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Challenges in Biochemical Engineering and Biotechnology for Sustainable Environment

Effect of Various Pretreatment Methods on Osmotic Dehydration of Fruits for Qualitative and Quantitative Advantage

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Abstract : Osmotic dehydration has diverse application in fruits, vegetables and food processing industry. It is the process of partial removal of water from the sample by immersing it in the osmoactive solution. This preservation technique removes water in the form of liquid which does not involve latent heat of vaporization. This is one of the major attractions of osmotic dehydration to be used as the upstream partial dehydration technique. When compared to drying, osmotic dehydration combined with other drying techniques produces more desirable product qualities in terms of less enzymatic browning, retaining texture, color and flavor. Sensory characters are closer towards the natural product.The main problem with osmotic dehydration is, it is a slow and time consuming process, especially when it is used as infusion technique than as partial dehydration technique. Osmotic dehydration is focused on water removal where as infusion is focused on solid gain from osmoactive solution. It may even take weeks to complete infusion. In both the cases if the sample is pretreated the process of water removal or solid gain is hastened. Here both thermal and non thermal techniques like blanching, application of high pressure, high electric field pulse, ultrasound, gamma – irradiation, vacuum centrifugal force etc., can play a vital role in making the cell membrane more permeable. In this paper such techniques and their qualitative and quantitative advantage to the osmotic dehydration and infusion process were reviewed.
Keywords: Osmotic dehydration, infusion, fruits and vegetables, preservation.

Introduction

Fruits and vegetables contain nearly 70% to 95% of moisture which make them highly perishable[1]. If this moisture is reduced to some extent, bulk transportation of the final product can be made to other parts of the county where it is not available. Also the shelf life of the product is increased. Conventionally sun drying and hot air drying is used to dry and preserve the product. This produced discolored and shrinked products which were of not interest to patronage. When osmotic dehydration is used prior to drying steps it is evident that it conserves energy and reduces the heat damage to the product in terms of color, flavor etc.,[2 &3].

Osmotic dehydration generally removes moisture and reduces the weight of vegetables and fruits up to 50%[4]. But this quantity is insufficient to increase the shelf life or stability of the product. To ensure maximum moisture removal, osmotic dehydration is followed by air drying or other hybrid drying techniques such as Osmo-convective, osmo-freeze drying, osmo-microwave drying,osmo-solar drying and osmo-microwave drying to get aesthetically acceptable and palatable product. In all the cases to improve the efficiency of the process, the porosity of the cell wall must be increased or the cell wall should be made more permeable or the fruit core should be exposed. This is the forum where this kind of review plays an important role. Optimization of process parameter would be essential for each fruit, keeping in mind the fruits final consumption and application.

Osmotic Dehydration

Osmotic dehydration (OD) is a partial dehydration technique, where the foods (vegetables, fruit, meat and fish) are immersed in osmoactive solutions such as sugar, salt or combined solutions. It involves 3 simultaneous mass transfer operations such as 1.Removal of water from the sample, 2. Intake of solids into the sample from the solution and 3. Elution of the samples own solute into the osmoactive solution. The following figure1shows the movement of solvent and solute during osmotic dehydration.

The word osmotic dehydration and infusion are sometimes used interchangeably, but perception wise they are different. The purpose is also different. In osmotic dehydration water removal from the product is targeted, in infusion uptake of solids from hypertonic solution, intothe product is aimed. The osmotic dehydration may be completed within few hours whereas infusion may take few days to few weeks.

The infusion process is also called as candying process. In both cases the complex cellular matrix acts as semi-permeable membrane, and offers resistancetowater diffusion from the sample and solute diffusion from the hypertonic solution[5& 6]. Generally OD is a fusion of impregnation and dehydration technique that gives improved functional properties to food that are encouraging for drying and results in enhanced product quality. The graph in fig. 2 explains dehydration and infusion stages in detail.

