Plant Archives Volume 21, No 1, 2021 pp. 98-103 *e-ISSN:2581-6063 (online), ISSN:0972-5210*

Plant Archives

Journal home page: www.plantarchives.org

DOI Url: https://doi.org/10.51470/PLANTARCHIVES.2021.v21.no1.013

RECENT TRENDS IN OSMOTIC DEHYDRATION OF FRUITS: A REVIEW

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(Date of Receiving-15-09-2020 ; Date of Acceptance-09-12-2020)

ABSTRACT

The marvel of expulsion of water from lower solvent concentration to higher concentration by a semi-perimeable membrane is osmotic dehydration, resulting in equilibrium state on both sides of the membrane. As it decreases the water activity of fruits. It is found to be most widely used application for preserving food materials. Due to colour, scent, nutritional constituents and flavour compound retention value, osmotic dehydration is favoured over other methods. Drying, shower drying, freeze-drying, solidifying, vacuum packing, canning, syrup conservation (osmotic dehydration), sugar crystallization, nourishment illumination and the addition of preservatives or inert gases such as carbon dioxide are typical methods of applying these processes. The solutes used in osmotic parchedness are ordinarily sugar syrup with fruit slices or 3d shapes, and salt (sodium chloride) or vegetable brine. This can be the method of multicomponent diffusion. Water moves from fruits or vegetables to the solution in this process and certain fruit and vegetable components such as minerals, vitamins, fruit acids, etc also pass into the solution along with water to the fruits and vegetables, sugar and salt migrate. Examples that are considered are Gooseberry Murabbas (Aonla), apples, sweets, candies of Different fruits and vegetables, including pethas, parwal, Osmosis-made sweets in sugar syrup are the most popular items of commercial value available in the market made from fruits. It is processed in a brine solution before drying in pickles made from raw mango. In brine, various vegetables are handled to lower their moisture content.

Keywords: Osmosis, Fruits, Preservation, Mass transfer kinetics, extend shelf life, dehydration

INTRODUCTION

Osmosis dehydration is mechanical process which helps in removal of water from fruits which contain water soaking them in a concentrated aqueous solution. It has a capacity to remove water at very low temperatures. Osmotic dehydration process is useful in decreasing the post harvest losses. OD helps in maintenance of colour, texture, nutritional composition of fruits. It wouldbeused bysmall scale entrepreneurs. During theprocess of mass transfer mathematical models can beused. Dehydration is oldest methods of preserving food preservation known to humankind. One of dehydration methods which is osmotic dehydration used to remove water from fruits and vegetables by steeping in concentrated aqueous solutions like brine or sucrose solutions (Pandharipande *et al.,* 2012).OD process helps in increased shelf life of fruits, it helps in decreasing the freezing load without causing any textural damage by icing but in this process we can see some loss of aroma in dried foods (Petrotos and Lazarides, 2001).The glucose, sodium chloride, fructose and others can be used as osmotic agents in OD process (Azuara and Beristain, 2002). Simple molecules like glucose, sucrose etc are helpful in uptake of sugar because of their high diffusion rate of molecules and proved to be good quality technique because of similar sensory characteristics between natural and dried products (Sousa *et al.*, 2003). Osmotic dehydration involves the submerging the pieces of fruits, vegetables, fish, meat in solutions like salts, sugar , alcohols and starch solutions which help in dehydration of food (Erle and Schubert, 2001). Osmotic dehydration is one of the most common forms of dehydration. In the significant supportive preservative process in the Dehydrated food production,results in some profitable characteristics such as reducing the damage of heat to flavour, colour, preventing the browning enzymes of fruits (Alakali *et al.*, 2006; Torres *et al.,* 2006).

