SİDAS MEDYA
Akademik Gıda® / Academic Food Journal
ISSN Print: 1304-7582
http://www.academicfoodjournal.com

Akademik Gıda 8(6) (2010) 24-28

Review Paper / Derleme Makale

Recent Developments in Osmotic Dehydration

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ABSTRACT

Osmotic dehydration is an operation used for partial removal of water from foods such as fruits and vegetables. In this process, foods are placed in hypertonic (osmotic) solution. Three different mass transfer mechanisms occur in the osmotic dehydration; (i) water migration from food to the solution, (ii) solute migration from solution to food, and (iii) solute concerning product extracted to solution. Osmotically dehydrated fruits and vegetables are generally dried by hot air flow. In recent years, osmotic dehydration has been combined with various methods such as the high hydrostatic pressure, high electrical field pulses, gamma irradiation, ultrasound, vacuum and centrifugal force. These new combination methods increase mass transfer and drying rate and foods by increasing the cell membrane permeability. The operation time in the combined methods is shorter than that in traditional osmotic dehydration, causing further energy saving. In this study, recent advances in osmotic dehydration will be reviewed.

Key Words: Osmotic dehydration, Hipertonik, Fruits and vegetables, Drying

Ozmotik Kurutmada Son Gelişmeler

ÖZET

Ozmotik kurutma, meyve ve sebzeler gibi gıdalardan suyun kısmi olarak uzaklaştırılması amacıyla kullanılan bir işlemdir. Bu işlemde, ürünler hipertonik (ozmotik) bir çözelti içine konur. Ozmotik kurutmada üç farklı kütle aktarım mekanizması gerçekleşmektedir; (i) gıdadan çözeltiye su geçişi, (ii) çözeltiden gıdaya çözünen madde geçişi ve (iii) üründeki çözünen maddelerin çözeltiye özütlenmesi. Ozmotik olarak kurutulmuş meyve ve sebzeler genellikle sıcak hava akımında kurutulurlar. Son yıllarda, ozmotik kurutma yüksek hidrostatik basınç, vurgulu elektrik alan, ışınlama, ultrason, vakum ve santrifüj kuvvet uygulamaları gibi farklı yöntemlerle kombine edilmektedir. Bu yeni yöntemler hücre zarı geçirgenliğini artırarak kütle transferi ve kurutma hızını arttırmaktadır. Kombine yöntemlerde ozmotik kurutma süresinin geleneksel ozmotik kurutma işlemine göre daha kısa olması nedeniyle enerji tasarrufu sağlanmaktadır. Bu çalışmada ozmotik kurutmadaki son gelişmeler özetlenecektir.

Anahtar Kelimeler: Ozmotik dehidrasyon, Hypertonic, Meyve ve sebzeler, Kurutma

INTRODUCTION

Fruits and vegetables are perishable due to their high moisture content. Drying, a process of moisture removal caused by simultaneous heat and mass transfer, is one of the processes used for preservation. Drying also results in reduced transportation and storage costs [1]. The basic objective of drying is to remove water from food tissue up to a certain amount so that microbial spoilage and deteriorating chemical reactions are greatly minimized [2]. Many fruit and vegetables can be dried. One of the most important aspects of industrial drying is to predict the drying behavior to increase the efficiency of the process. The rate of drying, storage stability, rehydration characteristics, and quality changes depend on the type of the drier, processing parameters, and also pretreatment of the dried material [1].

In general, the drying is energy consuming. Thus, in order to reduce the energy consumption per unit of product moisture, it is necessary to improve the energy efficiency and reduce the processing time. Moreover, the product quality depending notably on its texture, color, and flavor are often deteriorated by thermal drying [3].

Osmotic dehydration (OD) has received considerable attention in recent years as a pre-drying treatment in order to reduce energy consumption, improve food quality, and speed up the drying time [3]. Osmotic dehydration naturally occurs in foods, such as fruits and vegetables, placed in a hypertonic sugar or salt solution presenting a high osmotic pressure and a low water activity [1]. In this present study, recent developments in osmotic dehydration technique were reviewed.

OSMOTIC DEHYDRATION

The osmotic dehydration (OD) is a process that partially removes water from food material by means of food immersion in a hypertonic solution (i.e. sugar and salt). It is a counter-current mass transfer process, in which water is drained from the interior of the food to the hypertonic solution and the solute flows into the food. Generally, OD is a slow process depending on the permeability of cell membranes and cell architecture [4].

