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Recent Developments In Osmotic Dehydration Technique For Improving The Post-Harvest Quality Of Fruits And Vegetables.

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ABSTRACT

Post-harvest management of fruits and vegetables is the major concern of most of the Food Processing Industries. To satisfy the growing market demand for commodities in a fresh like state, minimal processing such as osmotic dehydration is being extensively used. Osmotic dehydration, a less energy intensive process when compared to other drying techniques, helps to improve the nutritional and sensory attributes of food products, besides extending the shelf life. It is a versatile process for the infusion of bioactive compounds to produce functional foods which increase commercial market opportunities. Recently, the combination of osmotic dehydration with other non-thermal processes has gained much importance. High pressure and pulsed electric field treatments combined with osmotic dehydration have shown improved dehydration rates in the production of intermediate moisture products with high quality characteristics. Ultrasound treatment during osmotic dehydration resulted severe changes in cell structure. Vacuum applied prior to osmotic dehydration improved the porous structure of the food material, which enhances the mass transfer. Osmodehydro-freezing, a novel technology can develop products with increased textural and quality characteristics with prolonged shelf life. Furthermore, the understanding of mass transfer mechanism during osmotic dehydration plays an important role in devising novel applications of this technique in food processing.

Keywords: Osmotic dehydration, Functional foods, Vacuum impregnation, osmodehydro-freezing.

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INTRODUCTION

Post-harvest management of fruits and vegetables is a crucial step to increase the quality characteristics. The main aim of post-harvest management is to add value to the produce and there is also a need for efficient post-harvest management system for the production of sustainable products with high quality and shelf life [8].

India is largest producer of fruits and vegetables next to China. India being the fruit and vegetable basket in the world faces much of post-harvest losses that occur due to poor storage facilities, poor conditioning facilities. Production practices have a major impact on the overall quality of fruits and vegetables that are produced. Efficient storage and transportation techniques have to be used to reduce the post-harvest losses that are incurred in this country. Quality cannot be improved after harvest it can only be maintained. There is a greater need for efficient tools for the post-harvest management of fruits and vegetables in India [5].

Osmotic pressure has an inhibitory effect on microorganisms. Most of the microorganisms like bacteria, yeasts and molds do not proliferate at $P > 12.7$ MPa, $P > 17.3$ MPa, and $P > 30.1$ MPa, respectively. Therefore the shelf life of the product can be increased by the osmotic pressure of the solution in the material [15].

Overview of Osmotic dehydration process:

Osmotic dehydration is a water removal technique which is characterized by soaking the food stuff in the hypertonic solutions of sugars, salts, alcohols etc., and the resultant product is of intermediate moisture content having moderate water activity to low water activity. At this low water activity, the chemical reactions and microbial growth are ceased [34].

Osmotic dehydration is a complementary food preservation technique, which is used as pretreatment for dehydration of fruits and vegetables. It is a process of counter current transfer of mass, in which solute flows to the food, while water present in the food comes out [1].

Osmotic treatment is a multicomponent transfer process in which simultaneous, countercurrent solution flows with a combination of dehydration and impregnation of the tissue matrix, which minimizes the negative modifications of fresh food components[25].Raoult-Wack, (1994) defined osmotic dehydration as dewatering impregnation soaking (DIS) [29]. DIS can induce different effects on the raw material with different variables like temperature, time, type of solute, surface area, mass ratio of product to the solution etc.,[39].

Osmotic dewatering also enables water removal and modification of the chemical composition of the material without much affecting the integrity of the product. Osmotic dehydration can remove 30 to 40% of moisture from the product depending on the process variables. Water loss during the initial phases of osmotic dehydration is higher when compared to the end stages of osmotic dehydration [36]. Moisture is removed mainly by the capillary flow and diffusion in the fruits. The flux of osmo active substance is lower than water. For this reason it is called osmotic dewatering.

Osmotic dehydration and its mass transfer rates mainly depend on the semi permeability of the cell membrane and the cell architecture [1]. Since it is a dynamic process, mass transfer occur due to osmotic pressure gradient. Difference in osmotic pressure of two systems i.e., the fruits and the hypertonic solution is the cause for mass transfer [15].