Food tissues which are immersed in sugar or saline solution during osmotic dehydration results in 3 different types mass transfer phenomenon which are : 1. Water from fruit tissues outflow into osmotic solution 2. Transfer of solutes from osmotic solution to fruit tissues is observed 3. Washing out own solutes of fruit tissues. Low molecular cell elements, such as sugars and natural acids, to disperse high osmotic content into the surrounding solution. Because of this osmotic dehydration regarded as the process of complex movement of water an low molecular components of cell and osmo-active substances (Tortoe, 2010). Cell and osmo-active compounds studied by (Rahman, 2007). A hypertonic solution with a higher osmotic pressure and a low osmotic pressure. Water behaviour, which plays a crucial role as a force for the removal of water from food tissues. The evaporation of water from osmosis is by transmitting and capillary flowwas observed by (Rahman, 2007). Due to presence of semi-permeable membrane character in plant tissues less molecular components and water molecules flew outside into surrounding solution , hence this results in weight loss of food tissue and their water activity as well. Some works showed that 50% weight loss is reported by osmotic dehydration process (Yetenayet and Hosahalli, 2010).

Shi and Xue, (2009); Jalaee *et al.,* (2010), Phisut, (2012) showed their concern on minimizing the osmotic solids uptake, because they can rapidly change the organoleptic and nutritional characteristics loss in fruit tissues like vitamins and minerals present in pieces.Some features are used to speed up the water transfer by using high concentration of solutions , less weight agents used during process , temperature during dehydration, reduced uptake of large solutes is seen by using edible coatings of fruits is done before the start of osmotic dehydration was studied by (Khin *et al.,* 2007; Garcia *et al.,* 2010; Jalaee *et al.,* 2010).

Factors affecting Osmotic dehydration

Different types of Osmotic agents and concentrations, temperature during the processing, agitation method during dehydration process, applications of edible coatings and pre-treatment techniques were explained.

1. Osmotic agents concentration

Phisut, (2012) observed that during osmotic process higher solute concentrations leads to increase in water loss and increase in solids gain.Ispir and Togrul (2009) concluded that transfer of molecules during osmotic dehydration process of apricot showed that after they are soaked in different sugar concentrations of 40, 50, 60 % the results obtained were increase in osmotic pressure gradients and increase water loss and solid weight gain uptake were seen throughout the process.Giraldo *et al.*, (2003) reported in his paper that mass transfer during osmotic dehydration of mango that the study was carried out at 30^0c of temperature in 30^0c, 45^0 c , 35^0 c and 65^0 c brix solution. Results obtained are water molecules transfer is high when the sucrose solution is at 45^0 brix and anything was seen during 55^0 and 65^0 c brix because of hardening of solution , when surrounding solution is highly concentrated penetration is difficult because of viscosity.Sucrose is not capable of distributing in cell membrane as water does at high degree.It manipulatehigh solvent concentration temperature while blueberry mashing up in sample: solution ratio I, e; 1:1 solution concentration,Increased then the water loss rate is also increased by the osmotic gradient recorded in fruit and vegetables.Whenthe blueberries were submerged in different sugar solutions(Shi and Xue,2009; Rafiq Khan, 2012). Fragoso *et al.,* (2002) told that , for OD process clearly, $1cm^3$ apple cubes showed that processing plant contains of a strong agitation system, extraction system, filtering bag, vacuum evaporator. The analysis was conducted at 50^0c in 60 0 B sucrose syrup. It was maintained at 60^0c only.

