Effect of osmotic dehydration pretreatments on drying rate and post-drying quality attributes of red bell pepper (capsicum annuum)

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Abstract: Bell pepper (capsicum annuum) is a common vegetable plant and the most popular world-wide and mildest member of capsicum family. It is very easy to cultivate but highly perishable because of its characteristic lower sugar and acidic contents. It lacks built-in protection mechanisms which makes it more vulnerable to deterioration and thus leading to rapid metabolic activities within its cells once harvested. As a result of the aforementioned, it usually experience high postharvest losses in its season and becomes scarce and of low standard at off-season. This work was done to study the factors affecting the drying process of pretreated red bell pepper; and also to investigate the effect of osmotic pretreatments(solution concentration, solution temperature and process duration) on the drying rate and quality attributes (vitamin C, vitamin A and ash content) of red bell pepper. A 43 factorial experiment in Randomized Complete Block Design (RCBD) was used. The factors taken into consideration were osmotic process duration (60 min-150 min), osmotic solution concentration 5% (w/w)-20% (w/w), and osmotic solution temperature (30℃-60℃), all at four levels and replicated three times. A drying temperature of 60˚C was used for all the pretreated samples inside a temperature-controlled fabricated dryer. Results revealed that not all the osmotic dehydration pretreatments showed significant effect on the drying rate at $p \leqslant 0.05$. Also, increase in osmotic dehydration pretreatment conditions did not cause the average values of vitamin C, vitamin A and ash content to fall below 120 mg/100g, 1.40 mg/100g and 8.0% respectively. Further studies should be carried out on the storability, shrinkage and rehydration properties of dried samples, and modeling and optimization of the process.

Keywords: osmotic dehydration, drying rate, quality, red bell pepper (capsicum annuum)

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1 Introduction

Bell pepper is also known as sweet pepper. It is the common name for a cultivar group of the species *capsicum annuum*, the widely cultivated bell shaped fruits with three or four lobes (GMF, 2008), and is characterized by a diverse glossy external colours such as green, red, yellow, orange, purple, blue, black and so on. Bell pepper contains recessive genes that eliminate capsaicin (a chemical content that causes hotness or pungency in other plants in the genus capsicum). Walshi and Hoot (2001) reported that capsicum, the genus to which bell pepper belongs, contains approximately 20-27 species.

Bell Peppers are vegetable and highly perishable because of their characteristics lower sugar and acidic contents. Because of this, they lack built-in protection mechanisms, which make them more vulnerable to deterioration because of rapid metabolic activities that take place within their cells. These situations make them to be of low standard when not kept under the best storage conditions after harvest. Even with refrigerated storage, they can only maintain their maximum natural nutritional values for a maximum of 10 days (Moody, 1985).

In 2007, the world production of peppers (bell peppers inclusive) was 26,056, 900 MT. People's

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Republic of China produced the highest with 14,033,000MT, followed by Mexico with 1,690,000MT; the fifth on the list was USA with production capacity of 855,870MT. In Africa, Nigeria produced the highest tonnage of 723, 000MT, followed by other countries (GMF, 2008).

GMF (2008) reported that bell peppers had protective effect against cataracts, rheumatoid, arthritis and lung cancer. Because of some level of capsaicin in bell peppers, they also have some traditional medicinal uses, which are: keeping cholesterol level under control, curing of diabetes, stimulation of stomach secretion and improvement of food digestion, treatment of sore back muscles and bruises. They have also been proven to control fever and colds (www.fruitsinfo.com). Bell pepper is very rich in Vitamin C (195.8%), followed by Vitamin A(57.6%). Vitamins Bs are in the range of 2.8%-4.7%. In addition, they are very low in calories (1%) and contain some good amount of fibre(7.4%) and other trace elements (GMF, 2008).

Drying is a simultaneous heat and mass transfer process, and it is one of the oldest methods of food preservation, which is achieved by the removal of enough moisture from the food with the aim of preventing decay and spoilage. Kiremire (2010) reported that there is need to encourage the drying of fruits and vegetables in order to ensure an all year round supply. Barehet al. (2012) solar-dried some bell peppers (sweet peppers) after pretreatment, it was found that the fresh samples of the sweet peppers had lower physico-chemical characteristics with the exception of carbohydrate and vitamin C than those pretreated. Osunde and Makama-Musa (2007) reported that sundried sweet peppers showed a lower B-carotene (vitamin A) retention capability, the value realized was 65%. Similarly, for vitamin C (ascorbic acid), there was a loss of 69.67% in its value. Awogbemi and Ogunleye (2009); Idahet al.(2012); Mu'azuet al. (2012) and Phisutet al. (2012) reported that the best temperature range for drying fruits and vegetables was 35 ℃ to 75 ℃.

