APPLICATION OF RESPONSE SURFACE METHODOLOGY (RSM) TO THE STUDY OF MASS TRANSFER PARAMETERS OF OSMO-PRETREATED AND DRIED GREEN BELL PEPPER

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Abstract

Osmotic dehydration was carried out on fresh green bell pepper at different osmotic solution concentrations (5% (w/w), 10% (w/w), 15% (w/w), 20% (w/w) and 25% (w/w)) of common salt and osmotic process durations of 60 min, 90 min, 120 min, 150 min and 180 min at an average room temperature of 31 ˚C and the effect of osmotic dehydration factors was investigated on mass transfer parameters; water loss and solid gain. A temperature of 50˚C was used to dry all pre-treated samples to moisture content of about 7 % (wb) in a fabricated cabinet dryer and were further analysed for rehydration ratio and shrinkage. Response Surface Methodology (RSM) under central composite design in Design Expert 8.0.3 computer software package was used to design the experiment, analyse data and present all results with contour and 3-dimensional plots. Results showed that increase in osmotic process duration and osmotic solution concentration caused reduction in solid gain and increase in water loss to values in the range of 0% - 0.3g/g, and 0.1% - 0.3g/g respectively. Also, increase in osmotic process duration and osmotic solution concentration led to increase in shrinkage and reduction in rehydration ratio to values in the range of 40% – 60% and 2.0 -3.5 respectively. Further study should be done on modelling and optimization of the process.

Keywords: osmotic dehydration, green bell pepper, mass transfer parameters, Response Surface Methodology (RSM), drying.

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1. INTRODUCTION

Bell peppers are members of the nightshade family, which also includes potatoes, tomatoes and eggplants. They are also known as sweet peppers, are plump, bell-shaped vegetables featuring either three or four lobes (GMF, 2008).

Historically, bell peppers are native to Mexico, Central America and Northern South America and they are available in various colours such as green, red, yellow, orange and more rarely, white, rainbow (between stages of ripening) and purple (GMF,2008).

Green bell pepper is highly nutritional and contains vitamins and minerals including vitamin C, vitamin A, vitamin B, vitamin K, vitamin E, magnesium, manganese, potassium, fibre, low calories, folate, protein, carbohydrate (Taheri-Garavand *et al*., 2011). Green bell pepper can cure cataracts, rheumatism, fever, cold, diabetes, sore and bruises, arthritis and cancer. It has the potency of keeping cholesterol level of the body under control, and promotes stimulation of stomach secretion thereby leading to improvement of food digestion. (Vengaiah and Pandey, 2006 and GMF, 2008).

Like most other crops, postharvest losses occur in green bell pepper due to poor harvesting, handling, transportation and storage conditions. Some of the ways of reducing post-harvest losses are drying, effective pre-treatment before further processing and storage. Under better storage conditions, like refrigeration, bell peppers would have maximum of 10 days to maintain their maximum natural nutritional qualities (Moody, 1985). This 10-day is too short for the product to get to end users; especially in developing countries where there is irregular power supply, poor harvesting systems, ineffective storage systems and bad roads networks for quick conveyance of fresh produce from farm to the market.

Osmotic dehydration is a pretreatment process that partially removes water from food material by means of food immersion in a hypertonic solution (i.e sugar or salt or combination of both) (Ebru and Hassan, 2010). Osmotic dehydration involves a counter current mass transfer in which water drains from the food to the hypertonic solution (water loss) and solutes flow into the food (solid gain). It is effective even at ambient temperatures, so heat damage to texture, colour and flavor can be minimized (Rastogi *et al.,* 2005).

Mass transfer rate during osmotic dehydration is affected by factors such as temperature, concentration of the osmotic medium, size and geometry of the sample, sample to solution ratio and the degree of agitation (Fasogbon *et al*., 2013). The kinetics of osmotic dehydration is estimated via the mass transfer in terms of water loss. Since osmotic dehydration cannot make products to reach a shelf stable moisture content, it necessary to dry pre-treated products. If the drying of fruits and vegetables is done properly, there will be concentration of their available nutrient. Most times, dried fruits and vegetables are consumed in reconstituted forms. This is done by soaking them in suitable solvents in order to make them to regain some level of their fresh nature. The mass transfer kinetics after drying and during reconstitution of dried osmo-pretreated food materials can be estimated via shrinkage and rehydration ratio. Shrinkage is the change in size that occurs during the process of osmotic dehydration as a result of viscous flow and redistribution of solute. Korsrilabut *et al*., (2010) said that stepwise increment in concentration of osmotic agent could maintain the shape and reduce tissue shrinkage of the finished product. Solid gain, water loss and shrinkage of food tissues occur simultaneously during osmotic dehydration process. Thus, for a certain operating time, mass transfer and tissue shrinkage are related to a specific part of the whole material (Le Maguer *et al*., 2003).

