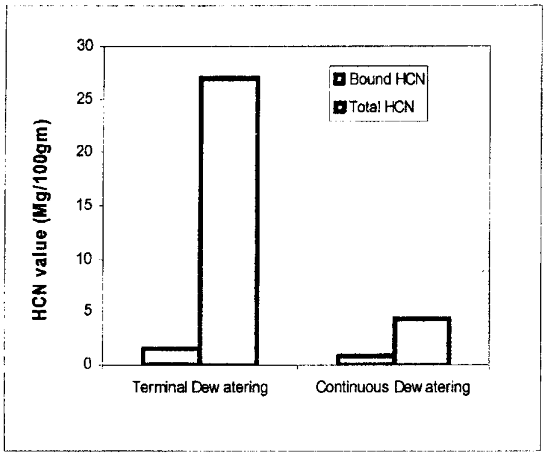

Fig 1: Effect of dewatering method on cyanide content of gari

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REVIEW OF OSMOTIC DEHYDRATION OF FRUITS AND VEGETABLES FROM THE PERSPECTIVE OF ITS POTENTIAL APPLICATION IN FOOD PROCESSING IN NIGERIA

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ABSTRACT

Traditional sun and hot air drying appear to be the major preservation methods employed in Nigeria owing to poor energy system and slow advancement in technological development. Excessive dependence of traditional sun drying on climatic conditions has made the method inadequate as an effective response to recurrent post–harvest losses encountered yearly in the country. Besides, evidence abounds to the effect that conventional drying of fruits and vegetables affects their physical and biochemical status leading to shrinkage and alterations in nutritional and organoleptic properties.

The relationship between consumption of fruits, vegetables and health necessitated the need for particular attention not only to be focused on their nutritional composition but also on the continual development of technological processes that are more effective for preserving these products in a form most acceptable to consumers.

Osmotic dehydration is a process which partially removes water from cellular materials. This method has recently been receiving increased attention as a potential pretreatment to conventional processes such as terminal drying for quality improvement of fruit products and for energy consumption reduction in such processes. In particular, the effectiveness of the osmotic drying process at ambient temperature may, from the point of view of minimizing energy demand, be one of the most powerful indications of its appropriateness in food processing in Nigeria.

In this paper, the potentials of incorporating osmotic dehydration as a complimentary processing step in the processing of foods in Nigeria are explored.

Keywords: Tropical food materials, post-harvest losses, osmotic dehydration, Nigerian food processing, quality preservation.

INTRODUCTION

Plant foods are the primary basis for human food supply of which fruits and vegetables play a very important role in the human diet. The concentrated activities of several researchers on improving agricultural technology have resulted in increased world production of fruits and vegetables (Jayaraman and Gupta, 1995). The continuous emphasis of government of Nigeria on agriculture has led to massive production of food including fruits and vegetables. However, the post-harvest life span of many fresh fruits and vegetables is relatively short. Consequently, more than ever before a larger proportion of important fruits and vegetables is handled, transported, and marketed all over the country with concomitant losses that call for more suitable post-harvest techniques for processing and storage to ensure improved shelf-life.

An estimate of food losses due to spoilage and mishandling in the lesser and underdeveloped countries has been stated to be between 25 and 40% (Jagtiani et al., 1987). There is, therefore, the need to develop simple, low-cost practicable methods for prolonging the shelf-life of food products so as to allow greater flexibility in local marketing and possibly, encourage export to neighbouring countries.

Mass production of dried foods is often accomplished in Nigeria through the use of the traditional method of sun and hot air drying owing to lack of adequate equipment. The traditional method of sun drying has been shown to depend largely on climatic conditions and that the resultant quality and yield of such dried products are negatively affected due to uncontrolled conditions of dehydration. Conventional hot air drying has also been demonstrated to result in low thermal efficiency, lengthy drying time and losses of volatile flavour and aroma components upon exposure to heat (Van Arsdel et al., 1973; Yongsawatdigul and Gunasekaran, 1996).

Increasing consumer markets for minimally processed fruits and vegetables, which retain their natural characteristics alongside with high nutritive and organoleptic qualities, have prompted researchers to study suitable technologies considered as milder techniques that preserve the prime qualities of fruits and vegetables. One of these technologies is osmotic dehydration at mild temperature.

Osmotic dehydration is a process that results in intermediate moisture products having microbiological stability due to reduced water activity. Osmotic dehydration techniques in fruit preservation have been widely applied as they have inherent advantages over the traditional drying process. Fruits and vegetables are not subjected to high temperatures, thus minimizing changes in nutritional and sensory attributes such as colour, aroma, flavour and texture (Fito et al., 1995; Heng et al., 1990; Raoult–Wack, 1994; Shi, 1994). The absence of phase change during osmotic dehydration but present in conventional drying process, conserves the integrity of the food structure in significant degree (Forni et al., 1987; Giangiacomo et al., 1994; Torreggiani and Bertolo, 2000).