During the course of osmotic dehydration process, water is transported by several mechanisms which occur simultaneously. The mechanisms for transport include molecular diffusion, liquid diffusion, vapor diffusion (through gas flow), hydrodynamic flow, capillary transport, surface diffusion[25].Most frequently a combination of these mechanisms is observed

The mass transfer process includes the following[6]:

1. Water and solutes are transported because of concentration gradients of diffusion process

2. Water and solutes are transported by capillary flow because of the differences in total system pressure which caused by external pressure, shrinkage and capillarity
3. Hydrodynamic flow occurs
4. Water vapor diffusion occurs within partly filled or because of the capillarity- condensation mechanism
5. Water diffusion occurs at pore surfaces because of gradients at the surfaces

Recent advances in osmotic dehydration to increase the mass transfer rates in fruits and vegetables

Since the mass transfer rates depend on many process variables, many methods have been evolved to enhance the mass transfer during osmotic dehydration process.

Ohmic heating and osmotic dehydration:

Ohmic heating (OH) is a thermal process in which the food is heated by an electric current where in food serves as an electric resistor. The electrical energy is dissipated into heat; as a result the product is heated. Based on the properties of electrical resistance, heat is internally generated in the food products. Ohmic heating along with vacuum dehydration is said to prolong the shelf life osmotically dehydrated products [33].Moreno *et al*., (2011) reported extension of shelf life to 25 days by subjecting the fruits to osmotic treatment at 5ºC under vacuum and Ohmic heating at 13V/cm at 30°C. Moreno *et al*.,(2011) demonstrated that the mass transfer mechanism during osmotic dehydration is enhanced the application of Ohmic heating. The mechanism for the extension of shelf life is due to the deactivation of polyphenol oxidase enzyme which is present in most of the fruits and vegetables [20].

Pulsed electric treatments during osmotic dehydration:

Consumer concerns for the nutritional and health based characteristics are increasing day by day. Pulsed electric fields (PEF) involve the application of high voltage energy (typically 0.5–80 kV/cm) in form of very short pulses (microseconds to milliseconds) to foods placed between two electrodes, causing structural changes in the food product or any biological tissue. This phenomenon could be called as electroporation or electro compression[18].Pulsed electric field (PEF) is a process which modifies the membrane permeability by the application of high voltage short time pulses[2].

Tylewicz et al., (2017) studied the effect of pulsed electric fields combined with osmotic dehydration on the physic chemical properties of organic strawberries and reported that the PEF treatments positively affect the mass transfer, in terms of water loss from the tissue. They concluded that PEF treatment positively affected the mass transfer during OD even at the lowest electric field strength applied (100 V/cm), partially preserving the cell viability and maintaining at the same time the fresh-like characteristics of strawberries [39]. Traffano-schiffo *et al*., (2017)studied the effect of PEF on osmotic dehydration of kiwi fruit using NMR. The pre-treatment included three different voltages (100, 250. And 400 volts) and 60 number of pulses. The results showed a substantial decrease in the water activity of the product. The PEF treatments also result in significant increase in water loss and solid gain, by reducing the dehydration time. PEF treatment is considered as a novel technology that balances the nutritive quality, appearance and dehydration rate [37]. Yu *et al*., (2017) reported that the PEF pretreatments significantly enhanced the efficacy of osmotic dehydration, and the PEF treatment reduced the chemical degradation and increased the migration rate than thermal pretreatment[41].

High hydrostatic pressure and osmotic dehydration:

High hydrostatic pressure treatment (HHP) is used in most of the industries to increase the product stability by inhibiting microorganisms and enzymes present in the food. High pressure treatment increases cell permeability as it alters the cell wall structure. The index of cell disintegration increases with time and application of high pressure. This phenomenon is used to increase mass transfer rates during osmotic dehydration process if the food material is treated with high pressure prior to the contact with osmotic solution [20]. The process is applied to change the functional, rheological, textural properties of the food material. Combination of osmotic dehydration and high hydrostatic pressure leads to cell dehydration and soluble solid gain till the system reaches equilibrium in which the net transport mechanism is negligible. Moreover, this process also invokes changes in the food product as there are physical and chemical changes that occur throughout the process[5]. Simultaneous application of osmotic dehydration and high hydrostatic pressure on strawberry was investigated by Nuñez-mancilla *et al*, (2013), in the range from 100 to 500 MPa. They also reported that total phenolic content of the samples increased with pressure treatments. Many researchers reported a substantial increase in mass transfer rates during osmotic dehydration when combined with high hydrostatic pressure treatments [20].

