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Application of SAFES (systematic approach to food engineering systems) methodology to apple candying

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Abstract

The application of a vacuum pulse for a specified time before long term osmotic dehydration has been proposed to obtain candied fruits at mild temperatures, thus maintaining the characteristic attributes of fresh fruits. Information about main changes involved in apple candying by long term pulsed vacuum osmotic dehydration is missed by applying traditional methods of modelling foods and processes.

A new systematic approach to food engineering systems (SAFES) methodology has been recently developed and applied to predict quality and safety attributes from compositional and volumetric changes taking part throughout food processing. Identification and quantification of main components, phases and aggregation states at different stages of changes in which the process can be divided into would be required. Apart from experimental data and data found in references, several hypotheses related to water and soluble solids flow were also formulated for this purpose.

The application of SAFES methodology to the apple candying process highlights the usefulness of this tool in making evident that different mechanisms are involved in the process in a coupled way. Indeed, not only osmotic, but also pseudo-difusional and hydrodynamic mechanisms were responsible for compositional and volumetric changes occurring during apple candying to a different extend, depending on the concrete stage of the process. As a result, it should be necessary to analyse the process in different steps in order to avoid a confused knowledge of it.

Keywords: Candying; Vacuum impregnation; Osmotic dehydration; SAFES

1. Introduction

In the last years, the osmotic process has received considerable attention due to its potential application in the food processing industry for the partial dehydration of food materials, especially fruits and vegetables. It has been commonly employed either as an independent process or as a pre-drying treatment, to reduce energy consumption and improve food quality. In particular, a new jam manufacturing process using osmotically dried fruits at low temperature and short time has been reported to preserve most of the original flavour, aroma, nutrients and natural colour (Shi et al., 1996). The application of vacuum osmotic dehydration (Shi & Fito, 1993; Shi & Fito, 1994) or the application of a vacuum pulse for a specified time before long term osmotic dehydration (Barat, Fito, & Chiralt, 2001; Barat, Talens, Barrera, Chiralt, & Fito, 2002; Shi, Fito, & Chiralt, 1995) have also been proposed to obtain candied fruits at mild temperatures, thus maintaining the characteristic attributes of fresh fruits. On the other hand, many authors have claimed that the quality (colour, flavour and texture) of aired or freeze-dried fruits and vegetables was improved by a prior osmotic dehydration step (Abbas, Moreira, & Xidieh, 2003; Fernandes, Rodrigues, Gaspareto, & Oliveira, 2006; Krokida, Karathanos, & Maroulis, 2000; Piotrowsky, Lenart, & Wardzynsky, 2004; Prothon et al., 2001; Talens, Martínez-Navarrete, Fito, & Chiralt, 2001;

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Torringa, Esveld, Scheewe, van der Berg, & Bartels, 2001). Therefore, research on process variables and their effect on mass transfer rate during osmotic dehydration has been widely performed (Barat, Chiralt, & Fito, 2001; Castro et al., 1997; Cháfer, González-Martınez, Ortolá, Chiralt, & Fito, 2001; Chaudhari, Kumbhar, Singh, & Narain, 1993; Escriche, Garcıa-Pinchi, Andrés, & Fito, 2000; Giraldo, Talens, Fito, & Chiralt, 2003; Gekas, González, Sereno, Chiralt, & Fito, 1998).

2. Materials and methods

2.1. The "fuzzy" approach to model foods and processes

Traditional methods for describing and quantifying changes taking part throughout apple candying by pulsed vacuum osmotic dehydration considered the food as composed of two different phases (the solid matrix, consisting of all insoluble compounds, and the liquid phase, consisting of water and soluble solutes) and the process as integrated by two basic unit operations (vacuum impregnation and osmotic dehydration), according to the main macroscopic change caused in the product or the main equipment involved (Fig. 1).

