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Osmotic drying of pineapple

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■ **ABSTRACT :** Osmotic dehydration in hot air drying of pineapple cubes by using sucrose solution is able to improve the quality like colour, aroma, texture, appearance as well as overall accepabilty. Regression equation is used to predict optimum condition for weight reduction, minimal solid gain, maximum water loss and physical properties of dehydrated pineapple cubes. Potassium metabisulphat is most useful for the browning inhibition. Osmotic and infrared dryings are reduced the water activity, which prevents the microbial growth. The dose of 1 kGy radiation is adversely effective in eliminating the residual microbial load on pineapple cubes, thus ensuring microbial safety of the product sensorial accepted during storage. When calcium is use as a component of osmotic solution in the osmotic dehydration of pineapple cubes. Then the calcium is responsible for increasing the mechanical properties, microbial stability and physico-chemical properties of pineapple slices. By using high density polyethylene film inhibits the moisture content of the products and minimal quality deterioration of dehydrated pineapple slices. HDPE film having high moisture barrier material caused minimal change in moisture content of samples, and hence, minimal quality deterioration of dried pineapple slices. Mostly laminated aluminium (Al) is not affected by the ambient storage temperature and suitable for preserving dehydrated pineapple slices. Alone blanching pre-treatment is not suitable for the drying of pineapple slices due to disintegration of negative impact and cell wall observed on the sensory quality. While Sulphiting pre-treatment protects the ascorbic acid from degradation and improved effective moisture transport. In sensory evaluation of pre-treated dehydrated pineapple slices is highly the acceptable. combination of pre-treatments of: 60 per cent sucrose/2500 ppm SO; 40 per cent sucrose/60°C blanching/2500 ppm SO; 60°C blanching/ 2500 ppm SO is suitable for production of dried pineapple slices. The application of different antibrowning agents can be used to prolong the shelf-life of fresh-cut pineapples. The predictions of water content and per cent charred pieces by quadratic surface models are validated with an additional drying experiment, and the use of such models to define multicriteria points of optimum. Drying rates and drying time of pineapple slices are affected by the blanching temperature-time combinations. Increasing the blanching temperature time combinations are increased drying times. The logarithmic model sufficiently describes the drying behaviour of blanched pineapple slices. The Fick's diffusion model is suitable for the experimental results which enabled the determination of the effective moisture diffusivity.

■ **KEY WORDS :** Pretreatments, Drying, Drying models, Pineapple, Ascorbic acid, Osmotic dehydration

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In most tropical developing countries, the natural abundance of tropical fresh fruits often leads to a surplus with regard to the local requirements. Unfortunately, the excess of these fruits is not always fully used, once a limited variety and quantity of tropical fruit products are produced and commercialized. The relatively short shelf-life of fresh fruit after harvest is one of the main factors that demonstrate the necessity of developing an efficient and cheap preservation process. Also, the growing search for products with similar sensory and nutritional properties to fresh fruits, such as minimally processed fruits and vegetables, and for products enriched with some compounds, such as functional foods, also stimulates the food industry to look for new food preservation techniques. One of the techniques being widely studied is osmotic dehydration. The process involves removal of water by immersing them in concentrated aqueous solutions mainly sugar, salt and spices. In osmotic dehydration, three types of counter-current mass transfer occur: (i) water flows from the product to the solution, (ii) a solute transfer from solution to the product and (iii) a leaching out of the product's own solutes (sugars, organic acids, minerals, vitamins, etc.) (Agarry *et al.*, 2013; Aguilara *et al.*, 2004 and Amarowicz and Chavan, 2012). Besides reducing the drying time, osmotic dehydration is used to treat fresh produce before further processing to improve sensory, functional and even nutritional properties. It has been proven to improve the texture characteristics of thawed fruits and vegetables (Bolin *et al*., 1983 and Bothaa *et al*., 2011), decreases structural collapse (Chiralt *et al*., 2001 and Del Valle *et al.* (1988) and retain natural colour as well as volatile compounds during subsequent drying (Islam *et al*., 1982). Water content reduction and sugar gain during osmotic dehydration have been observed to have some cryoprotectant effects on colour and texture in several frozen fruits (Bolin *et al*., 1983).The two most important advantages for its use as pretreatment in a complementary process are: quality improvement and energy saving (Agarry *et al*., 2013). Response surface methodology (RSM) is widely used in food industries. In RSM, several factors are simultaneously varied. The multivariate approach reduces the number of experiments, improves statistical interpretation possibilities, and evaluates the relative significance of several affecting factors even in the presence of complex interactions. It is employed for multiple regression analysis using quantitative data obtained from properly designed experiments to solve multivariate equations simultaneously.