2. Types of osmotic agents

Sucrose, glucose, sorbitol, corn syrup are some solute types used as osmotic agents as well as low molecular weight The common solute types used as an osmotic agents are easier to penetrate through fruit cell compared to high molecular one (Phisut, 2012). The mixtures of sucrose and glycerol in the osmotic solution had an effect on mass transfer of a gradient of pressure and increased loss of water. The peeled mandarin samples were soaked in osmotic samples.Solution prepared from a separate solution of sucrose to glycerol (60%) in various ratios like 9:1,8:2,7:3,6:4,5:5 w/w. 5:5 ratio osmotic solution more water loss compared to others because of glycerol having lower molecular weight than sucrose(Pattanapa *et al.,* 2010). Pan *et al.,* (2003) studied that Selecting the correct osmotic solutions for food was important as they perform driving force of water and solute, then measuring its rate and extent of solute uptake and water removal from the tissues. Selection of osmotic solutes is done carefully according to criteria. Rashmi *et al.,* (2005) studied on giant kew is a pineapple variety which dipped in 70^0 brix sugar syrup used as a osmotic agent found efficient for moisture removal and also he reported that 60^0 brix glucose syrup along with 0.2% citric acid and KMS of 700ppm gave best results on basis of sensory scores of dry fruit yield, carotenoid content, ascorbic , citric acid content and lower moisture content for period of 24h and these observations were done before and after 6 months storage.

Prepared and observed the honey quality based on amla murabba. As it is prepared by using honey as natural sweetener in place of sugar. It was kept in observation for quality evaluation which packed in PET and glass jar separately for 6 months. As according to observations recorded samples packed in PET jar sensory quality scores were decreased and opposite for glass jar samples and concluded that glass jar did better job as packageing material in various aspects like physiochemical properties, sensory qualities, microbiological properties and told murabba prepared can be preserved for 180 days (Durrani and Verma, 2011).

Durrani *et al.,* (2011) through osmotic dehydration prepared carrot candy using honey. He observed that candy which is prepared from carrot can be preserved for 6 months in both LDPE and glass packaging materials. Teles *et al.,* (2004) studied that osmotic dehydration of tomato in which different coefficients of water solutions, sucrose and NaCl were studied. They divide duration of time into both and long (60h) and short (4h) duration. In the former one equilibrium of concentration was studied and in later one energy of water misfortunes and strong take-up were considered. Mass exchange closed to be reliant on both sucrose and NaCl. Sucrose diffusivity and NaCl were free net water evaporation expanded with NaCl focus while higher level of sucrose. Distinctive coefficient during osmotic parchedness of tomato in arrangement of water, sucrose and salt were contemplated.

3. Temperature

Bchir *et al.,* (2009) conducted studies on Osmotic dehydration of pomegranate seed at different temperatures of 30,40 and 50 ^{0} c in 50:50 ratio in 50^0 Brix of sucrose, glucose. In this combination after 20 minutes water loss is seen as 46% in sucrose, 37% in glucose, 41% in mixed solution. He also found that temperature of glass transition depends on type sugar used. Castello *et al.,* (2010) told that Osmotic dehydration has a effect on respiration rate and other properties like mechanical and optical of strawberries which are evaluated for six days at 10^0c. Changes in shrinkage, density, porosity and shape of samples through osmotic dehydration process. Air drying was directed at 70^0c . volume about samples diminished linearly similarly as weight lessens. Molecule thickness might have been improved , porosity discovered should be diminished throughout high degree of temperature for parchedness. osmotic dehydration increased elongation and decreased roundness and compactness of sampleswere observed and reported by (Mayor *et al.,* 2011). Tortoe, (2010) studied that in osmotic treatment temperature around 50^0 c is mostly used in fruits and vegetables for some reasons they are : temperature is restricted the decay of flavour, surface and thermo reasonable mixes of material, at 49 ^{0} c of temperature. Enzymatic browning and deterioration of fruit taste It was seen, and the temperature was fine for holding the viscosity of the solution without altering the condition of the fruit.

ShiandXue; (2012): Rafiq Khan: (2009) concluded that changes were seen in the temperature of blue berries above 50^0c.Tortoe, (2010) told that temperature affects the kinetics of mass transfer in osmotic dehydration. In osmotic dehydration process, increase in temperature causes water loss and solid gain uptake (Alakali *et al.,* 2006, Rafiq Khan, 2012). Pereira, *et al.,* (2004) studied that in minimally processed guavas in osmotically dehydrated which are packed under passive modified atmosphere, their quality were studied . By keeping them in observation for 24 Storage days at 5^0C. He examined that samples were deposited under modified atmosphere packaging (MAP) in polyethylene. Terephthalate (PET) containers have a very strong effect on the colour retention and weight loss of guavas.