It was stated by Fasogbon *et al*., (2013) that rehydration is a complex process aimed at the restoration of raw material properties when dried material is in contact with water. During rehydration, absorption of water into the tissue and leaching out of solutes into the medium occur concurrently. Dry material, subjected to rehydration undergoes many chemical and physical changes due to the property of water imbibition and solute loss. Imbibition of water by dry material is dependent on the porosity of the material which is related to drying and the pre-drying processes involved. Other factors of interest during rehydration include: temperature, the chemical composition of the product, drying techniques and conditions, composition of the rehydrating medium.(Taiwo and Adeyemi , 2003).

Drying is a simultaneous heat and mass transfer process leading to moisture removal from cellular materials. The basic objective of drying is to remove water from food tissue up to a certain amount so that microbial spoilage and deteriorating chemical reactions are greatly minimized (Amami *et al.,* 2007). Drying is used to remove water from foods for two reasons; to prevent (or inhibit) micro-organisms thereby preserving the food and to reduce the weight and bulk of food for cheaper transport and storage. A safe temperature is required to dry products in order to prevent them from cooking in the process and reasonably retain their qualities. Phisut (2012) suggested that the best temperature range for drying fruits and vegetables should be between 35 ˚C to 75 ˚C. Drying is generally energy consuming therefore to improve energy efficiency and also reduce the processing time while avoiding or reducing to a minimum the deterioration of the product quality in terms of sensory qualities (texture, colour, flavour) which is often caused by thermal processing (Ebru and Hasan, 2010), it is required to subject products to pre-treatment before drying. Singh *et al*. (2006) and Dhkordi (2010) used RSM in the study of osmotic dehydration and drying of carrots and edible button mushrooms respectively. Alabi *et al*., (2016), Olaniyan and Omoleyomi(2013) Odewole et al (2014), Odewole and Olaniyan (2016), Rahman and

Lamb (1991), and Odewole and Olaniyan (2015) worked on osmotic dehyration and drying of various food materials. Their results showed that osmotic dehydration factors and drying caused some form of effects on their outputs in terms of nutritional qualities and mass tranfer parameter. Therefore, the objective of this study was to use Response Surface Methodology (RSM) to investigate the effect of osmotic process duration and osmotic solution concentration on mass transfer parameters (water loss, solid gain, and shrinkage and rehydration ratio) of dried osmo-pretreated green bell pepper.

2. MATERIALS AND METHODS

2.1. Experimental Equipment and Materials

The equipment used for the study were: laboratory oven(GENLAB, Model N53 CF, England), a fabricated cabinet dryer, electronic weighing balance(OHAUS CL Series, Model CL 201, China), stop watch(Nokia X2-01), desiccator, containers for osmotic dehydration pretreatment, stainless steel tray and knife, foil paper, spatula and hand gloves. Common salt, distil water, fresh green bell pepper.

2.2. Experimental Design

Design Expert 8.03 version Computer Software was used to design the experiment. RSM under Central Composite Design was used. Five levels of osmotic solution concentrations of common salt (5% (w/w), 10% (w/w), 15% (w/w), 20% (w/w) and 25% (w/w)) and five levels of osmotic process duration (60 min, 90 min, 120 min, 150 min and 180 min) were substituted into the experimental design interface of the software. The outcome gave combinations of various levels of the two process conditions that were used as “map” for conducting the experiment.