The objectives of this study are to study the osmotic dehydration and effects of pretreatments on shelf-life of pineapple slice. Prediction of shelf-life of dehydrated pineapple slices and to determine the optimum operating conditions (Temperature, Immersion time, Sugar concentration) that maximizes water loss and weight reduction and minimizes the solid gain by response surface methodology.

Historical background :

Osmotic syrup is highly concentrated and reused for five times with no adversely affect on concentration of fruit. The penetration rate of high fructose corn syrup is higher than sucrose but in sensory evaluation, sucrose solution is preferred over high fructose corn syrup for preparing osmotic solution (Bolin *et al.*, 1983). The water activity and water loss of final product depends upon the water activity of osmotic solution and the amount of solids in the sample, treatment, chemical composition of syrup, solid gain, and shape of sample. The addition of NaCl increase the drying process (Lerici *et al*., 1983). The use of a simultaneous flux of solutes and water in osmotic dehydration as a pretreatment before air drying to reduce the water content from 30 per cent to 70 per cent of food. In osmotic dehydration preceding air drying decreases increase retention in dried fruit and vegetables and colour changes (Lenart and Lewicki, 1988). The removal of moisture from Giant kew a variety of pineapple is very effective at 70 ^{0}B sugar syrup. In sensory analysis maximum dry frui yied, high ascorbic acid and carotenoid content while at 60 ^{0}B sugar syrup with 0.2 per cent citric acid and 700ppm potassium meta bi sulphite is best for osmotic dehydration for the period of 24 h (Rashmi *et al*., 2005). Response surface methodology was used for quantitative investigation of water loss, solid gain and weight reduction during osmotic dehydration of pineapple in sugar syrup. Effects of temperature (30, 35, 40, 45 and 50°C), processing time (30, 60, 90, 120 and 150 min), sugar concentration (40, 45, 50, 55 and 60°B) and sample to solution ratio 1:10 (constant) on osmotic dehydration of pineapple were estimated. Quadratic regression equations describing the effects of these factors on the water loss, solid gain and weight reduction were developed. It was found that effects of temperature and sugar concentrations were more significant on the water loss than processing time. For solid gain, processing time and sugar concentration were the most significant factors. The osmotic dehydration process was optimized for water loss, solid gain and weight reduction. The optimum conditions were found to be temperature 38.2°C, processing time 128.7 min and sugar concentration 44.05°B. At these optimum values, water loss, solid gain and weight reduction were found to be 30.0921 per cent, 13.3634 per cent and 20.3772 per cent, respectively (M and Er TR 2012). A process has been developed to prepare shelf stable ready-to-eat (RTE) intermediate moisture pineapple (*Ananas comosus*) slices, using hurdle technology. The combination of hurdles including osmotic dehydration, infrared drying and gamma radiation dose of 1 kGy, successfully reduced the microbial load to below detectable limit. The shelf life of the intermediate moisture pineapple slices was found to be 40 days at ambient temperature (26 ± 2 ºC). The untreated control samples spoiled within 6 days. The RTE intermediate moisture pineapple slices were found to have good texture, colour and sensory acceptability, during this 40 days storage (Saxena *et al*., 2009). Osmotic dehydration has received greater attention in recent years as an effective method for preservation of fruits and vegetables. Being a simple process, it facilitates processing of fruits and vegetables such as banana, sapota, fig, guava, pineapple, apple mango, grapes, carrots, pumpkins, etc. with retention of initial fruit characteristics *viz*., colour, aroma, texture and nutritional composition. It is less energy intensive than air or vacuum drying process because it can be conducted at low or ambient temperature. It has potential advantages for the processing industry to maintain the food quality and to preserve the wholesomeness of the food. It involves dehydration of fruit slices in two stages, removal of water using as an osmotic agent and subsequent dehydration in a dryer where moisture content is further reduced to make the product shelf stable. Keywords: Osmotic dehydration, Preservation, Fruits, Vegetables, Organoleptic quality (Amarowicz and Chavan, 2012). The aim of this study was to analyze the effect of calcium on microbial stability and texture of osmotic dehydrated pineapple slices in the preparation of minimally processed pineapple slices by osmotic dehydration in atmospheric conditions. Pineapple slices of 10 mm thickness were treated with osmotic agents consisting of glucose solutions of 50 °Brix incorporated with 0, 1, and 2 per cent calcium lactate, until they reached 30° and 40 °Brix at room temperature. The effect of osmotic dehydration on mechanical properties and microbial stability of pineapple slices were analyzed throughout storage at 10 °C for 28 days. Moisture content was determined using the standard method. Mechanical properties were analyzed using a penetrometer, and microbial analysis was done according to the standard microbial tests. Compared to fresh cuts and control samples, samples treated with osmotic agents containing 2 per cent calcium lactate showed a significantly lower growth of mesophilic bacteria, yeast and moulds. Furthermore, the samples treated with calcium lactate had a better firmness compared to those without treatment. Out of all sample tested, 30° Brix sample with 2 per cent calcium lactate and 40 °Brix sample with 1 per cent calcium lactate were identified as the better samples with good firmness and low microbial growth. Treatment of pineapple using dehydration solutions with calcium lactate has been found useful in producing osmotic dehydrated pineapple slices characterized with good firmness, high microbial stability and high keeping quality (Karunarathna and Rathnayaka, 2012).