Ultrasound and osmotic dehydration:

In a solid medium sound waves cause a series of rapid and successive compressions and rarefactions, depending on their frequency. The mechanical and physical effects of sound can be used to enhance the mass transfer during diffusion process [12, 21]. The use of ultrasound technique is a novel approach for developing novel food products and is of great importance in the food processing industry. Primarily ultrasonic waves with high power at low frequency (20-100 kHz) are applied at minimal temperature to stimulate a rapid series of alternative expansions and compressions, which results in the removal of moisture from the product and also provide a sponge like effect. The mechanism is of great relevance to the drying and dewatering of foods. Cavitation is the distinct phenomenon that is produced as a result of sonication is characterized by the formation of bubbles in liquid, which collapse explosively in generalized pressure fluctuations. Diffusion across the boundary between the suspended solid and the liquid is substantially increased in the presence of ultrasonic field. This effect increases the diffusion during osmotic treatment as degassing of the tissue is accelerated [12].Cheng *et al,.* (2014)studied the effect of pulsed vacuum treatment and ultrasound treatment during osmotic dehydration process, wherein they found that the samples treated with ultrasound showed highest water loss and decrease in firmness [4].

Ultra sound treatment leads to the formation of microscopic channels and through these channels, the osmotic solution flows into the intercellular spaces of partially dried materials [10].When the intensity rates are increased, there is a gradual increase in mass transfer during osmotic dehydration. This is mainly due to intense turbulence or vapor locks at the boundary [28]. The application of continuous high frequency ultrasound enhances the mass transfer during osmotic dehydration process. Ultrasound in the combination of high frequency and sugar concentration increases the rate of dewatering from the tissue and speeds up the dehydration time. Ultrasound assisted osmotic dehydration involves dipping of fruits and vegetables in hypertonic solutions where ultrasound is applied. The process does not need any thermal assistance, as both osmotic dehydration and ultrasound are non-thermal processes. This process is beneficial as there is no heat, so there is no thermal degradation of the product [32].Ultrasound - osmotic dehydration technology can be carried out at low solution temperatures to obtain higher water loss and solid gains, while preserving the natural flavor and nutritional components. Ultrasound combined with osmotic dehydration induced changes in pineapple and melon structure and the water diffusivity was increased when the treatment was given for more than 30 mins as there is formation of microscopic channels and rupture of cells. The water diffusivity decreased with osmotic solutions of high soluble solid contents [9,25].

Gamma irradiation and Osmotic dehydration:

Gamma irradiation is widely used to extend the shelf life of a fresh food product. It helps to retard the growth of microorganisms, sprouting of vegetables, insect disinfectant and sterilization of foods. The inner structure of food materials is altered due to the exposure to gamma radiation. It recompenses the tissue structure and increases the permeability, which helps in improving mass transfer during osmotic dehydration process [29]. Wang & Chao, (2003) studied the effect of gamma radiation on the drying quality, appearance characteristics, vitamin C, rehydration ratio and dehydration characteristics of potato. They concluded that the grater the dose, the higher the dehydration rate, the lesser the vitamin C content, and lower the rehydration ratio [40].

The combined effect of osmotic dehydration and gamma irradiation on carrots was studied by Rastogi, (2005). They concluded that solution diffusivity values were lower when compared to the water diffusivity values during rehydration of osmotically treated and gamma irradiated carrot samples. The use of 10 °Brix during the combined process resulted in minimal water uptake and higher solute loss[27].Rastogi *et al.,* (2006) studied the combined effects of osmotic dehydration and gamma irradiation on potatoes. They concluded that the application of gamma radiation (3.0- 12.0 kGy) reduced the firmness of the potatoes and thus enhanced the diffusion rates. This is attributed to the increase in the cell wall permeability after the exposure to gamma radiation [29].

Pulsed vacuum osmotic dehydration (vacuum impregnation):

Vacuum impregnation is widely applied in the food processing industry for developing novel dehydrated products. The method is highly beneficial for rapid transfer of liquids into the tissue in a controlled manner [11].The osmotic dehydration process can be conducted at both atmospheric pressure and at vacuum. The reduction in pressure leads to expansion of the food material and occlusion of gases in the pores. As the pressure is restored, the pores can be filled with the osmotic solution, thereby enhancing the surface area for mass.