2.3. Experimental Procedure

Fresh green bell peppers were procured from a commodity market in Ilorin, Kwara state, Nigeria early in the morning. They were graded in order to get better quality for the experiment. Other procedures are stated in Odewole and Olaniyan (2016). A constant mass of sliced (3mm) green bell pepper (100g) was introduced into the osmotic solution for each pretreatment combination which took place at average ambient temperature of 26 ˚C. At the end of the pretreatment, reduction in mass of samples(less than 100g) was achieved. For the drying operation, 75g of each pre-treated sample was introduced into the dryer. The temperature of 50˚C was used for the drying operation. Hourly loss in mass for each sample was measured with the use of the electronic weighing balance. After drying to average moisture content to about 7 % (wb) for about 4 hours, all the dried samples were arranged inside the desiccator and were later used for estimation of shrinkage and rehydration. The experiment was performed at the Processing and Storage Laboratory of the Department of Agricultural and Biosystems Engineering, University of Ilorin, Ilorin, Nigeria in June 2016. The average room temperature was around 31 ˚C and relative humidity of about 65 % throughout the period of the experiment.

2.4. Output Parameters

Solid gain and water loss were the mass transfer parameters determined after the osmotic dehydration process according to Fasogbon *et al*., (2013). Shrinkage and rehydration ratio were determined after drying of pretreated samples according to Singh *et al*., (2006).

2.5. Data Analysis

Analysis of data was done after introducing all the output data obtained into the experiment table earlier designed with Design Expert computer software package. The data were analysed following the stipulated procedures of the software for RSM in order to get the 3-dimensional (3-D) and the contour plots that show the effect of the two process conditions(osmotic process duration and osmotic solution temperature) with each of the output parameter.

3. RESULTS AND DISCUSSION

3.1. Effect of Osmotic Solution Concentration (% w/w) and Osmotic Process Duration (min) on Solid Gain (g/g) of Osmo-Pretreated Dried Green Bell Pepper

Figures 1(a) and 1(b) below show the effect of osmotic solution concentration and osmotic process duration on the solid gain of osmo-pretreated dried green bell pepper. Figure 1(a) and 1(b) are the contour plot and 3-dimensional plot respectively.

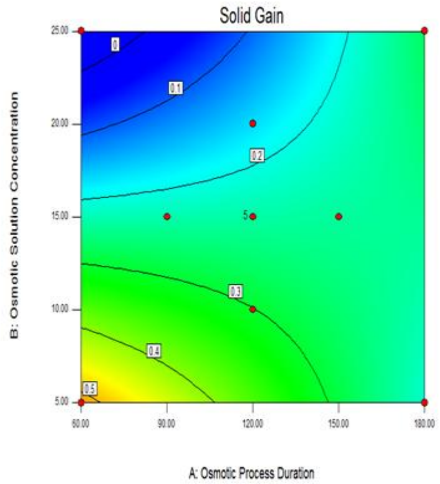

Figure 1(a): Effect of process conditions on Solid gain (g/g)

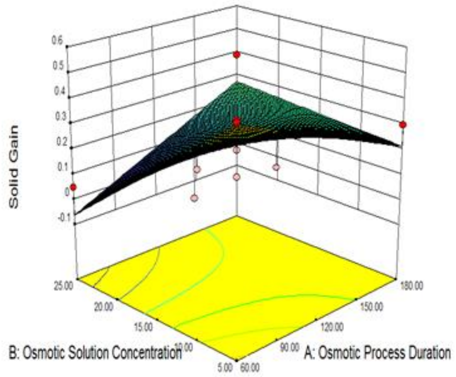

Figure 1(b): 3D plot of effect of process conditions on Solid gain (g/g)

The two illustrations show that a decrease in solid gain as the osmotic solution concentration and osmotic process duration increased. Solid gain decreased was not beyond about 0.3 g/g with increase in osmotic process duration, but progressive reduction in solid gain to up to close to 0g/g was achieved with increase in osmotic solution concentration. This means that at higher concentrations, the flow of solutes (salt) into green bell pepper reduced and eventually stopped probably because the green bell pepper had taken in so much solute thereby making the osmotic solution to be weak. It could also be as a result of quality in terms of maturity, variety (Chavan and Amarowicz, 2012) of the pepper and the complex internal structure (Phisut, 2012) of food material.

The reason for the solid gain increasing with increase in osmotic process duration might be because the highest duration (120 min) was still within the optimal range of 2-3 hours as suggested by Gaspartero *et al.*,(2003) and Chavan and Amarowicz (2012). Furthermore, other osmotic dehydration experiments carried out on litchi by Kumar *et al*., (2012), mango and pineapple by (Tiwari and Jalali, 2004) showed that solid gain increased as osmotic process duration increased, which is in agreement with the plots shown.