The effect of pre-treatment methods on drying kinetics and quality attributes of air-dehydrated pineapple slices was investigated. *Smooth cayenne* pineapple specie obtained from Nigeria Institute of Horticultural Research (NIHORT), Ibadan was used for the study. A 2 factor-factorial experimental design of 3-levels of 3 pre-treatment methods (sucrose, blanching and sulphiting) and 1-level of drying temperature drying time resulting into 27 treatments was used for the study. The physico-chemical qualities of the fresh pineapple fruit were determined before hand peeling and slicing to spherical slices of 5 cm radius/0.5 cm thickness. The slices were air-dried in a cabinet direr; the moisture and ascorbic acid content were monitored during drying and the physical and chemical qualities of the dried products analysed at the end of drying. The data obtained were analysed statistically using the Statistical Analysis System. The results revealed that there were significant effect ($p<0.05$) of the pre-treatments on moisture, pH, TTA and ascorbic acid of the samples before drying. Sample pre-treated with S0 absorbed moisture from 82.41 per cent of fresh pineapple to 83.53 per cent while 2 the 60 per cent sucrose sample had a reduction to 81.70 per cent. The quality attributes showed that there were significant differences ($p<0.05$) between the mean values of the samples. The 60 per cent S/60°C B/2500 ppm S0 at 70°C drying 2 had the least value of moisture content of 8.75 per cent; 25.16 mg/100 g of ascorbic acid and 1.19 per cent fibre. The result of the web diagram of the sensory evaluation indicated that the 60 per cent S/2500 ppm S0, 40 per cent S/60°C B/2500 ppm 2 S0 and 60°C B/2500 ppm S0 ranked the first, second and third on overall quality acceptability, while the control 2 2 sample was rated the least in all the evaluated sensory attributes. The statistical analysis revealed that there were significant effects of the pre-treatment methods on the quality attributes of the samples (Karim *et al*., 2008). Fruits are good source of essential nutrients which is important for human nutrition. However, in view of their perishability and seasonality, fruits need to be processed in more shelf stable products to ensure their availability throughout the year. The current study was carried out to determine the effect of using sodium metabisulphite and lemon juice as pre-treatments on sensory quality attributes and extent of vitamin C degradation in dried pineapple, mango and banana fruit pieces. The sliced fruit pieces 5-8 mm thick were dipped in 1 per cent sodium metabisulphite and lemon juice solutions before being dried in a developed food drier with temperatures ranging from 40-45^{o}C for 10-16 hours. Vitamin C was determined before and after drying and subsequently evaluation of sensory quality attributes in terms of flavour, colour, texture and taste was performed using 10 trained panelists. Results showed that the use of pre-treatments reduced the vitamin C degradation with sodium metabisulphite registering the highest reduction and the control samples the lowest reduction. Furthermore, pre-treatments significantly affected ($p<0.05$) affected sensory quality attributes in different ways. However, texture was not affected by the use of pre-treatments. Pre-treated fruit samples had better colour than the control samples. It was further found out that control samples had higher scores in taste and flavor with the exception of pineapples, where the pre-treated samples had a higher score than the control samples (Masamba *et al.,* 2013). The present study was under taken to investigate the effect of packaging materials and storage conditions on quality of capsicum (red and yellow) dried using microwave drying. The samples were heat sealed and packaged in: polypropylene (PP), Laminated Aluminum (Al) and High density polyethylene (HDPE). Then, these were stored at ambient atmosphere for four month and at every fifteen days, the quality parameters such as browning index (BI), total colour difference (TCD), water activity (Aw), moisture content (MC), total carotenoid (Tc) and Sensory Score (SS) were measured. The result indicated that storage period had significant effect ($P<0.05$) on response variables after 45-60 days of storage except sensory score. Laminated Aluminum (Al) was least affected by the ambient environment followed by HDPE and PP having low water vapor transmission rate (WVTR) (Swain *et al*., 2013). The physiological responses of pineapple slices to antibrowning agents have been studied. Slices were immersed for 2 min in solutions of isoascorbic acid (IAA) 0.1 mol/l, ascorbic acid (AA) 0.05 mol/l or acetyl cysteine (AC) 0.05 mol/l, packaged in polystyrene trays, prior to storage for up to 14 days at 10^{0}C. The use of these antibrowning agents reduced browning and decay of pineapple slices significantly. These treatments also reduced changes in L_ and b_ values as well as firmness loss. Changes of inpackage atmosphere did not adversely affect quality of slices. Slices treated with 0.1 mol/l IAA had the best visual appearance and were more acceptable compared with the control slices. The best results were obtained using IAA, followed by AC and AA. Organoleptic attributes were not affected and no off-flavors were detected in the treated slices. We conclude that pineapple slices can be maintained in good condition for up 14 days at 10^{0}C following treatment with antibrowning agents (Aguilara *et al*., 2004).