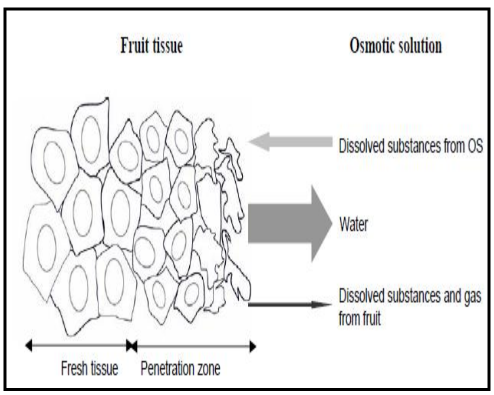

Fig. 1 Mass transfer in fruit tissue during osmotic dehydration

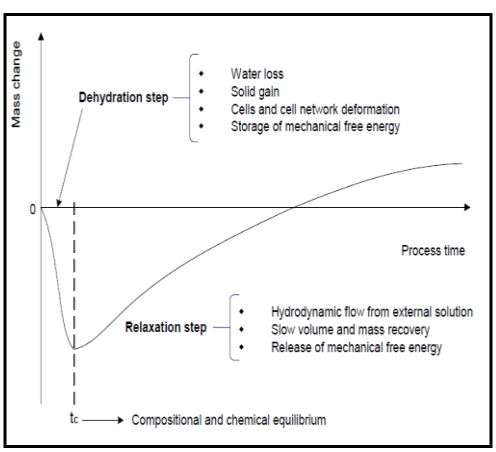

Fig. 2 Pathway inlong term osmotic dehydration process.

Parameters evaluated

The study reviewed in this work is based on various fruits and vegetables whose skin characteristics vary widely which in turn affects the mass transfer characteristics significantly. It is clearly noticed that the results and conclusions from these research work cannot be compared directly due to variability in equipment tested, experimental procedure, fruit variety, and parameters upon which effectiveness of drying was based.

Traditional quality factors or parameters used to assess dryers are physical aspects such as taste, color, bulk density, puncture strength, shearing, and rehydration ratio[7, 8, 9, 10, 11 &12]. The results and conclusion focus on various technological developments. The potential and problematic areas are high lightened, which is the need of the hour. With the availability of various advance new techniques recently the quality factors studied are minerals, vitamins level, bioactive compounds level and energy efficiency.

Comparison of Pretreatment technologies

Pre-treatment methods and drying may contribute to the deterioration of both the eating quality and the nutritive value of a food product[13 &14]. Hence selection of pretreatment method according to consumer satisfaction is more important, which is left to the reader's decision. It should be decided keeping in mind the end use of the product. Detailed pretreatment values and process parameter measurements were omitted from this discussion owing to the inability to contrast various researches that uses different equipment, methodologies, operating conditions, evaluation parameters, fruit variety and the climate in which it is grown. Fig. 3 shows various classifications of pretreatment methods. The following section discusses various pretreatment methods such as chemical and physical treatments, the use of microwaves, pulsed electric fields, ultrasound, blanching and use of high hydrostatic pressure and its effect on the osmotic dehydration of food stuff.

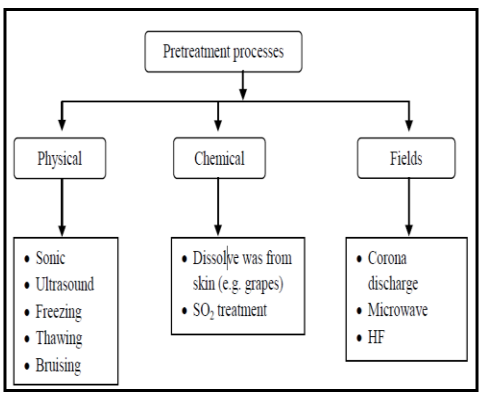

Fig 3. Classification of various pretreatment techniques

Steam or Hot water Blanching

Blanching is a thermal treatment used to loosen the cellular structure. It is the process of exposing the fruits in hot water or steam for a short time, to soften the skin. This treatment will loosen the skin and augment the solute or solvent transfer in and out of the membrane. For example tomatoes are dipped in hot water to loosen its skin. Blanching and cooking reduces the browning through the heat inactivation of Polyphenol oxidase (PPO) [15]. But however the disadvantage of blanching or precooking was the destruction of food quality attributes like flavor, texture and nutritional losses. Optimization of the process for individual fruit and vegetable may help in this regard depending upon the end use of the product.