3.2. Effect of Osmotic Solution Concentration (%w/w) and Osmotic Process Duration (min) on Water Loss (g/g) of Dried Osmo-Pretreated Green Bell Pepper

Figures 2(a) and 2(b) show the effect of process conditions on water loss. Increase in osmotic solution concentration from 5% (w/w) to 25% (w/w) caused an increase in water loss up to about 0.3g/g as can be seen in figure 2(a) that shows a pattern of an inclined plane.

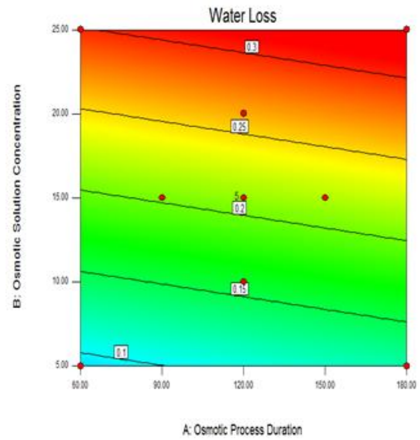

Figure 2(a): Effect of process conditions on water loss (g/g)

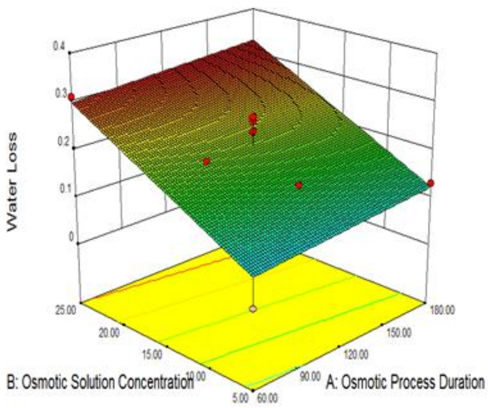

Figure 2(b): 3-Dimensional plot of the effect of process conditions on water loss (g/g)

Reports from Rahman and Lamb (1991), Chavan and Amarowicz (2012) and Singh *et al*. (2006) aligned with this observation. This could be attributed to the fact that higher osmotic solution concentration led to a greater concentration gradient hence resulting in a greater osmotic dehydration driving force. A high water loss is favourable as it reduces the drying time of the product and this is one of the advantages of osmotic dehydration.

Although, the case is different with osmotic process duration as there was no significant increase in water loss as the process duration increased. There was a water loss of about 0.1g/g at 90mins, no occurrence of such at higher durations (120mins, 150mins and 180mins) as shown in figure 2(b). Also, Odewole and Olaniyan (2015) reported that osmotic process duration of 90 mins was the most suitable for osmotic dehydration on the experiment carried out on red bell pepper. A probable explanation for this is that prolonged osmotic process duration could have resulted in high solid gain by green bell pepper thereby making the osmotic solution concentration reduce.

3.3. Effect of Osmotic Solution Concentration (%w/w) And Osmotic Process Duration (min) on Rehydration Ratio of Dried Osmo-Pretreated Green Bell Pepper

The effect of osmotic process duration and osmotic solution concentration on rehydration ratio on dried osmo-pretreated green bell pepper is presented in Figures 3(a) and 3(b).

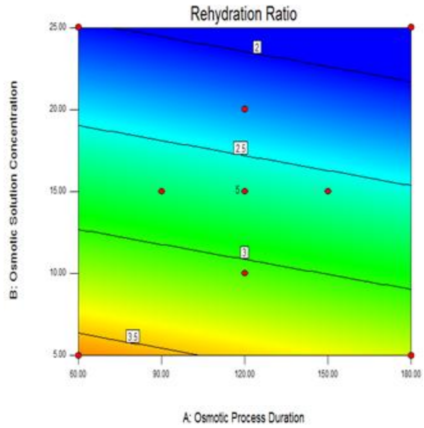

Figure 3(a): Effect of process conditions on rehydration ratio

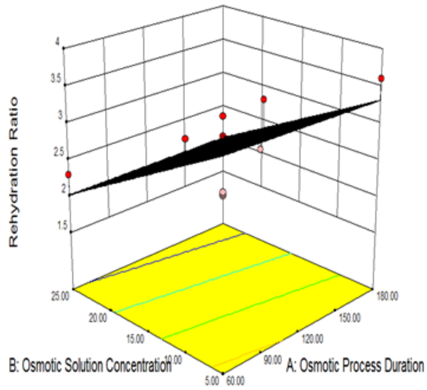

Figure 3(b): 3-dimensional plot of the effect of process conditions on rehydration ratio