4. Agitation

Improve the mass transfer, stirring process are used in OD because of its high viscous glucose solutions which creates some troubles like food pieces floating, blockage between food pieces and osmotic solutions which results in reduction of mass transfer (Moreira *et al.,* 2007; Phisut, 2012). Moreira *et al.,* (2007) studied the effect of agitation in some of his reports he mentioned that agitation degree has good effect on water loss. Loss of water is higher in turbulent flow region than in laminar flow region.

Moreira *et al*., (2007); Shi and Xue, (2009) they studied oneffect of agitation and non – agitation treatments. In which they observed that samples showed great weight reduce, water loss compared to non – agitated samples. Agitation improves turbulent flow which leads to increase in liquid diffusion during the dehydration process.Phisut, (2012) studied that Agitation process will be a good way to improve mass transfer, by reducing contact time to benefit and achieve better moisture content in the food pieces.

5. Treatments

Sunjka and Raghavan (2004) reported that various pretreatment methods for cranberry osmotic dehydration like Mechanical, chemical and osmotic dehydration were performed, in mechanical pretreatment method samples were sliced into half and quarter size. In chemical pretreatment there was a difference in temperature of agents used In treatment and time in dipping process of fruits in OD. changes in osmotic agents and OD process time. Considering this basis Based on the mass gain, the solid gain and the moisture, it is stated that the quarter half showed the best in time and concentration of osmotic agents.Influence of pretreatment as of blanching, freezing on osmotic dehydration (pumpkin) sample. firstly pumpkin are cut into cubes of and dehydrated in sucrose, glucose and starch solutions for 180 min. they showed great water loss and solid gain increase in pretreated samples compared to non- pretreated samples. High water loss was seen in blanched pretreated osmotic dehydrated samples for 180 min , the sample used for OD is starch solution and lowest from frozen sample which is dehydrated in sucrose solution. Final results showed that pretreatments like blanching and freezing doesn't have significant influence on the coefficient of diffusion of water and solids studies were examined by (Kowalska *et al.*, 2008) .

Lombard *et al*., (2008) dealt with Osmotic dehydration as preliminary treatment on pineapple and studied benefits of Osmotic dehydration on mass fluxes such as water depletion, solid gain absorption, weight loss. The slices of pineapple were submerged in sucrose solutions of 45, 55, 65 ^{0} B at 30, 40 , 50 ^{0} c at 20, 40, 60, 20, 180 and 240 min. Osmotic dehydration mechanism was used. Studies performed on all ambient pressures by applying 200 mbar of vacuum force during the first 10 min. vacuum speed increased water loss capability and solid gain was obtained. Viewed with greater concentration and temperature. However, water loss is affected by increase in temperature and osmotic solution concentration affects solid gain of product. finally quality was evaluated on the basis of water loss and solid gain combination. Calcium lactate effect on cell structure and osmodehydrated melon pieces mechanical properties along with sucrose solutions were studied. Some samples were treated with sucrose solutions (40 or 60^0 B) which contain calcium lactate and also salt concentrations treatments. Over 15 g kg-1 carried out along with sucrose solution encouraged cytoplasm plasmolysis and cell wall damage. They are processed with sucrose solution 60^0 Brix in mixture with or without calcium lactate resulted in good sensory scores (Ferrari *et al.,* 2010).

