiming to find the best process conditions. Pumpkins (*Cucurbita moschata*) were selected, peeled, sliced, blanched and dehydrated by different methods: i) microwave multi-flash drying (*MWMFD*), ii) microwave vacuum drying (*MWVD*), iii) conductive multi-flash drying (*KMFD*), iv) freeze-drying (*FD*), and v) air-drying (*AD*). Micrographs of dried samples showed the compacted structure of *AD* samples and the spongy structure of *FD* samples. Otherwise, large pores and a highly porous structure were observed in samples dried by *KMFD*, *MWVD*, and *MWMV*. Porosity *MWMFD* samples were 2.6 times higher than those observed in *AD* pumpkins and slightly higher than the observed in *FD* samples. Puncture test results from *KMFD*, *MWVD* and *MWMFD* samples showed force oscillation that is typical of crispy products, which was not observed from *AD* and *FD* samples. Moreover, *KMFD*, *MWVD*, and *MWMFD* samples showed low color changes. Thus, microwave under vacuum and both multi-flash drying processes result in dried-and-crisp pumpkins, with high porosity and big pores. Therefore, these drying processes are suitable for the production of dried-and-crisp pumpkins.

1. Introduction

Pumpkin is one of the most cultivated vegetables in the world; this product presents high content of vitamins, carotenoids, fibers, and minerals (Seremet, Botez, Nistor, Andronoiu, & Mocanu, 2016; Yang, Zhao, & Lv, 2007). Moreover, pumpkin has received considerable attention in recent years, especially pumpkin seed oil, because it has positive effects on the strengthening of the immune system (Bardaa et al., 2016). Pumpkin seeds protect against many diseases, such as hypertension, carcinogenic diseases, and diabetes. Besides, these seeds have antibacterial, antioxidant and anti-inflammatory effects (Bardaa et al., 2016; Boaduo, Katerere, Eloff, & Naidoo, 2014; Hammar, Carson, & Riley, 1999; Jian, Du, Lee, & Binns, 2005; Nawirska-Olszańska, Kita, Biesiada, Sokół-Łętowska, & Kucharska, 2013; Procida, Stancher, Cateni, & Zacchigna, 2013; Rabrenovic, Dimic, Novakovic, Tesevic, & Basic, 2014; Zuhair, Abd El-Fattah, & El-Sayed, 2000). Pumpkin seed oil has high added value and has been produced in high scale in many countries, due to its high demand and low cost of the pumpkin fruit. A large amount of pumpkin pulp represents an interesting opportunity for the development of novel products to increase industrial profitability. Pumpkin pulp presents high moisture content (> 80 g/100 g) and needs a preservation technology for increasing its shelf life, such as drying, canning or freezing. In particular, pumpkin dehydration is an interesting alternative to reduce postharvest losses of this fruits. It is well known that the reduction of moisture and water activity of foods decreases microbial growth, enzymatic activity, and chemical reactions rates. Drying extend food shelf life, reduces transportation and storage costs due to reduced product weight and volume, and adds value to vegetables, developing a new product.

Different drying methods can be used to produce dehydrated fruits and vegetables, e.g., air-drying, vacuum drying, freeze-drying, microwave drying, among others. The selection of the most appropriate process depends mainly on the food to be dehydrated and the desired characteristics for the final product.

Freeze-drying is a suitable dehydration technique for sensible foods because it preserves the sensorial, nutritional and structural characteristics of foods (Ibarz & Barbosa-Canovas, 2003, pp. 604–613; Ratti, 2008). However, the high equipment costs, energy needs, and the long processing times associated to freeze-drying limits its use for product with high added value (Louka & Allaf, 2002).

The development of novel drying processes that result in dried products with desirable properties has been increasing in recent years