There was a decrease in rehydration ratio as osmotic solution concentration increased. Rehydration ratio was found to be highest (3.5) at a low concentration level (between 5% (w/w) and 10% (w/w)) and at osmotic process duration between 90mins and 120mins and this is in agreement with what Singh *et al*., (2006) reported that rehydration ratio was maximum at about 11% concentration and 120mins. Increase in osmotic process duration did not cause the rehydration ration to increase beyond 3.5. These observations could be attributed to the fact that higher solution concentrations could have compacted the cellular structure of the green bell pepper to the point that resulted into greater firmness, hence reducing the rehydration ability.

3.4. Effect of Osmotic Solution Concentration (%w/w) and Osmotic Process

Duration (min) on Shrinkage (%) of Osmo-Pretreated Dried Green Bell Pepper

Figure 4(b) is the 3-dimensional plot of the effect of osmotic process duration and osmotic solution concentration on shrinkage of dried osmo-pretreated green bell pepper.

The figure shows an inclined plane pattern. Increase in osmotic process duration and osmotic solution centration caused the shrinkage to increase to about 60%, and from 40% to about 50% respectively. What this means is that an increase in osmotic solution concentration would probably did not increase the ability of green bell pepper to shrink further, this is in agreement with the advantage of osmotic dehydration to retain the shape of food and protect against structural collapse (Chavan and Amarowicz, 2012).

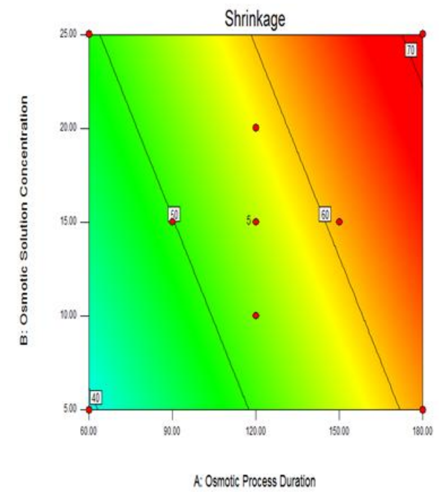

Figure 4(a): Effect of process conditions on shrinkage (%)

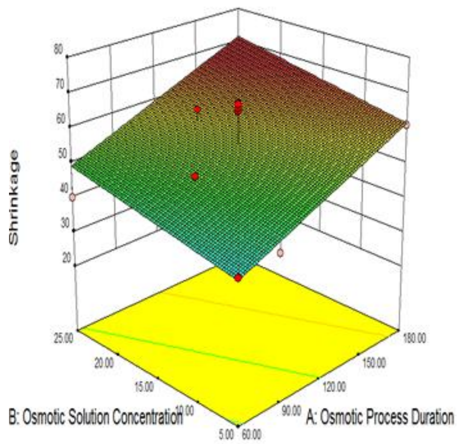

Figure 4(b): 3 dimensional plot of the effect of process conditions on shrinkage (%)

Increase in the osmotic process duration, however, caused an increase in the shrinkage of the green bell pepper. This could be as a result of the physiology of green bell pepper. This could also be as a result of outflow of solutes from the green bell pepper as a result of the solution becoming diluted after prolonged osmotic process duration.

4. CONCLUSIONS

The contour plots and 3-dimensional plots show the responses of the effects of increasing the osmotic solution concentration and osmotic process duration on the mass transfer parameters (solid gain, water loss, rehydration ratio and shrinkage) of osmo-pretreated dried green pepper. The 3-dimensional plots represent a highly illustrative pattern of these effects. Specifically, increase in osmotic process duration and osmotic solution concentration caused reduction in solid gain and increase in water loss to values in the range of 0% - 0.3g/g, and 0.1% - 0.3g/g respectively. Also, increase in osmotic process duration and osmotic solution concentration led to increase in shrinkage and reduction in rehydration ratio to values in the range of 40% – 60% and 2.0 - 3.5 respectively. Further study should be done on modelling and optimization of the process.

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