Chemical Treatment

In this process the fruit skin is either dissolved or treated with alkaline solution for the given time and temperature. Alkaline solutions with Ethyl Oleate ($C_{20}H_{38}O_2$) improves the water diffusion process and hence enhance the drying rates of fruits such as strawberries, grapes, prunes, blueberries, cherries and guavas[16 & 17].It is showed that Ethyl Oleate (EO) redispenses the wax present on the skin of the treated cherries and they are moderately dewaxed and thus increases the mass transfer rate of water through the cuticle. EO effect on grapes was it wets the cell wall and improves its porosity[18]. Use of chemicals like anti browning agents (Lye treatment) removes the substrate (Phenolics and Oxygen) available for enzymatic browning. Example apple was dipped in 1% ascorbic acid solution for 5 minutes before proceeding with OD[19].

Mechanical Treatment

Mechanical treatments are recommended for those fruits and vegetables which have waxy skin, such as tomatoes, grapes, berries etc. Skin pricking with needle, mechanical cutting into halves, extrusion (to increase the surface area for drying), abrasion and drilling holes on the surface[20] are more commonly used. Increasing the porosity is found to yield good mass transfer rates. Porosity plays an important role in osmotic dehydration, especially in the beginning when, gas trapped in fruit tissue brings down the mass transfer rate. Thus, perforation will facilitate the degassing with an increase of the cell permeabilization[21].

For crane berries based on overall estimation of taste acceptability and moisture removal, cutting them into two halves provided the most convenient and practical pre-treatment technique prior to osmotic dehydration as compared to other techniques such as thermal and chemical methods[12]. Mechanical cutting for tomatoes and blueberries is not feasible due to the soft nature of these fruit. One more mechanical pre-treatment, that is perforating the skin, was tested on cherry tomatoes and cranberries[22&23].It was estimated that the perforations should be not less than 20 to 30% of total surface area for this technique to be more effective[12]. The tomatoes are cleaned and perforated using needles with 1 mm diameter to a hole density of 16 holes/cm2, earlier to osmotic dehydration and convective air drying[22].

Application of High hydrostatic Pressure

High Hydrostatic pressure processing (HPP) and ultrasounds are also used to alter the cell wall and to increase mass transfer during osmotic dehydration. The effect of HPP, vacuum, PEF and ultrasounds were studied and compared on osmotic dehydration of strawberries[21]. Pretreatment with PEF and HPP conserved the product properties (compactness and color) and enhanced mass transfer. The vacuum treatment during OD augmented solid gain and reduced the processing time. In some cases activation of polyphenoloxidase is triggered by high pressure treatment[23].Also it reduced the floating of berries in further processing steps.

Polyphenol oxidase (PPO) enzyme activity is reduced when high pressure treatment is combined with other methods such as blanching[23 & 24].This gives fresh look to the cut or processed fruits or vegetables.

High Electric Field Pulse and OD

Pulsed electric fields (PEF) studied by Ade-Omowaye et al. (2001, 2003) seems to be an excellent option to improve water loss during osmotic dehydration and to reduce solute uptake, which results in minimal change of product taste. In this technique short bursts or pulse of voltage was given to food material that is placed between electrodes. The electrical parameters that should be controlled to optimize the process comprises of pulse duration,the field strength, number of pulses and pulseshape.In red bell peppers, membrane permeabilization was augmented by PEF of 1, 1.5 and 2 kV strength field pulse with a steady pulse number of 20 and pulse duration 400 ± 50 µs was used[26& 27]. The OD treatment was given with sucrose/NaCl solution, 21.9 ºBrix and 2 ºBrix, respectively, and 50 ºBrix sucrose solution at 30 ºC. Although water loss was augmented by 11-25 %, solid gain was improved by only 2-5 % in comparison with untreated samples. Also the authors observed that after PEF, pore creation and pore development in cell membrane was time dependent and moreover it is not an instantaneous process. The basic PEF processing set-up consists of a capacitor, a voltage power supply, a charging resistance, a discharge switch and a treatment chamber[25].The PEF circuit that produces square pulse and exponential decay pulse were given in figure 4 & figure 5 respectively[36].The application of electric fields results in breakage of cell wall, cell membrane, pore formation or compression of cell membranes. Electrical breakage phenomenon is irreversible.