Osmotic dehydration is a common pre-treatment used before air-drying. The technique consists of immersing the fruit in a hypertonic solution to remove part of the water from the fruit. The driving force for water removal is the difference in osmotic pressure between the fruit and the hypertonic solution. The complex cellular structure of the fruit acts as a semi-permeable membrane creating an extra resistance for diffusion of water within the fruit [5].

The osmotic dehydration process has often been used for the development of new products of fruit and vegetable because it positively affects the sensorial and nutritional properties of the fresh product [6]. It generally precedes processes such as freezing, freeze drying, vacuum drying or air drying. It also increases the sugar to acid ratio and improves the texture and stability of pigments during dehydration and storage. It is effective even at ambient temperatures, so heat damage to texture, color and flavor can be minimized [7].

DEVELOPMENTS IN OSMOTIC DEHYDRATION

The osmotic dehydration is not rapid enough and should be improved with the further permeabilization of cell membranes and by reducing the water activity of foods so that microbial growth can effectively be inhibited. The damage of membranes can be achieved by blanching or nonthermal pretreatments, such as the application of high pressure, ultra-sound or a pulsed electric field and also can be achieved applying gamma-irradiation, vacuum or centrifugal force during osmotic dehydration [8, 7].

Application of High Hydrostatic Pressure

The pretreatment application of high hydrostatic pressure (HHP) changes the cell wall structure and makes the cells more permeable [7], it also results in cells disintegration [9]. The cell disintegration index (Zp, as measured by an electro-physical measurement based on electrical impedance analysis) after high pressure treatment increases with time. It is well known that application of high pressures (100–800 MPa) causes permeabilization of the cell structure [9].

HPP was reported to enhance drying rate during osmotic dehydration by making the cells more permeable thereby increasing the rate of mass transfer. Compression and decompression taking place during the high pressure pre-treatment itself cause the removal of a significant amount of water in the case of pineapple and this is attributed to cell wall breakage [10].

In a study by Rastogi and Niranjan [10], HHP pretreatment (100–700 MPa for 5 min) was applied to enhance mass transfer rates during osmotic dehydration of pineapples at 40˚C and 50˚Brix. The diffusivity increased with treatment pressures up to 400 MPa above which it was remained almost unchanged. Osmotic dehydration of HHP-treated (200 and 400 MPa for 10 min at 25˚C) potato samples was also shown to be faster than that of the untreated ones due to the combined effects of osmotic stress and high-pressure-induced cell permeabilization [1].

In another study, pineapples were subjected to a given pressure in the range 100 - 700 MPa for 5 min. The maximum temperature experienced by the sample during pressurization was 35˚C, cooling to about 15˚C during decompression. In osmotic solution, the temperature and concentration were maintained at 40˚C and 50˚Brix. Then, the samples were then weighed and dried in a vacuum oven at 60˚C for 18 h. Consequently the pre-treated samples have been reported to be faster than untreated ones and the diffusivity increased with treatment pressures up to 400 MPa above which it did not significantly vary [10].

Application of High Electric Field Pulse Pre-Treatment

Application of pulsed electric field (PEF) is one of the several emerging nonthermal methods. The application of sufficiently high electric fields results in pore formation and breakage of cell membranes. Electrical breakage may involve various mechanisms: critical transmembrane potential, viscoelastic properties, structural defects in the cell membrane, compression of the membrane, etc., and this dielectric breakdown within a biological structure makes the cell membrane become more permeable to electrical current and to solutes [11].

PEF is the application of high- intensity pulsed electric fields. PEF provides fresh-like minimally processed products with a bit loss of color, flavor and nutrients and show of short bursts of voltage to a food material placed between two electrodes. The treatment occurs at ambient or controlled temperatures for microseconds, thereby minimizing energy losses caused by heating. When PEF applied to a food, it undergoes dielectric breakdown causing disruption of the cell membrane, which improves solute transportation across the membrane during further processing [12]. It has also been reported that high PEF reduces the activity of some enzymes [13, 14]. High intensity electrical field pulse (0.22–1.60 kV/cm) pre-treatment was shown for the first time to accelerate osmotic dehydration [7]. Ade-Omowaye et al. [15] indicated that combined PEF and partial osmotic dehydration in a solution of sucrose and sodium chloride before air drying might offer a good potential in satisfactorily enhancing mass transfer rates and preserving color quality of red peppers.