6. Benefits of Osmotic dehydration

Yetenayet and Hosahalli, (2010) said that some advantages of osmotic dehydration method in food industries are quality aspect like colour, flavour, texture, product stability and nutrient availability during storage, energy usage, process of packaging, and cost value, final product quality.Tortoe, (2010) reported in paper that osmosis means removal of water , its application of osmotic treatments to fruits as gained much recognition in recent times. Which helps in gaining improved quality of products like dried fruits by saving cost value. Osmotic dehydration helps in enhancing original flavour, colour retention and texture of fruit samples by using suitable solutes and by avoiding additives like antioxidants. The apple which is used as sample for osmotic dehydration experiment, the structure of tissue was studied after water removal in apple cubes which are present in 61. 5% sucrose solution under light microscope. Computer generated analysis showed that there was no cell rupture took place because of osmotic dehydration. Due to osmotic dehydration cells attained smaller size and their intra cellular space increased. Improvement is found to be more 30% until 120 min of process. If the process is prolonged there will be disintegration in tissues of apple experiment was done by (Lewicki and Pawlak 2005).

Mayor *et al.,* (2011) studied on the sample shrinkage changes, density, porosity and shape throughout the osmotic dehydration process of pumpkin. The sample slices with 5/3 ratio of length/diameter were taken at 70 ^{0} c of temperature air drying was conducted in that volume of samples were reduced along with weight reduction. Bulk density showed variation in 5-13% of range, Particle density was increased , porosity decreased at higher temperature by showing a lower value at initial stage of OD. He also told that osmotic dehydration was isotropic, food materials which undergone osmotic dehydration process increased in product elongation but resulted in decreased roundness and compactness.

Quality issues

Lazarids, (2001) studied the concentration of OD was main useful thing to reduce the water content in fruits with some damage on the quality of fresh products. But the products were treated with low temperature (30-50 ^{0} c) which did not affect the cell membrane properties. Hosahalli, (2010) told that Parchedness from claiming nourishment materials ,by submerging them previously, osmotic results when performing air drying enhances it. Caliber of the last item since it keeps the browning and loss in flavour constituents and reduce acidity in fruits. Reduction in water content and gain glucose content. Some cryoprotective influences on colour and texture in fruit have been observed during osmotic dehydration was concluded by (Chiralt *et al.,* 2001).

Energy efficiency

Drying is one of the most energy-intensive procedures of both food and non-food units in processing factories. Because of high heat of water vaporization from the product (Yetenayet, and Hosahalli, 2010). Kudra, (2009) told that, For batch drying, energy consumption is the average value over drying rate, but for persistent dehydration it is above moisture. Components, or volume . in other cases efficiency of drying and energy demand is in association with drying time, which related to volume of moisture to be removed from drying.

On different types of OD applications in fruits and vegetables processing. Osmotic dehydration was used along with other drying methods like freeze, vacuum drying to get product stability. Osmotic dehydration and other drying methods were used in combination for cost reduction in production. However, water removed from samples without applying external energy was studied by (Lazarids, 2001).

Osmotic dehydrated Product market

The osmotic dehydrated products removed 30-70% of water are used to make shakes. In terms of degree stabilisation, these items are being used in the bakery, dairy and candy industries. OD process makes food semi dried, frozen and treated with chemicals. These foods are mostly used in France, Italy, Europe countries along with other modern methods but in Asia the osmotic dehydration of became popular for tropical fruits. Osmotic dehydrated fruits like orange and kiwi are used in preparation of jam to get high quality products which are useful in commercial gainby (García-Martínez *et al.*, 2002).

Rafiq Khan, (2012) reported that Quince pieces which were dehydrated in fructose solutions in 45, 55 and 60^{0} B at 30, 40 and 50^{0}c . high quality colour, vitamin C, ascorbic acid preservation and texture was seen in solution concentrations of 45 and 55^{0} B at 30^{0} c.

CONCLUSION

Osmotic dehydration is one of the most quality enhancing treatment and preservative technique used in dehydrated food processing. It helps in reducing 50% of food materials weight and helps in increase the product shelf life. OD is energy saving and quality enhancing process. Some combinations osmotic dehydration methods like osmo-air drying is good for some tropical fruits, osmo-dehydrofreezing is not only economical but energy save method. Dehydrofreezing method is helpful in improving quality of product. Osmotic dehydration is helpful as small business for self- entreprenuers. It is one of high rated preservative method because it does not do much damage to nutrients, colour, flavour, texture of the product. It is useful in reducing post harvest losses of fruits and vegetables. In osmotic dehydration factors like osmotic agents, temperature, processing time, agitation ,coatings and pretreatments play important role in mass transfer kinetics. Processing temperature is important in initiating the mass transfer during OD. Increase in water loss is caused by agitation process.