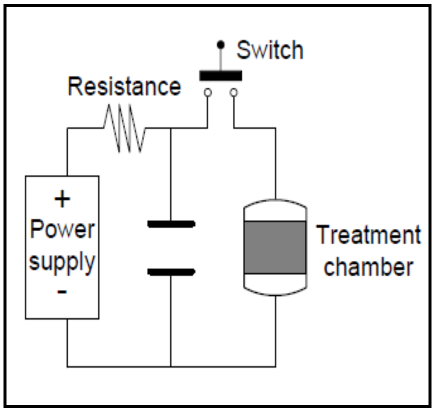

Fig. 4 PEF circuit – exponential decay pulse

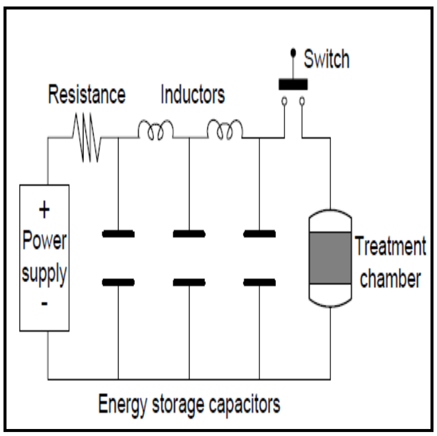

Fig. 5 PEF circuit – produces square pulse

Gamma – Irradiation and OD

Ionizing radiation (IR) is one of the most controversial food preservation methods. In 1992 even though WHO considered IR as nutritionally adequate and a safe method under the established Good Manufacturing Practice, several consumers still remain skeptical[28]. The maximum dose applied does not usually exceed 10 kGy, but there is no maximum limit recommended by WHO. During IR, gamma radiation from isotopes e.g. 137Cs, 60Co, or electron beams were used. Compared to their food penetration the manipulation costs are high.

The 137Cs, 60Co irradiation enhance food penetration, except it leads to environmental risks and operation costs are high[29].Electron beams are easy to control and do not involve such risks. IR is considered a viable fumigant. In some cases it increases the product quality and shelf life[30]. A 1.74 kGy/h radiation is used to study the permeability of Witloof chicory. The radiation increased its membrane permeability, at the same time enhanced enzymatic browning[31].To avoid this IR technique should be used in combination with other techniques.

Vacuum Centrifugal force and Osmotic Dehydration

The vacuum pressure (VP) technique is more commonly used [32, 33 & 34]toimprove mass transfer rate during OD. The effect of mechanical vacuum osmotic dehydration (VOD), pulsed-vacuum osmotic dehydration (PVOD) on the mass transfer behavior using coconut pieces were studied[35]. The values of SG, WR and WL were comparatively higher than ordinary atmospheric pressure (OD) treatment. This may be due to the hydrodynamic mechanism which resulted in increased capillary action[34]. But the texture and color of the coconut pieces were affected by the vacuum pretreatment. The microstructure of PVOD treated samples were more deformed when compared to non-pretreated samples.