Osmotic dehydration is employed as a pretreatment to other terminal processes. Because of intermediate level of water activity achieved, it does not in itself yield a shelf-stable end product but improves sensorial, nutritional and functional properties of food while preserving its integrity (Torreggiani, 1993). The interest in introducing the osmotic dehydration process into conventional processes has two main objectives, namely: quality enhancement and energy conservation (Ponting et al., 1966; Heng et al., 1990; Lewicki and Lenart, 1995). It generally precedes processes such as freezing, conventional drying, and dehydrofreezing (Nieto et al., 1998).

Active research in the area of osmotic dehydration of fruits and vegetables is continuing all over the world. Considering the importance of the technique and the future potential it holds, the European Commission funded a related project titled "Improvement of food quality by application of osmotic treatments in conventional and new processes (FAIR – CT 961118)" headed by Professor W.E.L Spiess, of the Federal Research Center for Nutrition, Karlsruhe, Germany, involving 13 other European countries as partners. During the last 20 years, there has been a strong research and industrial development in the osmotic dehydration process. A very large number of papers and patents have been an important output of the concerted effort. Several reviews have been written on the subject (Ponting, 1973; Fito et al, 1994; Fito et al, 1998; Lazarides et al, 1999; Rastogi et al., 2002). Among the several process technologies commonly used on an industrial scale to preserve fruits and vegetables are dehydration, juice extraction and freezing. However, dehydration is especially suited for developing countries such as Nigeria with poorly established facilities for low temperature and thermal processing. Blanching and various chemical pre–treatments have been demonstrated to lower drying time significantly in comparison to controls (Shi et al., 1997; Ade-Omowaye et al., 2001). However, chemical and thermal pretreatment may confer negative quality on the product (Shi et al., 1997). Osmotic dehydration has therefore, been proposed as having potentials as a pre-processing step in further dehydration of fruits and vegetables.

Considering the multiple advantages of osmotic dehydration and most especially, its effectiveness at ambient temperature its potential application in Nigerian Food Processing is worth exploring. This paper therefore, sets out to undertake a brief review of its mechanism, the parameters affecting mass exchange rates during the process, food applications of osmotic dehydration generally and its potential uses in Nigeria or other developing countries.

THE THEORY OF OSMOTIC DEHYDRATION

Osmotic dehydration uses the principle of osmosis to concentrate the cellular content of bio-materials such as fruits and vegetables by placing the food tissue whole or in pieces into hypertonic solutions with high osmotic pressure. The complex cellular structure of food materials acts as a semi permeable membrane for transfers between the food tissue and the osmotic solution. Osmotic dehydration proceeds until the water activity of both the solution and the product reach equilibrium. At equilibrium, the chemical potential of water in the food tissue (μ_w) and in the osmotic solution (μ_s) become equal. Water activity is related to the chemical potential as shown below:

$$\mu_w = \mu_s \quad (1)$$

where: $\mu_w = \mu_o + P_1V$; $\mu_s = \mu_o + P_2V + RT\ln(P/P_o)$; μ_o is the chemical potential at standard conditions, V is the partial molar volume of water, P_1 and P_2 are the pressures exerted on the water (in the food tissue) and osmotic solution respectively necessary to maintain equilibrium; and P and P_o are partial pressure of water and saturation vapour pressure of water, respectively. Substituting the values of μ_w and μ_s in Eqn. 1, the following equation result:

$$\Pi = -(RT/V)\ln a_w \quad (2)$$

where Π, (osmotic pressure) is equal to $(P_2 - P_1)$ and a_w is equal to P/P_o. For non–ideal solutions, an activity coefficient (Y) is introduced to account for the deviation from ideality. Hence,

$a_w = Y x_w$, substituting the value of a_w in Eqn. 2 gives the following equation:

$$\Pi = -RT/V \ln(Y x_w) = C_e RT \quad (3)$$

where C_e is the equivalent concentration in the case of concentrated solution and is equal to $\ln(Y x_w)/V$. Since in foods, water is the solvent specie Eqn. 3 can be simplified to

$$\Pi = -4.6063\ 10^5\ T \ln a_w \quad (4)$$

In the mechanisms reported earlier, it has been proposed that during osmotic dehydration a superficial layer 2-3 mm thick forms in the product that has a major effect on mass exchange favouring water loss, while limiting solute deposition and reducing the loss of water soluble solutes (Marcotte and Le Maguer, 1992; Raoult–Wack, 1994).

