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Developments in osmotic dehydration technique for the preservation of fruits and vegetables

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ABSTRACT

In recent years much attention has been focused on maintaining the freshness of fruits and vegetables by immersion of cellular materials containing water in an osmotic solution. It results in the development of intermediate moisture products having lower water activity, which is imparted by solute gain and water loss. During the process, chemical, physical and biological activities, which deteriorate the foods, are lowered considerably; hence extends the shelf life of food products. In this process moisture is withdrawn from the product at ambient temperature by diffusion, so phase change has been avoided. Besides, it helps to improve the nutritional and sensory attributes of food products and is less energy intensive process as compared to other drying techniques. Osmotic dehydration is influenced by various factors such as osmotic agent, time and temperature, solute concentration, solution to sample ratio, agitation and geometry of the materials. Recently, osmotic dehydration has been combined with several other methods namely, pulsed high electric field, high hydrostatic pressure, ultrasound, centrifugal force, vacuum and gamma irradiation. These techniques have been employed during or after osmotic treatment to enhance osmotic dehydration performance by increasing the cell membrane permeability and mass transfer rate. These combined operations reduce the drying time, minimizing further energy costs. In this study, various segments of osmotic dehydration techniques and its application in food processing as well as recent advances in osmotic dehydration have been reviewed.

Industrial relevance: The osmotic dehydration technique is gaining popularity as a mean of obtaining minimally processed food. This review paper deals with the kinetics and mechanisms of osmotic dehydration technique for the preservation of fruits and vegetables. The various factors effecting osmotic mass transfer rate in food have been reviewed. In this paper, the combined effect of osmotic dehydration and several other innovative techniques (pulsed high electric field, high hydrostatic pressure, ultrasound, centrifugal force, vacuum and gamma irradiation) on the quality and shelf life of fruits and vegetables have been reviewed. These techniques have been employed during or after osmotic treatment to enhance osmotic dehydration performance by increasing the cell membrane permeability. These combined operations reduce the drying time, minimizing further energy costs as well as improving the quality of fruits and vegetables during storage.

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1. Introduction

Dehydration is one of the means of ensuring long lasting durability of food (fish, vegetables, fruits and meat) and is the earliest form of preservation method known to man (Nastaj & Witkiewicz, 2004). In recent year, the development of intermediate moisture food by the use of osmotic dehydration has received much appraisal among consumers due to minimal processing (Raoult-Wack, 1994; Silva, Silva, & Lins, 2014; Sutar, Raghavan, Gariepy, Prasad, & Trivedi, 2012). Osmotic dehydration is a pretreatment process, which depends upon the phenomenon of diffusion of moisture from food materials by immersing in a hypertonic solution (Shi & Xue, 2009; Tortoe, 2010). Various types of osmotic agents such as glucose, corn syrup, sodium chloride, starch concentrates, fructose and sucrose are used according to the final product. Osmotic dehydration is usually followed by other drying methods such as air drying, deep fat frying, freeze drying, etc. to produce better quality final product (Khan, 2012; Phisut, 2012; Tortoe, 2010).

Osmotic dehydration is a process of counter-current transfer of mass, in which the solute flows into the food, while moisture is eluted from the interior of the food to the hypertonic solution. However, due to the semi-permeability of the cell membrane, the solutes i.e. organic acids, minerals, fragrances and colorants move into the hypertonic solution from the food materials. This transfer is negligible quantitatively but essential in terms of composition of the product (Phisut, 2012; Tortoe, 2010). Generally, it is a slow process which depends mostly on cell membrane permeability and cell architecture (Amami, Fersi, Khezami, Vorobiev and Kechaou, 2007). The osmotic pressure difference between the food material and the hypertonic solution, provides the necessary driving force for the removal of water from the food to the osmo-active solution. The cellular structure of the biological material is complex enough to cause hindrance in the diffusion of water (Fernandes, Gallão, & Rodrigues, 2009). Moisture is removed mainly by capillary flow and diffusion, whereas leaching and solute uptake take place only by diffusion (Rahman, 2007; Shi & Xue, 2009). All these exchange of masses between the food stuff and the hypertonic solution may have an effect on the overall quality and yield of the dehydrated products (Shi, 2008). The semi-permeable nature of plant tissues and the lower molecular size of water molecules allow water movement from the food and solute gain from hypertonic solution. This results in the reduction of moisture content up to 50% weight of fresh fruits and vegetables with the passage of time until equilibrium condition is reached (Yetenayet & Hosahalli, 2010).

2. Mechanism of osmotic dehydration

When food materials are soaked in a highly concentrated osmotic solution, multi-component transfer process resulted, in which solution flows concurrently with a combination of drying, leaching and impregnation processes in the matrix of biological tissues. The moisture loss from the product takes place at a faster rate in the first few hours, and then the rate decreases slowly in succeeding hours (6 h) and at last flattens out. However, the diffusion of the solute into the material is not significant at the initial stage of osmotic treatment. But as the dewatering rate decreases, the solute rate increases into the food material (Phisut, 2012; Raoult-Wack, 1994). Generally, the diffusion of liquid takes place in non-porous solids, while capillary movement takes place in porous solids. In porous food materials; gas filled cavities, capillaries and cell walls, as well as intracellular and extracellular spaces provide the pathways for the transfer of masses (Shi & Xue, 2009). The mass transfer phenomenon in a food material is shown in Fig. 1.

The modeling of mass transfer phenomena in osmotic dehydration is mainly based on the simplified semi-empirical models (Yao & Le Maguer, 1996). The cell mainly entailed in osmotic dehydration is the parenchymatous cells, which comprises three parts: extracellular volume, intercellular volume and a cell membrane in between these. The extracellular volume includes cell wall and free spaces in between respective cells. The intercellular volume contains vacuole and cytoplasm. The chemical potential difference across a semi-permeable membrane between the cellular material and osmotic solution is the driving force for mass flow, which is related to temperature and water activity. The osmotic dehydration phenomena precede until the water activity of both the solution and the sample attain the equilibrium state. However, lower osmotic pressure of the surroundings than that of a cell results in migration of water into the cells. The cells start swelling up to a limited extent due to the rigid structure of the cell wall. The solute flows into the extracellular volume and it might or might not penetrate the cell membrane and diffuses into the intracellular volume depending on the geometry of the solutes. As the solutes penetrate the tissue, a potential difference is developed across the cell membrane; hence water flows into the extracellular volume. A cell submerged in a hypertonic solution will lose water. Dehydration of protoplasm resulted in cell shrinkage, consequently, detaches plasmalemma from the cell wall. This process is called plasmolysis. Due to the permeability of the cell wall, the volume between the plasmalemma and cell wall gets filled with the osmotic solution (Lewicki & Lenart, 2006). These spaces are large enough for the transport of water, ions and tiny molecules to pass through them. A continuous matrix capable of diffusing water