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The influence of freeze drying conditions on microstructural changes of food products

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Abstract

The drying of food products can result in significant changes in the chemical composition, morphology and physical properties of foods and can lead to stabilized products with longer shelf-life and easier commercialization. Information on porous structure of foods is very important, characterizing the quality and texture of dehydrated food products. Therefore, structural properties, such as porosity, bulk density and true density of freeze-dried food products were investigated as affected by process conditions. Rice kernels were boiled for different time periods and agricultural products, including potato, mushroom and strawberry, were cut into cubes. The samples were frozen, tempered in liquid N_2 and freeze-dried, under various vacuum conditions, using a laboratory freeze-dryer. True density of the products was measured using a helium stereo-pycnometer. Bulk density was obtained by measuring the dimensions of the samples with a Vernier caliper. Simple mathematical models were developed in order to correlate the structural properties with process conditions. The microstructure of food products was also analyzed by Scanning Electron Microscopy and image analysis. Bulk density of freeze-dried materials increased with the applied pressure during freeze-drying, while porosity decreased. In addition, bulk density of freeze-dried rice kernels decreased with the increment of boiling time, while porosity increased. The changes in bulk density and porosity were closely supported by microstructural observations, according to SEM images. The microstructural changes of products, freeze-dried under various vacuum conditions, can be predicted using the proposed models and image analysis.

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Keywords: agricultural products; freeze drying; rice; SEM; structure

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1. Introduction

Dehydration operations are widely used for the preservation of foods, since the removal of water minimizes the microbial spoilage and prevents the physical and chemical reactions of the foods' compounds during storage [1, 2]. Dehydrated food products are easily obtained and maintain the characteristics of natural products [3]. Drying procedure comprises of simultaneous heat and mass transfer, which cause significant changes in the physical and chemical composition as well as in the structure of food products, depending on the transport mechanisms applied. Therefore, the microstructure and morphology of foods and as a result the quality of the final product, are related to the drying method and selected conditions applied [2].

Among the drying methods that are used in food processing industries, freeze-drying is considered one of the most advanced methods for drying high value products sensitive to heat, since it prevents undesirable shrinkage and produces materials with high porosity, unchanged nutrition quality, superior taste, aroma, flavor and color retention, as well as better rehydration properties [4], superior to those dried with conventional techniques.

Freeze-drying is used for the preservation of sensitive materials and the facilitation of transport and is carried out in two stages; the product is first frozen and then the ice is removed by sublimation directly from the solid to the vapor phase. During freeze-drying, ice sublimation causes significant changes in the shape and volume of the food products. Depending on the process conditions, the ice crystals which sublimate create pores or gaps with different characteristics, thus, it seems very interesting to investigate the effect of freeze-drying process conditions on the structural properties of food products [4].

Structural properties, like density and porosity, characterize the texture and quality of dehydrated products by controlling the taste and appearance. Besides the porosity of food products, pore size distribution plays a crucial role. Pore size distribution can be estimated by image analysis of two dimensional images [5]. Information on porous formation in foods during processing is needed for process design, influencing a wide variety of other properties, such as mechanical properties, thermal conductivity, thermal diffusivity and mass diffusion [2, 6].

The effect of drying conditions on structural properties of freeze-dried agricultural products has been studied by Krokida et al. (1998) [4]. Rahman et al. (2003) examined the variation of porosity of freeze-dried abalone depending on the changes of freeze-drying temperature. Karathanos et al. (1996) [7] investigated the structural collapse of agricultural plants during freeze-drying. Regier et al. (2007) [5] determined the pore size distribution of two dimensional images of bread and extruded snacks using image analysis.

The objective of the present research was to determine the effect of process conditions on the structural properties of freeze-dried food products. Freeze-drying was performed under controlled drying conditions, regulating pressure during drying. Simple mathematical models were developed according to the experimental data, in order to predict the values of porosity and bulk density correlated with process conditions**.** The microstructure of food products was also analyzed by Scanning Electron Microscopy and image analysis.

2. Materials & Methods

2.1. Freeze Drying

Parboiled rice and fresh agricultural products, including potato, mushroom and strawberry, were chosen as raw materials. The materials were stored at room temperature and dark conditions before the experimental procedure. Rice was boiled in excess de-ionized water at 100^{o}C for different time periods, ranging from 4 to 24 min. Agricultural products were cut into cubes of approximately 20 mm length, 20 mm width and a thickness of 10 mm. The materials were then frozen at -30^{o}C for 72 h, tempered for 1 h