Vacuum impregnation (VI) of a porous product consists of exchanging the internal gas or liquid occluded in open pores for an external liquid phase by the action of hydrodynamic mechanisms promoted by pressure changes (Fito, 1994; Fito & Chiralt, 2001; Fito & Pastor, 1994; Fito, Andrés, Chiralt, & Pardo, 1996). The operation is carried out in two steps. In the first step, vacuum pressure promotes the expansion and outflow of the product internal gas, taking the product pore native liquid with it. In the second step, atmospheric pressure restoration leads to the compression of the remaining gas and the in flow of the external liquid in the porous structure. The response of several plant tissues to vacuum impregnation has been widely studied (Chiralt et al., 1999; Salvatori, Andrés, Chiralt, & Fito, 1998; Sousa, Salvatori, Andrés, & Fito, 1998).

During the osmotic dehydration (OD), the chemical potential gradients existing across the product-medium interface promote water and, almost negligibly, product solutes to flow from the product into the osmotic medium, while the osmotic solute is transferred from the medium into the product. Mechanisms working during OD can be classified into two groups (Fito & Chiralt, 1996): those depending on water activity gradients (pseudo-diffusionals) and those depending on pressure gradients (hydrodynamics). OD experiments of apple isolated protoplasts (Seguí, Fito, Albors, & Fito, 2005a, 2005b) corroborated that trans-membrane water flux causes simultaneous cell shrinkage and three-dimensional structure deformations, thus implying some mechanical energy accumulation at the elastic elements of the structure being deformed (Aguilera, 2003; Chiralt & Fito, 2003; Fito & Chiralt, 2003).

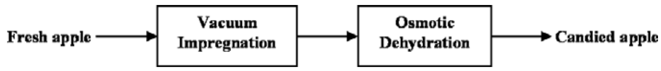

Fig. 1. Process diagram of the apple candying process, according to traditional methods used to describe foods and processes.

Equilibration studies on osmotic dehydration (OD) and pulsed vacuum osmotic dehydration (PVOD) of apple cylinders in water–sucrose solutions (0–65% w/w) at 30, 40 and 50 °C showed evidence that true thermodynamic equilibrium was achieved after passing through several pseudo-equilibrium steps (Barat, Chiralt, & Fito, 1998). At short times, OD samples suffered a strong loss of weight and volume, mainly due to relatively fast water removal and subsequent shrinkage promoted by activity gradient dependent mechanisms. On the other hand, PVOD samples increased their mass during the vacuum impregnation step, but followed the pattern of OD samples thereafter. When minimum weight and volume were reached, the food liquid phase and the osmotic solution were reported to have the same concentration and the same water activity. At this stage, intercellular spaces in OD samples were reported to be large in comparison to cell size, while both extra and intracellular volume in PVOD samples appeared to be filled with an aqueous solution. After compositional equilibrium, stress remaining in the system relaxed with simultaneous suction of external solution. As a result, pressure gradient dependent mechanisms stimulated an increase in total mass and volume, without any compositional change, until true thermodynamic equilibrium was achieved. In such state, no changes either in sample composition or weight occurred, differences in both activity and pressure disappeared and the solid cellular matrix became fully relaxed. The lesser initial decrease of mass and volume and slightly lower weight and volume recovery rates observed in PVOD samples were associated to structural changes created by the gas expansion and the massive penetration of the external osmotic solution during the vacuum pulse.

2.2. The SAFES methodology

Due to the "fuzzy" knowledge of the fruit candying process provided by traditional methodology, a new systematic approach to food engineering systems (SAFES) methodology has been recently developed in order to model complex structured food systems through the chemical, physical, biological and structural information of the product (Fito, LeMaguer, Betoret, & Fito, in press). In this way, the SAFES methodology is a useful tool that allows forecasting quality and safety attributes from food compositional and volumetric changes throughout the process.

The first step in the application of the SAFES methodology is the identification of different components, phases and aggregation states, according to their relevance in food properties. Then, the process is divided into several stages of changes, according to main changes expected in any component, phase or aggregation state. This new term