Chemical Science Review and Letters ISSN 2278-6783

Review Article

Food Preservation by Osmotic Dehydration-A Review

Nadia Bashir*, Monika Sood and Julie D. Bandral

Division of Food Science & Technology, Sher-e-Kashmir University of Agricultural Science and Technology Jammu,
Chatha-180009, India

Abstract

Osmotic dehydration is employed for shelf life extension of fruits and vegetables that are highly susceptible to spoilage because of their higher water content. Osmotic dehydration involves partial removal of water from food surfaces immersed in hypertonic solution facilitated by osmosis. This partial removal of water lowers the water activity of fruits and vegetables thereby enhancing their shelf life. Osmotic dehydration is often used as pre-treatment prior to other drying methods. Osmotic dehydration retains original characteristics of fruits and vegetables to larger extent as it does not cause moisture content to undergo phase change. It is accomplished in two steps *viz.*, initial water removal using a hypertonic solute solution followed by subsequent drying via different methods to further reduce moisture content of foods.

Keywords: Food Preservation, Mass Transfer, Osmosis, Phase Change, Solute Update

***Correspondence**
Author: Nadia Bashir
Email: nadiabashir00@gmail.com

Introduction

Fruits and vegetables are highly perishable because of their high water content. About 20-40 per cent of the fruit and vegetable production in India goes waste due to lack of proper retailing and adequate storage capacity. The vegetable and fruit production contributes more than 30 per cent of the agriculture GDP [1]. To increase the shelf life of these fruits and vegetables many methods or combination of methods have been developed. Dehydration of the fruits and vegetables is one of the oldest forms of food preservation techniques practised by man. Osmotic dehydration is one of the best and suitable methods to increase the shelf life of fruits and vegetables. Osmotic dehydration is the process of removal of water by immersion of water containing cellular solids (fruits/vegetables) in a concentrated aqueous solution of sugar/ salt. Osmotic dehydration (OD) is an intermediate drying process in which water containing food materials are submerged in a hypertonic solution of salt or sugar or salt-sugar mixtures. Cellular membranes of food tissues are semi-permeable in nature and are composed of living biological units that freely allow solvent (i.e. water) molecules to pass through, but allow the passage of solute molecules to a lesser degree [2]. The driving force for water removal is difference in osmotic pressure between the plant tissue and its surrounding solution [3]. During osmotic dehydration, water flows from the plant tissue into the osmotic solution whereas osmotic solute diffuses from the solution to the tissue. Simultaneously, leaching of tissue’s own solutes (sugars, organic acids, minerals, vitamins, etc.) into the osmotic solution occurs as well, but to a much lesser extent compared to the first two transfers. Therefore it is a multi-component process [4]. Osmotic dehydration lowers the water activity of fruits and vegetables thereby extending their shelf life. Osmotic dehydration is preferred over other methods due to their color, aroma, nutritional constituents and flavour compound retention property [1]. The solutes commonly used in osmotic dehydration are sugar syrup with fruit slices or cubes and salt (sodium chloride) or brine with vegetables. Osmotic dehydration is affected by several factors such as osmotic agent, solute concentration, temperature, time, size, and shape and tissue compactness of the material, agitation and solution/sample ratio [5].

Advantages of osmotic dehydration are as follows [6]:

- It is a low temperature water removal process and therefore minimum loss of color and flavour take place.
- Since fruit pieces are surrounded by solutes, enzymatic and oxidative browning is prevented thus making it possible to retain good color with little or no use of sulphur dioxide.
- Removal of acid and uptake of sugar by the fruit pieces give a sweeter product than conventionally dried product.
- It partially removes water and thus reduces water removal load at the dryer.
- Since no phase change is involved energy consumption is much less.
- It increases solid density due to solid uptake and helps in getting better quality product in freeze drying.

- If salt is used as osmotic agent, higher moisture content is allowed at the end of drying as salt uptake influences water sorption behaviour of the product.
- Better textural quality after reconstitution.
- Simple equipments are required for the process therefore it can be employed in rural areas as entrepreneurs, home scale or with NGO's (Non Government Organizations) at commercial level since it is economical.