Vacuum treatment of foods in osmotic solutions causes subsequent compression and expansion of occluded gases in the food materials due to hydrodynamic mechanism which is highly dependent on pressure. After the initiation of hydrodynamic mechanism, the uptake of solid and the water loss is increased, hence reducing the drying time and improving the product [13].

There are many considerations in order to develop suitable conditions for pulsed vacuum osmotic dehydration process which include type of osmotic agent used, the geometrical shape of the food material, and the porosity of the sample [3].Vacuum is applied for 10 to 20 mins and then it is released, this constitutes different pulsed vacuum osmotic dehydration cycles, which in combination with osmotic pressure gradients lead to compression and relaxation of food matrix, thus enhances the mass transfer during osmotic dehydration [31].

Osmodehydro freezing:

Lowithun & Charoenrein, (2009) stated that Osmodehydro-freezing refers to the combined process which includes partial dewatering by osmotic dehydration followed by freezing. Osmotic dehydration combined with freezing process actually reduced the energy required for ice crystal formation during freezing process and also reduces distribution and packaging cost [17]. This method helps to develop products with better textural properties like lesserdrip loss and structural collapse [7]. The moisture content of fresh fruits and vegetables is minimized during osmotic dehydration process, thus resulting less water available for freezing. This intern minimizes the changes in the quality of food product after thawing operation [38]. Many researchers found that osmotic dehydration combined with freezing showed a better product with high textural characteristics. Tregunno & Goff, (1996) studied the structural effects of osmotic dehydration on apples. They reported increased firmness in the apples in the presence of sugars [38].

Microwave assisted osmotic dehydration:

Very few researchers carried out their research on microwave assisted osmotic dehydration. Some of them combined microwave and vacuum during osmotic dehydration of apples, blueberries, strawberries, potatoes, tomatoes and mushrooms, in the production of high quality dehydrated products [14, 24, 34, 36]. Torringa *et al.,* 2001 studied the effect of microwave and vacuum during osmotic dehydration of mushroom samples. They concluded that the combined process minimized the shrinkage and drying time, whereas the dielectric properties were changed which resulted in the enhancement of solute uptake, porosity and rehydration characteristics [36].

The application of micro waves to the osmotic system increased the temperature of the osmotic solution and the product, which accelerated the evaporation of the moisture from the food materials. The osmotic pressure is higher which is developed between the solid matrix of the product and liquid surface, which results in the increase in the mass flow rate. The overall ratio of water loss and slid gain is higher in microwave assisted osmotic dehydration than in the osmotic dehydration alone.

The influence of micro-wave power, temperature and air velocity on the final drying kinetics of osmo-dried bananas was studied by Pereira, *et al*, (2007). They concluded that increasing the power of micro- wave minimized the drying time and enhanced the overall quality of the final product [22]. Heredia *etal.*, 2007 treated the cherry tomatoes with microwaves prior to osmotic dehydration with hypertonic solutions formulated consisting of sugar, calcium lactate and salt. They concluded that the samples treated with osmotic solutions with composition of 27.5% sucrose, 10% salt and water, with 2% calcium lactate in conjunction with micro- wave assisted air drying resulted in intermediate moisture and dried tomato products with better quality attributes and longer shelf life than the untreated samples [14].

The influence of microwave-assisted air drying on apple cubes with or without osmotic pre-treatment with sucrose solution as an osmotic agent followed by microwave assisted air drying at various temperatures (50, 60 and 70 °C) was studied by Prothon *et al.*, (2001). The infusion of sucrose in to the tissue resulted in the reduction in the drying rate and enhanced the quality of the final product. The effective diffusivity of moisture and rehydration capacity is lower than the untreated samples [24].

CONCLUSION

The technologies which are being developed should be used in order to improve the value addition to fruits and vegetables in the preparation of many products. Osmotic dehydration itself is a very good food preservation technique that is being used for many years. Tailor made food products can be made with osmotic dehydration when it is combined with the technologies that are being developed. These technologies not only increase the novelty of the products but also increase the quality of the products.

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