Combination of osmotic dehydration with microwave assisted air drying offers increased flexibility for process control and product quality. Osmotic dehydration (55 ^{0}Brix solution at 40^{0} C for 90 min) combined with microwave assisted air drying (MWAD) was tested on smooth cayenne pineapples. The influence of the four most relevant processing parameters (osmotic treatment time, microwave power, air temperature and air velocity) was studied using a 24 circumscribed central composite experimental design. The product qualitywas evaluated in terms of charred appearance at the surface, moisture content, soluble solids content, water activity, firmness, colour and volume.Microwave power and air temperature were the two most important processing parameters that influenced the quality of the dehydrated pineapple, with the parameters most affected by the operating conditions being water content and percentage of charred pieces. Only in the latter was a significant quadratic effect found, all others were approximately linear. There was also a significant interactive effect between microwave power and air temperature affecting the percentage of charred pieces. Model predictions using a quadratic surface for water content and per cent charred pieces were validated with an additional experiment. Quadratic models were used to indicate optimum drying conditions for various targets (Botha *et al.*, 2011).

Drying is an energy intensive unit operation and long drying periods tend to increase the energy requirements for the production of a unit dry product. In this study, the effect of blanching temperature – time combinations treatment conditions on the drying behaviour of pineapple slices was investigated. Slices of pineapple were blanched at different temperature-time combinations before being dried in an oven dryer at a dry bulb temperature of 70°C. Four thin-layer drying models were fitted to the experimental drying data. The results show that drying rates and drying times were affected by the blanching temperature-time combinations. Drying times increased as blanching temperature-time combinations increased. The predominant drying regime of the blanched pineapple was observed to be in the falling rate period. The logarithmic model best describe the drying behaviour of blanched pineapple slices with goodness of fit ($R^2 > 0.99$). The effective moisture diffusivity of blanched samples decreased with increase in blanching temperature-time combinations. This implied enhanced mass transfer activities of blanched pineapple slices at decreasing blanching temperature-time combinations. Therefore, blanching pretreatment at lower temperature-time combinations in the drying of fruits and vegetables reduces the drying time and energy cost of drying (Agarry *et al.*, 2013). The main cause of perishability of fruits and vegetables are their high water content. To increase the shelf-life of these fruits and vegetables many methods or combination of methods had been tried. Osmotic dehydration is one of the best and suitable method to increase the shelf-life of fruits and vegetables. This process is preferred over others due to their vitamin and minerals, colour, flavour and taste retention property. In this review different methods, treatments, optimization and effects of osmotic dehydration have been reviewed. Studied showed that combination of different osmotic agents were more effective than sucrose alone due to combination of properties of solutes. During the experiments it was found that optimum osmosis was found at approximately 40 °C, 40 °B of osmotic agent and in near about 132 min. Pretreatments also leads to increase the osmotic process in fruits and vegetables. Mass transfer kinetics study is an important parameter to study osmosis. Solids diffusivity were found in wide range (5.09–32.77 kl/mol) studied by Fick's laws of diffusion. These values vary depending upon types of fruits and vegetables and osmotic agents (Yadav and Singh, 2012). The advantages of osmotic dehydration are as follows: (Ponting *et al.*, 1966; Jackson and Mohamed, 1971 and Islam and Flink, 1982).