Tedjo et al. [16] suggested that the application of PEF resulted in increased cell membrane permeabilization of apple slices which facilitated better water loss during OD with limited sugar uptake resulting in minimal alteration in product taste. In this study, solute transfer was not mainly dependent on extent of cell membrane permeabilization. Field strength of 1.0 kV/cm appeared to be adequate for optimal water loss and solute gain. The increased water removal due to PEF pretreatment prior to OD, yields a product needing shorter drying times than the original fruit. Effect of increasing pulse number was not very evident on most of the parameters studied. Vitamin C content and the deformative force of dried samples were influenced by both field strength and immersion time. The data presented provide useful information on osmotic pretreatment kinetics necessary for the design of the osmotic process while ascertaining the acceptability of the final product.

Amami and Vorobiev [8] showed that, PEF enhanced mass transfer during the OD of apple tissue. Water loss and solids gain increased with an increase of the electric field strength and pulse number up to an optimum level, represented by 750 pulses at 0.90 kV=cm and pulse duration of 100 ms. Optimum pretreatment consumed energy at a rate of 13.50 kJ=kg. Evaluation of solute concentration (˚ Brix) and weight of the sample in the continuous mode can be adapted for the study of OD.

Application of Ultrasound during Osmotic Dehydration

Power ultrasound is a novel technique in the food industry and its use is increasing as new areas of use emerge. Ultrasonic waves can cause a rapid series of alternative compressions and expansions, in a similar way to a sponge when it is squeezed and released repeatedly (sponge effect). The forces involved by this mechanical mechanism can be higher than surface tension which maintains the moisture inside the capillaries of the fruit creating microscopic channels which may ease moisture removal. In addition, ultrasound produces cavitations which may be helpful to remove strongly attached moisture. Pores on the surface of fruits are becoming deformed by ultrasonic waves and thus there has formed microscopic channels that reduce the diffusion boundary layer and increase the convective mass transfer in the fruit [17]. Pressure and frequency are the two main factors needing further consideration. No increase in diffusion rates was reported when intensity was maximal due to violent cavitations that produced extreme turbulence or vapor locks at the interface [7].
Continuous high frequency ultrasound (CHFU) can be used to enhance mass transfer during osmo-concentration. At high concentrations of sugar, ultrasound accelerates the rate of water removal out of the tissue and may result in significantly shorter times of osmo-concentration. Ultrasound can cause fast and complete degassing, initiate various reactions by generating free chemical ions (radicals), enhance polymerization/depolymerization reactions, improve diffusion rates and many other effects [18].

The ultrasonic pre-treatment involves the immersion of the fruit in water or in a hypertonic aqueous solution to which ultrasound is applied. The advantages of using ultrasound are that the process can be carried out at ambient temperature and no heating is required reducing the probability of food degradation [19].

Simal et al. [20] reported the applicability of sonication to osmotic dehydration of porous fruit such as apple cubes and showed that the rates of mass transfer increased when ultrasound was applied and showed that water losses and solute gain rates were faster when ultrasound was used to carry out the osmotic dehydration. The most important differences were found in solute gain.

Application of Gamma-Irradiation in Osmotic Dehydration

Gamma irradiation is used to inhibit the sprouting of the vegetable, extension of shelf-life of fresh produce, control of pathogenic organisms, insect disinfestations, microbial inactivation, and sterilization of foods. Gamma irradiation pretreatment has been damaged the interior tissue structure, thus increasing the permeability of plant cells which results in improved mass transfer during air drying [21]. The effect of gamma irradiation on drying characteristic and quality (appearance, vitamin C content, and rehydration ratio) of the dehydrated apple and potato was studied by Wang and Chao [22, 23]. The interior tissue structure of agricultural products are changed and injured by γ-irradiation to some extent. These kinds of changes in structure resulted in increased permeability of plant cells leading to improved mass transfer during air drying [21].

Rastogi et al. [7] studied combined effects of gamma-irradiation and osmotic treatment. On carrots, they reported that during rehydration of gamma irradiated and osmotically treated (0˚Brix) dried samples, the diffusivity values for water infusion was higher and solute diffusion was lower as compared to control samples. The irradiated samples treated above 10˚Brix could not absorb as much water and loss of solute was also higher as compared to the control due to breaking of cell wall (as indicated by microstructure), because of combined effects of gamma irradiation and osmotic treatment [7]. Doses of gamma-irradiation applied in the range of 3.0–12.0 kGy resulted in a decrease in hardness of potato, thereby resulting in an increase in effective water as well as solute diffusion coefficients, which was attributed to an increase in cell wall permeability facilitating the transport of water and solute [21].