REFERENCE

Alakali, J.S., C.C. Ariahu and N.N. Nkpa. (2006) Kinetics of osmotic dehydration of mango. *Journal of Food Processing and Preservation* 30:597-607.

Azura, E and C.I. Beristai. 2002. Osmotic dehydration of apples by immersion in concentrated sucrose / matlodextrin solution. *Journal of Food Processing hesewation*. 26: 295-306.

Bchir B, Besbes S, Attia H, Blecker C (2009) Osmotic dehydration of pomegranate seeds: mass transfer kinetics and DSC characterization. *Int J Food Sci Technol* 44:2208–2217.

Castello ML, Fito PJ, Chiralt A (2010) Changes in respiration rate and physical properties of strawberries due to osmotic dehydration and storage. *J Food Eng* 97(1):64–71.

Chiralt A, Martínez-Navarrete N, MartínezMonzó J, Talens P, Moraga G, Ayala A, Fito P. 2001. Changes in mechanical properties throughoutosmotic processes cryoprotectant effect," *Journal of Food Engineering* 49, 129-135.

Durrani AM, Srivastava PK, Verma S (2011) Development and Quality Evaluation of honey based carrot candy. *J Food Sci Technol* 48(4):502–505.

Durrani AM, Verma S (2011) Preparation and Quality evaluation of honey Amla Murabba. *J Ind Res Tech* 1(1):40–45

Erle, U. and H. Schubert. 2001. Combined osmotic and microwave-vacuum dehydration of apples and strawberries. *Journal of Food Engineering*. 49:193-199.

Ferrari CC, Carmello-Guerreiro SM, Bolini HMA, Hubinger MD (2010) Structural changes, mechanical properties and sensory preference of osmodehydrated melon pieces with sucrose and calcium lactate solutions. *Int J Food Prop* 13(1):112–130.

Fragoso AV, Paz HM, Giroux F, Chanes JW (2002) Pilot plant for osmotic dehydration of fruits: design and evaluation. *J Food Proc Eng* 25:189–199

Garcia MR, Diaz R, Martinez Y, Casariego A. 2010. Effects of chitosan coating on mass transfer during osmotic dehydration of papaya," *Food Research International* 43, 1656-1660

García-Martínez E, Martínez-Monzó J, Camacho MM, Martínez-Navarrete N. 2002. Characterisation of reused osmotic solution as ingredient in new product formulation," *Food Research International* 35, 307-313.

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.

Ispir A, Togrul TI. 2009. Osmotic dehydration of apricot: Kinetics and the effect of process parameters, *Chemical Engineering Research and Design* 78, 166-180.

Jalaee F, Fazeil A, Fatemain H, Tavakolipour H. 2010. Mass transfer coefficient and the characteristics of coated apples in osmotic dehydrating, *Food and Bioproducts Processing* 89,367- 374.

Khin MM, Zhou W, Perera C. 2007. Impact of process conditions and coatings on the dehydration efficiency and cellular structure of apple tissue during osmotic dehydration, *Journal of Food Engineering* 79, 817-827.

Kowalska H, Lenart A, Leszczyk D (2008) The effect of blanching and freezing on osmotic dehydration of pumpkin. *J Food Eng* 86:30–38.

Kudra T. 2009. Energy Aspects in Food Dehydration. In: Cristina Ratti Ed," *Advances in Food Dehydration*, CRC Press, NW, U.S.A, 423-443.