Disadvantages and inconveniences associated with osmotic dehydration [7]:

- Due to uptake of sugar there is reduction in acidity level affecting the characteristic taste of some products.
- Sugar coating is not desirable in some products.
- Osmotic dehydration in combination with other processes such as vacuum drying, air drying or blanching are found to be expensive.
- Higher water activity in osmotic dehydrated products.
- It is a time taking process.

History of osmotic dehydration

Pointing *et al*. [8] were first to develop osmotic dehydration of foods and after that a continuous stream of research was carried out on osmotic dehydration [9]. Fakras and Lazar, [10] carried out osmotic dehydration and calculated its monograph. Vial *et al*. [11] and Heng *et al*. [12] studied the osmotic dehydration (kinetics) of papaya and kiwi in sucrose and glucose solutions. Torregianni [13] studied the quality of osmotically processed cherry studied and analysed the sugar content, colour, acidity, vitamin C, pH and organoleptic distinctiveness. The transfer of mass during osmotic dehydration of pineapple was studied by Beristain *et al*. [14]. Osmotic dehydration mechanism and modelling of gain and water loss were studied by many researchers Torregianni [13] and Rastogi *et al*.[9].

Mass transfer phenomena during osmotic dehydration

There are three major types of counter current mass transfer in osmotic dehydration process [15]. These include:

- Flow of water out from product to solution.
- Absolute transfer, from the solution to the product making it possible to introduce the desired amount of an active principle like a preservative agent, any solute, nutrient or a sensory quality improvement of the product.
- Leaching out of products own solutes (sugar, organic acids, minerals, vitamins etc.), which is quantitatively negligible when compared with the first two types of transfer, but essential with regard to the composition of final product.

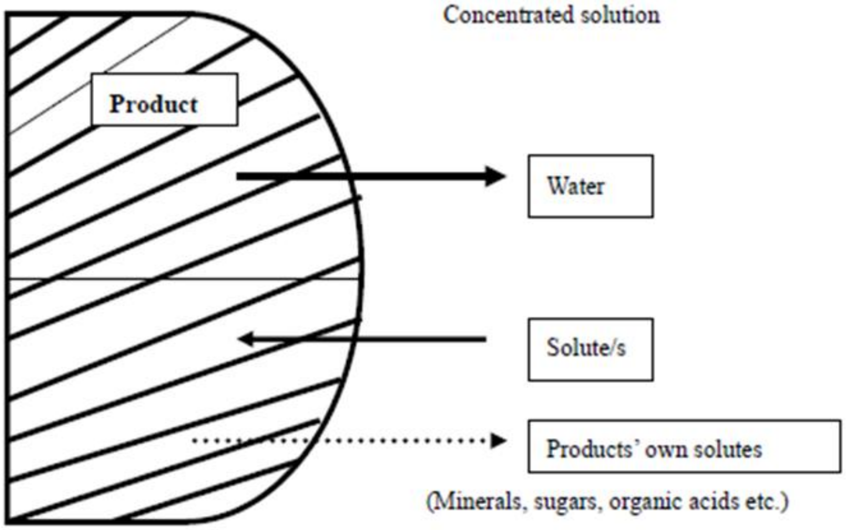

Figure 1 The schematic diagram of mass transfer during osmosis [16]

Different osmotic agents and their effects in osmotic dehydration process

Table 1 Different Osmotic Agent [17]