Application of Vacuum during Osmotic Dehydration

The osmotic process can be performed at atmospheric pressure (OD) or by vacuum pulse application (PVOD) for a small period at the beginning of the process. When the hydrodynamics mechanism takes place, the water loss and solid gain are higher in the beginning of the PVOD process, than in the OD process [24, 25].

When vacuum impregnation is applied at the beginning of osmotic dehydration, the operation is referred to as pulsed vacuum osmotic dehydration and it consists of the replacement of the gas phase of the product with osmotic solution by the action of hydrodynamic mechanisms [26]. Mass transfer during osmotic dehydration under vacuum has been reported to be quicker than that under ambient pressure [27].

The osmotic dehydration process and vacuum pulse combination is consisting of submerging the food into an osmotic solution and sub-atmospheric pressure is applying at a short interval followed by a large osmotic dehydration period at atmospheric pressure. This leads to the introduction of osmotic liquid into the pores of the food through the hydrodynamic mechanism [28], increasing the area of mass transfer in the food and producing a greater solid-liquid exchange [27]. Respiration rate of fresh-cut and vacuum impregnated samples of strawberries increases with temperature showing sigmoid behavior; a sharp increase in respiration rate occurs between 5 and 10˚C [29].

Application of Centrifugal Force during Osmotic Dehydration

The application of centrifugal force during osmotic dehydration increased the water loss but at the same time it decreased the solids gain. Therefore, the WL/SG ratio is increased in a centrifugal OD [2]. The effect of centrifugal force during osmotic dehydration was studied in a study. They reported the increase of water loss and lower solids uptake (decreasing of solids gain) in the centrifugal conditions compared to the static conditions. It was observed that centrifugation enhanced mass transfer (water loss) by 15% while considerably retarding the solid uptake (by about 80%) [7].

CONCLUSIONS

Osmotic dehydration is one of the most suitable energy-saving methods for the partial removal of water from foods. Application of some pretreatment methods such as high pressure, pulsed electric field, ultra-sound, gamma-irradiation, vacuum or centrifugal force with osmotic dehydration increase mass transfer, drying rate of foods by making the cell membranes more permeable. Moreover, these combined methods reduce the operation time significant, as compared to traditional osmotic dehydration.

REFERENCES

[1] Yucel, U., Alpas, H., Bayindirli, A., 2010. Evaluation of high pressure pretreatment for enhancing the drying rates of carrot, apple, and green bean. *Journal of Food Engineering* 98: 266-272.

[2] Amami, E., Fersi, A., Vorobiev, E., Kechaou, N., 2007. Osmotic dehydration of carrot tissue enhanced by pulsed electric field, salt and centrifugal force. *Journal of Food Engineering* 83: 605-613.

[3] Amami, E., Khezami, L., Vorobiev, E., Kechaou, N., 2008. Effect of pulsed electric field and osmotic dehydration pretreatment on the convective drying of carrot tissue. *Drying Technology* 26: 231-238.

[4] Amami, E., Fersi, A., Khezami, L., Vorobiev, E., Kechaou, N., 2007. Centrifugal osmotic dehydration and rehydration of carrot tissue pre-treated by pulsed electric field. *LWT* 40: 1156-1166.

[5] Fernandes, F.A.N., Gallão, M. I., Rodrigues, S., 2009. Effect of osmosis and ultrasound on pineapple cell tissue structure during dehydration. *Journal of Food Engineering* 90: 186-190.

[6] Corrêa, J.L.G., Pereira, L.M., Vieira, G.S., Hubinger, M.D., 2010. Mass transfer kinetics of pulsed vacuum osmotic dehydration of guavas. *Journal of Food Engineering* 96: 498-504.

[7] Rastogi, N.K., Raghavarao, K.S.M.S., Niranjan, K., 2005. Developments in Osmotic Dehydration. In: *Emerging Technologies for Food Processing*, Edited by D.W. Sun, Elsevier- Academic Press, Italy.

[8] Amami, E., Vorobiev, E., Kechaou, N., 2005. Effect of pulsed electric field on the osmotic dehydration and mass transfer kinetics of apple tissue. *Drying Technology* 23(3): 581-595.

[9] Knorr, D., Rastogi, N.K., Angersbach, A., 2000. Synergistic effect of high hydrostatic pressure pretreatment and osmotic stress on mass transfer during osmotic dehydration. *Journal of Food Engineering* 45: 25-31.

[10] Rastogi, N.K., Niranjan, K., 1998. Enhanced mass transfer during osmotic dehydration of high pressure treated pineapple. *Journal of Food Science* 63(3): 508-511.