As mentioned earlier, mass transfer during osmotic dehydration process occurs through the semi–permeable membranes of the cells which have been shown to be a dominant resistance to mass transfer in biological materials. Rastogi et al (2002) described another mechanism for osmotic treatment in which the changes in the state of the cell membrane was taken into consideration. They showed that the state of cell membrane could change from partial to total permeability resulting in significant changes in the tissue architecture. In the earlier mechanism proposed by several authors, it was generally assumed that constant rate diffusion occurs under the influence of a uniform moisture gradient. However, in the mechanism for cellular biological materials proposed by Rastogi et al (2002), it was suggested that the dehydration front moves during osmotic dehydration towards the center of the materials. This has been demonstrated to result in cell membrane permeabilisation in the dehydration region and the water transported across three different regions (each with its own characteristic properties) as follows: diffusion of water from the core of the material to the dehydration front, diffusion of water across the front and diffusion of water through the osmotically treated material into the surrounding medium.

During osmotic dehydration, at least two major simultaneous counter-current flows occur, namely: water flows out of the food into the solution and a simultaneous transfer of solute from the solution into the food takes place both due to the water and solute activity gradients across the cell membrane. As the membrane is only partially selective, there is always some leakage of solute from the food into the solution which although it may be quantitatively negligible, is nevertheless recognized as possibly affecting the sensory, nutritional and functional properties of the final product (Torreggiani, 1993).

Osmotic dehydration can be done basically by either a static or dynamic process. In a static process, food material is mixed with an osmotic agent, which can either be used as solids or solution and the mixture is left motionless until the desired water loss or solute uptake is achieved. In a dynamic process in contrast, the osmotic agent is mixed and different methods of mixing are possible (Lewicki and Lenart, 1995).

Process Parameters Affecting Mass Exchange Rates in Osmotic Dehydration

Mass transfer rates during osmotic dehydration have been shown to depend upon several factors including temperature, the concentration and type of osmotic medium, size and geometry of the sample, sample to solution ratio, degree of agitation of the solution, osmotic conditions, product pretreatment, etc. (Shi and Fito, 1994; Garrote and Bertone, 1989; Sharma et al., 1998; Rastogi et al., 1999; Ade–Omowaye et al., 2002).

The effect of concentration and temperature of the osmotic solution have been studied in detail and it has been shown that the rate of osmotic dehydration increases with both parameters (Falade et al., 2003; Panagiotou et al., 1999; Lazarides et al., 1999). A number of recent publications have described the influence of the various variables on mass transfer rates during osmotic dehydration (Raoult-Wack, 1994; Raoult-Wack et al., 1992; Rastogi et al., 1997; Lazarides et al., 1999). It is necessary to underscore that these variables can only be manipulated over a limited range. Outside that range, they adversely affect quality even though mass transfer rates may be enhanced. There is therefore, the need to identify methods that increase mass transfer rates without adversely affecting quality significantly.

The behaviour of mass transfer during osmotic dehydration is also controlled by the micro-structural properties of the food materials. At the beginning of immersion, porosity has an effective influence on mass transfer because gas is entrapped in the cellular tissue (Shi et al., 1995). Treating the food material prior to osmotic dehydration assists in degassing as well as increasing the permeabilisation of the cells. The application of high pressure, damages the cell wall structure (primarily by disrupting the non-covalent bonds), leaving the cells more permeable resulting in increased mass transfer rates during osmotic dehydration as compared to untreated samples (Rastogi et al., 2000; Tangwonchai et al., 2000). The application of pulsed electric field is another novel non–thermal pretreatment method reported to enhance mass transfer during dehydration due to increased permeabilised cells (Rastogi et al., 1999; Barsotti et al., 1999; Ade-Omowaye et al., 2002; Eshtiaghi and Knorr, 2000). Rastogi et al (2002) reviewed recent developments in osmotic dehydration with special emphasis on the various methods employed in enhancing mass transfer during the process. Such techniques include application of ultrasound, partial vacuum or centrifugal force during osmotic treatment.