Osmotic agent	Remark
Calcium Chloride	Increases the firmness of fruit slices and preserves the texture during storage. Prevents browning because of synergistic effect with ascorbic acid or sulphur dioxide. Imparts better taste to the product at levels above 0.5 per cent [17]
Ethanol	Decreases viscosity and freezing and freezing point of the osmotic solution in cooling and freezing processes [17]
Fructose	Increases the dry matter content by 50 per cent as compared to sucrose due to higher penetration rate. Water activity of the final product is also lower. However sucrose is preferred over fructose [17]
Invert Sugar	Theoretically more effective than same concentration of sucrose because when completely inverted, it has twice as many molecules per unit volume. Practically little difference in the rate of osmotic dehydration of fruit by sucrose or invert syrups of the same concentration and temperature [17]
Lactose	It has much lower level of sweetness than sucrose. Low solubility in aqueous solution [17]
Malto dextrin	It can be used as an osmosis solute at higher total solids concentration, or in mixed systems. Less effective than sucrose at the same concentration [17]
Sodium Chloride (Nacl)	Mostly used for vegetables as it retards oxidative and non-enzymatic browning. Increases the driving force for the drying owing to the lowering capacity of the salt. Sometimes blanching effect on coloured products can be prevented using mixture of salt and sugar. Organoleptically should be 10-12 per cent. Hinders shrinkage at the surface layers [17]
Sucrose / Sugar	Dry sugar is unsuitable because of oxidative browning during osmosis. Sugar solution is best as it reduces browning by preventing the entry of oxygen. Sweetness hinders its use in vegetable processing [17]
Starch / Corn syrup	Favours similar final water content with minimal solid gain as that obtained with sucrose [17]

Applications in Food Preservation

Fish

Fish contains large amounts of water content that makes it highly perishable. In order to enhance its shelf life water activity can be reduced using different preservation techniques like osmotic dehydration**.** Gubic *et al*. [18] carried out osmotic dehydration of fish (*Carassius gibelio*) using three different osmotic solutions (sugar beet molasses, the mixed solution of sodium chloride and sucrose and combination of these solutions in a 1:1 ratio), under atmospheric pressure, at temperature of 20˚C. The effects of osmotic dehydration on chemical composition (dry matter, protein, fat, total ash, minerals), water activity and microbiological safety of fish, were investigated. It was observed that the highest content of protein (60.03%) was reached during osmotic dehydration with sugar beet molasses. The minerals (P, Ca, Mg, K, Fe and Na), increased 2 times increased, while Hg amount decreased 2 times during dehydration in solution with sugar beet molasses. Water activity of the fresh fish meat was found to be 0.944 which decreased after the 5 hours of osmotic dehydration and were in order of 0.850 to 0.846 in all three hypertonic solutions. Bacterial count was reduced from 6 log CFU/g^{-1} to 3 log CFU/g^{-1} which is considered as microbiological limit for good fish meat quality.

Fruits

Pragati *et al*. [19] investigated the effect of drying methods on nutritional composition of dehydrated aonla fruit (Emblica officinalis Garten) during storage. Aonla fruit (*Emblica officinalis* Garten) cv. Chakaiya was dried using four different methods viz., osmo-air drying, direct sun drying, indirect solar drying and oven drying. It was observed that the osmo-air drying method resulted in better retention of nutrients like ascorbic acid and sugars. The level of anti-nutrients like tannins was also found to be lower in osmo-air dried aonla compared to other methods of drying because of leaching. Browning of the dehydrated fruits was also minimal in the case of osmo-air dried fruits. The nutrient content in osmo-air dried aonla was satisfactory after 90 days of storage.

El-Aouar *et al*. [20] studied the influence of two different osmotic agents (sucrose and corn syrup) on the osmotic dehydration of papaya slices (Carica papaya L.). The two factorial experimental designs, with three independent variables whose levels varied from 44 per cent to 56 per cent w/w for concentration, from 34 to 46 ˚C for temperature and from 120 to 210 min for immersion time were employed. The responses of the experimental designs were the weight reduction (WR), water loss (WL), solids gain (SG) and water activity (a_w). The results showed that, considering the same osmotic pressure for both osmotic agents, the values obtained for WR, WL and SG for dehydration in sucrose solutions were higher than those obtained in corn syrup solutions, due to their high viscosity and polysaccharide content.

Haj Najafi *et al*. [21] studied the effect of osmotic dehydration process on mass transfer and quality attributes of red pitaya (*Hylocereus polyrhizusis*) cubes using sucrose solution at mild temperature (35ºC). Sucrose solution in the concentration of 40, 50 and 60 per cent (w/w) was employed for osmotic dehydration process. Responses of color (L*, a* and b*) and texture (hardness) in response to different solute concentrations were evaluated. The results obtained revealed an increase in yellowness (b*), decrease in lightness (L*) and redness (a*) as the sucrose concentration increased. It was observed that increase in sucrose concentration and dehydration time caused softer tissue of dehydrated product compared with the fresh red pitaya.