Lazarides, HN. 2001. Reasons and possibilities to control solids uptake during osmotic treatment of fruits and vegetables. pp. 33–42. In Fito, P, Chiralt,A, Barat, JM Spiess, WEL and Behsnilian D (eds.),Osmotic dehydration and vacuum impregnation:Applications in food industries USA: Technomic Publ. Co

Lewicki PP, Pawlak RP (2005) Effect of osmotic dewatering on apple tissue structure. *J Food Eng* 66:43–50.

Lombard GE, Oliveira JC, Fito P, Andrés A (2008) Osmotic dehydration of pineapple as a pre-treatment for further drying. *J Food Eng* 85:277–284.

Mayor L, Moreira R, Sereno AM (2011) Shrinkage, density, porosity and shape changes during dehydration of pumpkin (Cucurbita pepo L.) fruits. *J Food Eng* 103:29–37.

Moreira R, Chenlo F, Torres MD, Vazquez G.2007. Effect of stirring in the osmotic dehydration of chestnut using glycerol solutions, LWT-*Food Science and Technology* 40, 1507-1514

Pan, YK., LJ. Zhao, Y. Zhang, G. Chen and AS. Mujumdar. 2003. Osmotic dehydration pretreatment in drying of fruits and vegetables. *Drying Technology*. 21: 1101-14.

Pandharipande SL, Saurav P, Ankit SS. 2012."Modeling of Osmotic Dehydration Kinetics of Banana Slices using Artificial Neural Network, *International Journal of Computer Applications* 48(3), 26- 31.

Pattanapa K, Therdthai N, Chantrapornchai W, Zhou W. 2010. Effect of sucrose and glycerol mixtures in the osmotic solution on characteristics of osmotically dehydrated mandarin cv. (SaiNamphaung), *International Journal of Food Science and Technology* 45, 1918-1924.

Pereira LM, Rodrigues ACC, Sarantópoulos CIGL, Junqueira VCA, Cunha RL, Hubinger MD (2004) Influence of modified atmosphere packaging and osmotic dehydration of minimally processed guavas. *J Food Sci* 69(4):172–177.

Petrotos, K.B. and H.N. Lazarides. 2001. Osmotic concentration of liquid foods. *Journal of Food Engineering*. 49:201-206

Phisut N. 2012. Factors affecting mass transfer during osmotic dehydration of fruits, International," *Food Research Journal* 19(1), 7-18.

Rafiq Khan M. 2012. Osmotic dehydration technique for fruits preservation-A review, *Pakistan Journal of Food Sciences* 22(2), 71-85.

Rahman MS, 2007. Drying and Food Preservation, In Rahman MS, Handbook of food preservation. 2nd ed, CRC press, 412.

Rashmi HB, Doreyappa GI, Mukanda GK (2005) Studies on osmo-airdehydration of pineapple fruit. *J Food Sci Technol* 42(1):64–67.

Shi J, Xue JS. 2009. Application and development of osmotic dehydration technology in food processing. In Ratti, C. (Ed). *Advances in food dehydration*," CRC Press. USA.

Sousa, P.H.M., M.A. Souza Neto, G.A. Maia, M.S.M. Souza Filho and R.W. Figueiredo. 2003. Desidrataçãoosmótica de frutos. *Boletim da SociedadeBrasileira de Ciência e Tecnologia de Alimentos*. 37: 94-100.

Sunjka PS, Raghavan GSV. 2004. Assessment of pretreatment methods and osmotic dehydration for cranberries, *Candadian Biosystems Enigeering*, 45-48.

Teles VRN, Murari RCBDL, Yamashita F (2004) Diffussion coefficient during osmotic dehydration of tomatoes in ternary solutions. *J Food Eng* 61:253–259

Tortoe Ch. 2010. A review of osmodehydration for food industry," *African Journal of Food Science* 4(6),303 – 324.

Yetenayet B, Hosahalli R. 2010. Going beyond conventional osmotic dehydration for quality advantage and energy savings, *Ethiopian Journal of Applied Sciences and Technology* (EJAST) 1(1), 1-15.