Considering the technological status of Nigeria, techniques such as the application of centrifugal force and partial vacuum may be adopted in enhancing mass transfer rates during osmotic treatments. Taiwo et al. (2003) in their work showed the significant influence of vacuum application during osmotic dehydration of pretreated strawberry halves. They demonstrated that water loss in samples under vacuum for 2 h was 8-73% greater than those at atmospheric pressure for 4h though the extent depended on the type of pretreatment given prior to osmotic dehydration. Similarly, it was shown that solids-gain under vacuum was greater than under ultrasound treatment while solids-gain at atmospheric pressure was the lowest. Solids-gain under vacuum for 2 h was 5 to 18 % higher than those samples at atmospheric pressure for 4h. Hence it was concluded that the influence of vacuum on solids-gain (5-18%) was not as high as that on water loss (8-73%). Similar findings were also reported on the notable influence of vacuum application on mass transfer rates during osmotic treatments (Talens et al., 2001; Sharma et al.,, 1998; Fito et al., 1994).

Food Applications of Osmotic Dehydration and its Potential Uses in Nigeria

The main industrial food applications of osmotic dehydration are in dried foods, candy and dehydrated vegetables. For commercial success, osmotic drying depends on reuse of strong syrup, which draws water from the raw material. Valdez Fragoseo and coworkers from Mexico and France recently described the reuse of sucrose syrup up to 20 times in the dehydration of apple cubes. The syrup was reconcentrated by evaporation, and while it picked up some reducing sugars and a little colour, it appeared to stabilize, suggesting that further reuse is probably justified.

At present, osmotic dehydration process makes it possible not only to improve but also to radically modify conventional processes. For instance, a new process for the production of fruit and vegetable aromatic concentrates was designed. These concentrates were obtained by introducing an osmotic pre-concentration stage of the fruit pieces, which were then crushed and refined, and were either pasteurized or frozen (Guilbert et al., 1990). Garcia–Martinez et al. (2002) recently reported on the production of kiwi and orange jams using osmotically dehydrated fruits mixed with osmotic solution, without thermal treatment. Recorded quality attributes of jams and marmalades prepared from the combination of osmodehydrated fruits and osmotic solution without thermal treatments were comparable or better than those of commercial products prepared by traditional methods.

Due to the fact that energy is becoming expensive globally, it can be envisaged that osmotic dehydration will gain popularity as a pre-processing dehydration step in the future. Osmotic dehydration can be applied to foods of any structure including products such as seafood, meat etc. Collignan and Raoult–Wack (1993) have demonstrated the possibility of reducing the traditional salting / drying sequence in fish processing through the use of osmotic dehydration process. Dehydrated pawpaw is produced in small and medium-scale industries in Asian countries such as India, Thailand, etc. This is mainly used in such products as fruit bread, cakes and ice creams, etc. Candy and dried fruits are produced from other fruits that include apple, banana, jackfruit, etc. Candied ginger obtained by osmotic dehydration is also a popular product. Employing osmotic dehydration as one of the steps in combined method preservation technologies (so-called handle-technologies) resulted in shelf-stable products from fruits such as pineapple, mango, etc. A more recent development in the use of osmotic dehydration is its potential in concentrating fruit juices (Rastogi et al., 2002).

Excessive post-harvest losses in Nigeria which have been rated to be about 40% can be addressed seriously by employing this simple technique of osmotic treatment to preserving over-abundant fresh produce during the full-production seasons. Since osmotic drying only removes some water, osmo-dehydrated products may later be finish-dried with air. The added sugar not only reduces water activity, but also enhances both taste and texture.

Recent market research in Europe and elsewhere has shown an important demand in dried tropical products (fruit and spices). Entering these buoyant markets supposes, on the one hand, that the product's quality responds to very strict norms and, on the other hand, that the product be plentiful which entails setting up semi-industrial drying units in tropical countries such as Nigeria. Osmotic dehydration as a technique is popular in Europe. For example, France is one of the European countries that has developed technologies for candy and other similar osmotic dehydrated products. Application of osmotic dehydration in Nigeria may create opportunities for processing available tropical fruits such as mangoes, pawpaw, guava, etc in abundance. The resulting products may be exported to demanding markets in Europe and elsewhere. This will assist the country in creating more jobs thereby alleviating the currently experienced high poverty level, in bringing in hard currency thus enhancing the country's foreign reserve and reducing heavy dependency on earnings from oil exportation. This will, in consequence, improve the economic status of the nation. Lastly, it will help to maximize the use of the surplus local products.

CONCLUSION

Considering the steps involved in osmotic dehydration, the technique can be adopted in Nigerian Food Processing with great anticipation of success. Osmotic dehydration may be an efficient way of regulating the imbalance between the supply and demand of fresh produce most especially during the full production seasons. Integrating osmotic treatment into Nigerian Food Processing chain may be an effective way of making fruits and vegetables available throughout the year. This, therefore, suggests an increase in the level of consumption of fruits and vegetables in Nigeria, which has been reported to lower the risk of certain diseases. The economic status of the country may also be positively influenced through the use of osmotic dehydration technique.

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