Ibitwar *et al*. [21] studied the effect of different osmotic agents (sugar and sugar glycerol) on the solid gain and water loss during osmotic dehydration of plum. Drying was conducted at 45, 55 and 65°C. It was observed that osmotic dehydration followed by air drying reduces the drying period and a decrease in total convective dehydration time by 240 min and 120 min in sugar and sugar-glycerol solution respectively as compared to air convective drying. The drying rate curves exhibited no constant rate period and showed a linear falling rate throughout the drying process.

Vegetables

Bashir *et al*. [22] investigated the impact of different drying methods on total sugars and titrable acidity of tomates. The study reported higher titrable acidity (0.75%) in osmo-air dried tomatoes indicating lesser damage to vitamin C content of tomatoes in contrast to oven and solar dried tomatoes reflecting titrable acidity of 0.21 and 0.30 per cent, respectively. Nishadh and Mathai, [23] carried out studies on osmotic dehydration characteristics of radish in different concentration of osmotic solutions such as salt (3, 6, 9) per cent and sugar (30, 40, 50) ˚Brix. It was observed that in the case of moisture content and dry matter content, sugar solution is more effective whereas in the case of rehydration ratio salt solution gave better results. It was concluded that using a combination of these osmotic agents increases the dehydration effect. The optimum concentration of osmotic agents at room temperature was found to be 6 per cent for salt solution and 400 ˚brix for sugar solution. The proximate analysis revealed that moisture content, ash content and ascorbic acid in osmotic dehydrated radish was found to be less than that of raw radish and higher than the oven dried radish indicating osmotic dehydration retains the nutritive properties of radish than normal drying.

Lee and Lim, [24] elucidated the effects of osmotic dehydration on pumpkin slice prior to hot-air drying. In this study Response Surface Methodology (RSM) with Central Composite Design was used to investigate the influence of three variables, namely sucrose concentration (30-60˚Brix), immersion temperature (35-65˚C) and immersion time (90-120 min). It was found that these factors increased the solid gains and decreased the water activity (a_w) of the sample while the temperature and sucrose solution concentration increased the water loss. The process temperature also affected the sensorial properties by increasing the sweetness, dryness, hardness and overall acceptance of the dried pumpkin slice. However, increasing temperature caused the deterioration of colour and aroma. Longer immersion time resulted in increase in shrinkage, sweetness and overall acceptability of the final product.

Conclusion

Osmotic dehydration in contrast to other drying methods retains the sensory and other characteristics of food products. However, the industrial applications of osmotic dehydration are limited because of large uptake of solutes that is further accelerated by porous structure of fruits and vegetables thereby hampering mass transfer. There is a need to carry out research that can limit uptake of solutes like use of edible coatings acts that can decrease solute uptake without having negative effect on the rate of water removal.

References

[1] Yadav, A. K. and Singh, S. V. 2012. Osmotic dehydration of fruits and vegetables: a review. Journal of Food Science and Technology, 51(9): 1654-1673.

[2] Khin, M. M., Zhou, W. and Yeo, S. 2007. Mass transfer in the osmotic dehydration of coated apple cubes by using maltodextrin as the coating material and their textural properties. Journal of Food Engineering, 81(3): 514-522

[3] Jokic, A., J. Gyura, Levic. L. J. and Z. Zavargo. 2007. Osmotic dehydration of sugar beet in combined aqueous