Conclusion

Osmotic dehydration (OD) is one of the most promising pre-treatment techniques. It gives product of high quality and preserves reasonably good quantity of naturally occurring microelements and vitamins in fruits and vegetables. It also provides good returns in terms of less energy consumption, palatable, aesthetically acceptable and consumerpreferred product. It is found that using techniques like chemical treatment, mechanical treatment, blanching, high hydrostatic pressure, high electric field pulse, gamma irradiation and vacuum centrifugal force before or with osmotic dehydration will increase the efficiency of osmotic degradation in terms of drying rate and mass transfer rate.

References

1. Janisiewicz, W.J., W.S. Conway and B.Leverentz. 1999. Biological control of postharvest decays of apple can prevent growth of Escherichiacoli O157:H7 in apple wounds. Journal of Food Protection. 62:1372-1375.
2. 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.
3. Torres, J.D., P. Talens and I.A Escriche. 2006. Chiralt Influence of process conditions on mechanical properties ofosmotically dehydrated mango. Journal of Food Engineering.74: 240-246.
4. Rastogi, NK and K. Raghavarao. 1997. Water andsolute diffusion coefficients of carrot as a function of temperature and concentration during osmotic dehydration. Journal of Food Engineering. 34:429-440.
5. 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
6. Fernandas, F.A.N., Gallao, M.I., Rodrigues, S.,2009. Effect of osmosis and ultrasound on pineapple cell tissue structure during dehydration. Journal of Food Engineering 96: 498-504.
7. Feng, H. and J. Tang. 2003. Heat and mass transfer modeling in microwave and spouted bedcombined drying of particulate food products. In Transport Phenomena in Food Processing, eds. J. Welti-Chanes, F. Velez-Ruiz, G.V. Barbosa-Cánovas 521-538. New York, NY: CRC Press.
8. Beaudry, C., G.S.V. Raghavan, and T.J. Rennie. 2003. Microwave finish drying of osmotically dehydrated cranberries. Drying Technology 21(9): 1797-1810.
9. Kim, M.H. and R.T. Toledo. 1987. Effect of osmotic dehydration and high temperature fluidized bed drying on properties of dehydrated Rabbiteye blueberries. Journal of Food Science 52(4): 980-984, 989
10. Grabowski, S., M. Marcotte, M. Poirier, and T. Kudra. 2002. Drying characteristics of osmotically pretreated cranberries: Energy and quality aspects.URL:http://cetcvarennes.nrcan.gc.ca/eng/publication/r2002083e.html
11. Feng, H., J. Tang, D.S. Mattinson, J.K. Fellman. 1999. Microwave and spouted bed drying offrozen blueberries: The effect of drying and pre-treatment methods on physical properties and retention of flavour volatiles. Journal of Food Processing and Preservation 23:463-479
12. Grabowski, S. and M. Marcotte. 2003. Pretreatment efficiency in osmotic dehydration ofcranberries. In Transport Phenomena in Food Processing, eds. J. Welti-Chanes, F. Velez-Ruiz, G.V. Barbosa-Cánovas 83-94. New York, NY: CRC Press.
13. Yang, C.S.T. and W.A. Atallah. 1985. Effect of four drying methods on the quality of intermediate moisture lowbush blueberries. Journal of Food Science 50(5): 1233-1237.
14. Crapiste, G.H. 2000. Simulation of drying rates and quality changes during the dehydration of foodstuffs. In *Trends in Food Engineering*, eds. J.E. Lozano et al. 135-148. Lancaster, PA: Technomic Publishing Company.
15. Zawistowski, J., Billaderis, C.G., Eskin, N.A.M. 1991. Polyphenol oxidases. In D.S. Robinson and N.A.M. Eskin, eds., oxidative enzymes in foods, London, Elsevier, pp.217 – 273.
16. Venkatachalapathy, K. and G.S.V.Raghavan. 1998. Microwave drying of osmotically dehydrated blueberries. Journal of Microwave Power and electromagnetic energy. 33(2): 95-102.
17. Tulasidas, T.N. 1994. Combined convective and microwave drying of grapes. Ph.D Thesis for Agricultural and BiosystemsEngineering, McGill University.
18. Saravacos, G.D., Marousis, S.N., and G.S.Raouzeos. 1988. Effect of ethyl oleate on the rate of air drying of foods. Journal of food Engineering. 7:263-270.