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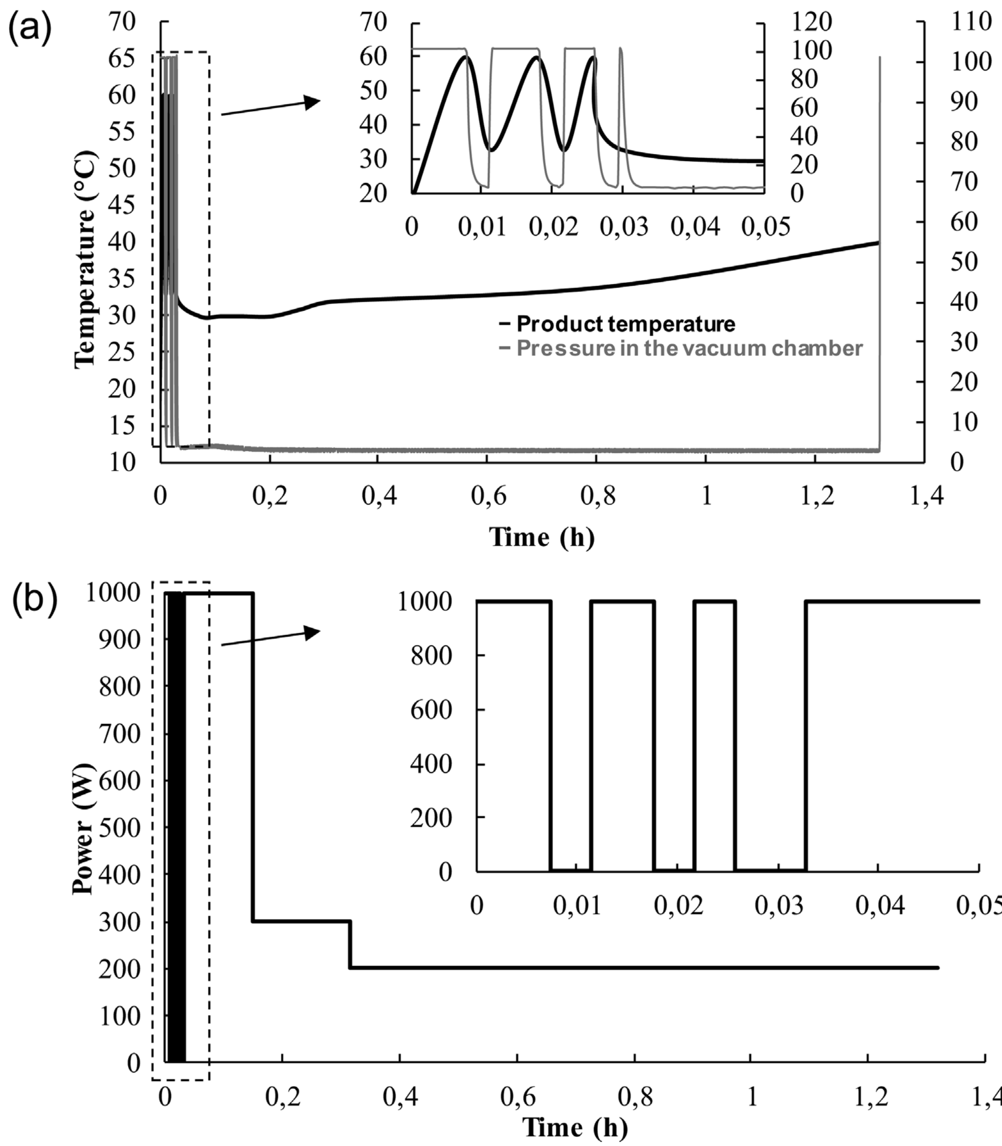

Fig. 1. a) Patterns of temperature (black) and pressure (grey) variation during *MWMFD*; b) Pattern of power variation during *MWMFD*. Magnifications were inserted for better visualization of the beginning of the drying process.

(Jangam, Law, & Mujumdar, 2010). A brief discussion of two of them are presented in the follow.

Microwave drying under vacuum has been considered a suitable process to produce crispy products with high nutritional and sensory quality. The costs of the equipments are affordable and the drying times are much shorter than the observed for freeze-drying (Drouzas & Schubert, 1996; Gunasekaran, 1999; Krokida & Maroulis, 1999; Lin, Durance, & Scaman, 1998; Mousa & Farid, 2002; Zhang, Tang, Mujumdar, & Wang, 2006).

A class of drying methods named multi-flash drying (*MFD*) has been reported as suitable for the production of dried-and-crisp fruits and vegetables (Link, Tribuzi, & Laurindo, 2017a, 2017b; Monteiro, Carciofi, & Laurindo, 2016; Porciuncula, Segura, & Laurindo, 2016; Zotarelli, Porciuncula, & Laurindo, 2012). The method is based on the application of successive vacuum-pulse cycles to a material inside a vacuum chamber. The product is heated at atmospheric pressure using heated plates, hot air, or microwaves until a desired temperature. Then, a sudden pressure reduction (vacuum pulse) is applied, resulting in rapid water evaporation (flash evaporation) and product cooling (adiabatic process, because the product provides the latent heat of vaporization), causing both dehydration and texturization.

Changes in the physical food properties (apparent density, porosity, texture, color) during drying are extremely important because they influence product quality and consumer opinion (Madiouli, Sghaier, Lecomte, & Sammouda, 2012).

The objective of this study was to assess the porosity, apparent density, texture, color, and microstructure of pumpkins dried by multi-flash drying processes, using microwaves (MWMFD) or heat conduction (KMFD) during the fruits heating step. The physical properties of the dried pumpkins are compared with the properties of pumpkin slices dried by hot air (AD), freeze-drying (FD) and microwave vacuum drying (MWVD).

2. Materials and methods

2.1. Pumpkins drying processes

Fresh pumpkins (Cucurbita moschata var. Menina Brasileira) samples were washed and peeled. Afterwards, their cylindrical part ("pumpkin neck") were cut into slices (half-moon shape with 5.9 ± 0.9 mm thickness, 30.0 ± 3.3 mm radius and 60.02 ± 5.0 mm diameter), blanched (97 °C ± 2 °C - 3 min), and cooled