– It is a low temperature water removal process and hence, minimum loss of color and flavor take place.

– Flavour retention is more when sugar or sugar syrup is used as osmotic agent.

– Enzymatic and oxidative browning is prevented as the fruit pieces are surrounded by sugar, thus making it possible to retain good colour with little or no use of sulfur di oxide.

– Removal of acid and uptake of sugar by the fruit pieces give a sweeter product than conventionally dried product.

– It partially removes water and thus reduces water removal load at the dryer.

– Energy consumption is much less as no phase change is involved.

– It increases solid density due to solid uptake and helps in getting better quality product in freeze drying.

– If salt is used as osmotic agent, higher moisture content is allowed at the end of drying as salt uptake influences water sorption behaviour of the product.

– The textural quality of product is better after reconstitution.

– The storage life of product is greatly enhanced.

– Simple equipments are required for the process.

The osmotic dehydration of fruits and vegetables is an important subject for studies. Therefore, the literature reported on the subject has been reviewed comprehensively.

It has some disadvantages and inconveniences too (Ponting *et al.*, 1966 and Jackson and Mohamed, 1971) and they are given below

– The reduction in acidity level reduces the characteristic taste of some products. This can overcome by adding fruit acid in the solution.

– Sugar coating is not desirable in some products and quick rinsing in water may be necessary after the treatment.

– Osmotic dehydration with other combined processes such as vacuum drying, air drying or blanching were found expensive.

– In osmotic dehydrated products water activity is found higher.

– It is a time taking process.

Conclusion and future trends:

After the study of previous research, we can say that the osmotic dehydration is enhance the shelf life of pineapple cubes which is suitable for 50 per cent weight reduction successfully from the material and require further drying and processing. Osmotic dehydration in hot air drying of pineapple cubes by using sucrose solution is able to improve the quality like colour, aroma, texture, appearance as well as overall accepabilty. Regression equation is used to predict optimum condition for weight reduction, minimal solid gain, maximum water loss and physical properties of dehydrated pineapple cubes. Potassium metabisulphat is most useful for the browning inhibition. Osmotic and infrared dryings are reduced the water activity, which prevents the microbial growth. The dose of 1 kGy radiation is adversely effective in eliminating the residual microbial load on pineapple cubes, thus ensuring microbial safety of the product sensorial accepted during storage. When calcium is use as a component of osmotic solution in the osmotic dehydration of pineapple cubes. Then the calcium is responsible for increasing the mechanical properties, microbial stability and physico-chemical properties of pineapple slices. By using high density polyethylene film inhibits the moisture content of the products and minimal quality deterioration of dehydrated pineapple slices. HDPE film having high moisture barrier material caused minimal change in moisture content of samples and hence, minimal quality deterioration of dried pineapple slices. Mostly laminated aluminium (Al) is not affected by the ambient storage temperature and suitable for preserving dehydrated pineapple slices. Alone blanching pre-treatment is not suitable for the drying of pineapple slices due to disintegration of negative impact and cell wall observed on the sensory quality. While Sulphiting pre-treatment protects the ascorbic acid from degradation and improved effective moisture transport. The application of different anti browning agents can be used to prolong the shelf-life of fresh-cut pineapples. The predictions of water content and per cent charred pieces by quadratic surface models are validated with an additional drying experiment, and the use of such models to define multicriteria points of optimum. Drying rates and drying time of pineapple slices are affected by the blanching temperature-time combinations. Increasing the blanching temperature time combinations are increased drying times. The logarithmic model sufficiently describes the drying behaviour of blanched pineapple slices. The Fick's diffusion model is suitable for the experimental results which enabled the determination of the effective moisture diffusivity.

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