19. Kehinde A. Taiwo, Alexander Angersbach and Dietrich Knorr, 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.
20. Mujumdar, A S. 1992. Innovative industrial drying technologies of the future. Drying of solids. Edited by A.SMujumdar.
21. Taiwo K. A., Enhtiaghi M. N., Ade-Omowaye B. I. O., Knorr D., 2003, Osmotic dehydration of strawberry halves: influence of osmotic agents and pre-treatment methods on mass transfer and product characteristics, International Journal of Food Science and Technology, 38 693-707.
22. Azoubel P. M., Murr F. E. X., 2000, Mathematical modelling of the osmotic dehydration ofcherry tomato (Lycopersiconesculentumvar.cerasiforme), Ciência e Tecnologia de Alimentos, 20 2 Campinas May/Aug.
23. Asaka, M and Hayashi, R 1991. Activation of polyphenoloxidase in pear fruits by high pressure treatment. Agric. Biol. Chem. 55(9):2439-2440.
24. Anese, M., Nicoli, M.C., Dall'Aglio, G., Lerici, C. R. 1995. Effect of high pressure treatments on peroxidase and polyphenoloxidase activities. J. Food Biochem. 18:285-293.
25. Rastogi N. K., 2003. Application of high- intensity pulsed electric fields in food processing, Food Reviews International, Vol. 19 (3) 229-251.
26. Ade-Omowaye B. I. O., Angersbach A., Taiwo K. A., Knorr D., 2001, Use of pulsed electric field pre-treatment to improve dehydration characteristics of plant based foods, Trends in Food Science & Technology, 12 285-295.
27. Ade-Omowaye B. I. O., Talens P., Angersbach A., Knorr D., 2003, Kinetics of osmotic dehydration of red peppers as influences by pulsed electric field as pre-treatment, Food Research International, 36 475-483.
28. Delincée H., 1998, Detection of food treated with ionizing radiation, Trends in Food Science &Technology, 9 73-82.
29. Pradell T., 2003, Irradiaciód'aliments, Industriaalimentària. Tecnologiesemergents, (MercèRaventós Santamaria), Edicions UPC, Barcelona.
30. Jakabi M., Gelli D. S., Torre J. C. M. D., Rodas M. A. B., Franco B.D. G. M., Destro M. T., Landgraf M., 2003, Inactivation by ionizing radiation of Salmonella Entiritidis, Salmonella Infantis, and Vibrio Parahaemolyticus in oysters (CrassotreaBrasiliana)., Journal of Food Protection, 1 June 66 (6) 1025-1029.
31. Barat J. M., Chiralt A., Fito P., 2001, Effect of osmotic solution concentration, temperature and vacuum impregnation pretreatment on osmotic dehydration kinetics of apple slices, Food Science Technology International, 7 (5) 451-456.
32. Moreno J., Burgueño G., Velasco V., Petzold G., Tabilo-Munizaga G., 2004, Osmotic dehydration and vacuum impregnation on physiochemical properties of Chilean papaya (*Caricacandamarcensis*), Journal of Food Science, 69 (3) 102-106.
33. Cháfer M., Gónzalez-Martínez C., Fernández B., Pérez L., Chiralt A., 2002, Effect of blanching and vacuum pulse application on osmotic dehydration of pear, Food Science Technology International, 9 (5) 321-328.
34. Zhao, Y. and J. Xie. 2004. Practical applications of vacuum impregnation in fruit and vegetable processing. Trends in Food Sci. and Technol.15: 434–451.
35. PimjaiManeepan and WichamaneeYuenyongputtakal. 2011. Osmotic dehydration of coconut pieces: Inflence of mass transfer and physical characteristics. Kasetsart J. Nat. Sci. 45 : 891 – 899.
36. JustynaWarczok, 2005. Thesis submitted on concentration of Osmotic dehydration solutions using membrane separation processe . Pg 14, 15.

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