solutions of sucrose and sodium chloride. Journal of Food Engineering, 78(1):74-51.
[4] Sagar, V. R. and Kumar, P. S. 2010 Recent advances in drying and dehydration of fruits and vegetables: a review. Journal of food science and technology, 47(1): 15-26.
[5] Pandharipande, S. L., Saural, P. and Antic, S. 2012. Modeling of osmotic dehydration kinetics of banana slices using artificial neural network. International Journal of Computer Applications, 48(3):26 -31.
[6] Islam, M. N. and Flink, J. M. 1982. Dehydration of potato II. Osmotic concentration and its effect on air drying behaviour. Journal of Food Technology, 17(3): 387-40.
[7] Jackson, T. H. and Mohamed, B. B. 1971. The shambat process: new development arising from the osmotic dehydration of fruits and vegetables. Sudan Journal of Food Science Technology, 3:18-22.
[8] Pointing, J. D., Warrers, G. G., Forrey, R. R., Jackson, R., and Stanley, W. L. 1966. Osmotic dehydration of fruits. Journal of Food Technology, 44: 1365-1368.
[9] Rastogi, N. K., Ragavarao, K. S. M. S., Niranjan, K. and Knorr, D. 2002. Recent developments in osmotic dehydration: Methods and enhance mass transfer. Trends in Food Science Technology, 13(2): 48-59.
[10] Farkas, D. F., and Lazor, M. E. 1969. Osmotic dehydration of apple pieces: Effect of temperature and syrup concentration. Journal of Food Science Technology, 23: 668-690.
[11] Vial, C., Guilbert, S. and Cuq, J. 1991. Osmotic dehydration kiwi fruit of kiwi fruits: Influence of process variables on the colour and ascorbic acid content. Science des Aliments, 11(1): 63-84
[12] Heng, K., Guilbert, S. and Cuq, J. L. 1990. Osmotic dehydration of papaya: Influence of process variables on the product quality. Science des Aliments, 10(4): 831-848.
[13] Torreggiani, D. 1993. Osmotic dehydration in fruit and vegetable processing. Food Research International, 26(1): 59-68.
[14] Beristain, C., E. Azuara, R. Cortes and Garcia, H. S. 1990. Mass transfer during osmotic dehydration of pineapple rings. International Journal of Food Science, 25(5): 576-582.
[15] Tiwari, R. B. 2005. Application of osmo air dehydration for processing of tropical fruits in rural areas. Indian Food Industry, 24(6): 62-69.
[16] Raout-Wack, A. L. 1994. Recent advances in the osmotic dehydration of fruits. Journal of Food Science Technology, 5: 255-260.
[17] Chavan, U. D. 2012. Osmotic dehydration process for preservation of fruits and vegetables. Journal of Food Research, 1(2): 202-209.
[18] Gubic, J., Plavsic, D., Varga, A., Saric, L., Curcic, B., Knezevic, V. and Filipovic, V. 2014. Osmotic dehydration of Fish (Crassus Gibelio). A pretreatment in three different osmotic solutions. Journal of Hygienic Engineering and Design, 7: 51-56.
[19] Pragati, S. Dahiya and S. S. Dhawan. 2003. Effect of drying methods on nutritional composition of dehydrated aonla fruit (Emblica officinalis Garten) during storage. Plant Foods for Human Nutrition, 58(3): 1-9.
[20] El-Aouar, A. A., Azoubel, P. M., Barbosa, J. L. and Murr, F. E. X. 2006. Influence of the osmotic agent on the osmotic dehydration of papaya (Carica papaya L.). Journal of Food Engineering, 75(2): 267-274.
[21] Haj Najafi, A., Yusof, Y. A., Rahman, R. A., Ganjloo, A. and Ling, C. N. 2014. Effect of osmotic dehydration process using sucrose solution at mild temperature on mass transfer and quality attributes of red pitaya (Hylocereuspolyrhizusis). International Food Research Journal, 21(2):625-630.
[22] Ibitwar, B. B., Kaur, B., Arora, S., Pathare, P. B 2008. Osmo-Convective dehydration of plum (Prunussalicina L). International Journal of Food Engineering, 4(8): 1-11.
[23] Bashir, N., Bhat, M. A., Dar, B. N., and Shah, M. A. (2014). Effect of Different Drying Methods on the Quality of Tomatoes. Advances in Food Sciences, 36(2): 65-69
[24] Nishadh, A. and Mathai, L. 2014. Osmotic dehydration of radish in salt and sucrose solutions. International Journal of Innovative Research in Science, Engineering and Technology, 3(1): 1514-1521.
[25] Lee, J. S. and Lim, L. S. 2011. Osmo-dehydration pre-treatment for drying of pumpkin slice. International Food Research Journal, 18(4): 1223-1230.

Publication History

Received	02.04.2020
Revised	19.04.2020
Accepted	04.05.2020
Online	30.05.2020