[11] Taiwo, K.A., Angersbach, A., Knorr, D., 2003. Effects of pulsed electric field on quality factors and mass transfer during osmotic dehydration of apples. *Journal* of *Food Process Engineering* 26: 31-48.

[12] Ngadi, M.O., Gachovska, T.K., Simpson, M.V., Raghavan, G.S.V., 2009. Pulsed electric field treatment of carrots before drying and rehydration *Journal of the Science of Food and Agriculture* 89: 2372-2376.

[13] Ho, S.Y., Mittal, G.S. and Cross, J.D., 1997. Effects of high field electric pulses on the activity of selected enzymes. *Journal of Food Engineering* 31: 69-84.

[14] Barbosa-Cánovas, G.V., Martín, O., Elez-Martínez, P., 2003. Food enzymes as affected by high

intensity pulsed electric fields. IFT Annual Meeting, Paper 23-4, Chicago.

[15] Ade-Omowaye, B.I.O., Rastogi, N.K., Angersbach, A., Knorr, D., 2003. Combined effects of pulsed electric field pre-treatment and partial osmotic dehydration on air drying behaviour of red bell pepper. *Journal of Food Engineering* 60: 89-98.

[16] Tedjo, W., Taiwo, K.A., Eshtiaghi, N.M., Knorr, D., 2002. Comparison of pretreatment methods on water and solid diffusion kinetics of osmotically dehydrated mangos. *Journal of Food Engineering* 53: 133-142.

[17] Fernandes, F.A.N., Gallão, M. I., Rodrigues, S., 2008. Effect of osmotic dehydration and ultrasound pre-treatment on cell structure: Melon dehydration. *LWT* 41: 604-610.

[18] Silva, J.L., Stojanovic,J., 2007. Influence of osmotic concentration, continuous high frequency ultrasound and dehydration on antioxidants, colour and chemical properties of rabbiteye blueberries. *Food Chemistry* 101: 898-906.

[19] Fernandes, F.A.N., Rodrigues, S., 2007. Ultrasound as pre-treatment for drying of fruits: Dehydration of banana. *Journal of Food Engineering* 82: 261–267.

[20] Simal, S., Benedito, J., Sánchez, E.S., Rosello, C., 1998. Use of ultrasound to increase mass transport rate during osmotic dehydration. Journal of Food Engineering 36: 323-336.

[21] Rastogi, N.K., Suguna, K., Nayak, C.A., Raghavarao, K.S.M.S., 2006. Combined effect of γ-irradiation and osmotic pretreatment on mass transfer during dehydration. Journal of Food Engineering 77: 1059-1063.

[22] Wang, J., Chao, Y., 2003. Effect of 60CO irradiation on drying characteristics of apple. Journal of Food Engineering 56: 347-351

[23] Wang, J., Chao, Y., 2003b. Effect of gamma irradiation quality of dried potato. *Radiat. Phys. Chem*. 66: 293–297.

[24] Chafer, M., Gonzalez-Martinez, C., Fernandez, B., Perez, L., Chiralt, A., 2003. Effect of blanching and vacuum pulse application on osmotic dehydration of pear. *Food Science and Technology International* 9: 321-328.

[25] Giraldo, G., Talens, P., Fito, P., Chiralt, A., 2003. Influence of sucrose solution concentration on kinetics and yield during osmotic dehydration of mango. *Journal of Food Engineering* 58: 33-43.

[26] González-Martínez, C., Chiralt, A., Atarés,L., 2008. Effect of solute on osmotic dehydration and rehydration of vacuum impregnated apple cylinders (cv. Granny Smith). *Journal of Food Engineering* 89: 49–56.

[27] Corzo, O., Bracho, N., Rodríguez, J., Gonzάlez, M., 2007. Predicting the moisture and salt contents of sardine sheets during vacuum pulse osmotic dehydration. *Journal of Food Engineering* 80: 781-790.

[28] Fito, P., Chiralt, A., 1997. An approach to the modeling of solid food–liquid operations: Application to osmotic dehydration. In: *Food Engineering* 2000, Edited by P. Fito, E. Ortega, & G. V. Barbosa-Canovas, Chapman & Hall, New Cork, pp. 231–252.

[29] Chiralt, A., Fito, P.J., Castello, M.L., 2006. Effect of osmotic dehydration and vacuum impregnation on respiration rate of cut strawberries. *LWT* 39: 1171-1179.