Drying is one of the most effective practical unit operations in agricultural and food processing. It has the tendency of greatly reducing postharvest loses of red bell pepper and other highly perishable produce. In addition, pretreatment of fruits and vegetables in hypertonic osmotic solution before hot air drying has the tendency of improving their final nutritional and sensory qualities. Some of the major factors governing osmotic dehydration process are osmotic process duration, osmotic solution concentration and osmotic solution temperature or combinations of any of the aforementioned factors.

Osmotic dehydration process is one of the simple methods of extending the shelf life of perishable products; and it preserves the colour, flavour, and texture of food from heat, thereby improving the nutritional, sensory and functional characteristics of products (Singh et al., 2006; Pokharkar and Prasad, 1998). In addition, Chavan and Amarowicz (2012) reported osmotic dehydration as an economical processing method, because the energy requirement for osmotic dehydration process is usually 2-3 times less than the conventional systems of drying. Likewise, cost of storage and transportation would be reduced as a result of the reduction in the volume of products after the process due to outward mass transfer in terms of water loss into the hypertonic osmotic solution. Some researchers who worked on osmotic dehydration of fruits and vegetables did not consider red bell pepper (Tortoe, 2010); others did not use salt solution for osmotic dehydration pretreatments of red bell pepper (Famurewa et al., 2006). In addition, those that used salt solution for green pepper considered a range of 2%-10% (w/w) solution concentration (Ozenet al., 2002).This range of salt solution concentration (2%-10% (w/w)) reported by Ozen et al. (2002) for osmotic dehydration of green pepper may not be appropriate for osmotic dehydration of red bell pepper. This is because the range of osmotic solution concentration used was low and could lead to slower rate of osmotic dehydration process (Chavan and Amarowicz, 2012); thereby leading to costly loss or delay in processing and operation time. Pointing et al. (1996) reported that apple slices were reduced to 50% of their original weight by immersing them in 60-70Bx of sugar solution. Singh et al. (2006), and Chavan and Amarowicz (2012) listed sucrose and glucose (for fruits) and sodium chloride (for vegetables) as the commonly used osmotic dehydration agent. Chavan and Amarowicz (2012) said in order to get a faster rate of osmotic dehydration process, osmotic solution concentration would need to be increased; however, Torreggiani (1993) suggested the avoidance of higher concentration for osmotic dehydration process for more than 50% weight reduction in order to prevent decrease in osmotic dehydration rate with time. Chavan and Amarowicz (2012) conducted a research on the optimization of duration of osmosis (osmotic process duration); it was reported that maximum rate of mass exchange occurred within two hours of osmotic dehydration treatment. Charles (2010) asserted osmotic solution temperature as the important factor controlling the kinetic of mass transfer during osmotic dehydration process. It was also reported that increase in osmotic solution temperature led to increase in the rate of osmotic dehydration; but higher solution temperature above 60˚C would cause destruction of products cell membrane (Chavan and Amarowicz, 2012).From all these past research conducted, it could be said that some of the major factors governing osmotic dehydration process included osmotic solution concentration, osmotic process duration, osmotic solution temperature and type of osmotic agent. Therefore, the main objective of this work was to study the factors affecting the drying process of pretreated red bell pepper. The specific objective was to investigate the effect of osmotic solution concentration, osmotic solution temperature, and osmotic process duration as pretreatment factors on the drying rate and some post-drying quality attributes (vitamin C, vitamin A and ash content)of red bell pepper.

2 Materials and methods

2.1 Experimental materials and equipment

Freshly harvested red bell peppers of average moisture content of 87% (w.b.) were purchased from a local market within Ilorin metropolis (North Central Zone of Nigeria).

The following equipment were used for the study: an experimental size dryer; two types of water baths (HH-W420, XMTD-204 model and SL Shell Lab model H_2O Bath Series manufactured by Sheldon Inc., Genlab electric oven, sensitive weighing balance (OHAUS 3001), distil water, common salt, desiccators, thermometers, measuring cylinders, stainless steel knives and trays.

Figure 1 and Figure 2 show the dryer. It has four major units: the drying chamber, the heating chamber, the blower and the heat controlling section (digital thermocouple in the range of 0 ℃-300 ℃).

Figure 1 Red bell pepper samples in the dryer

Figure 2 Back view of the dryer

The drying chamber has a rectangular cross-section, and it is double walled (3cm thick) insulated with fibre glass to prevent or reduce heat loss to the surroundings, the external part is made of mild steel sheet and the internal part is neatly made of aluminum plate. The external dimension is 56 cm x 56 cm x 86 cm, while the internal dimension is 50 cm x 50 cm x 80 cm. It has three trays separated at a distance of 15cm apart. Each tray has an area of 50 cm x 50 cm and was made from 2.54 cm square pipe at its sides around a square shaped galvanized steel net with sufficient aperture.

The heating chamber is the unit between the blower and the drying chamber and is pyramidal in shape. The length of the part connected to the drying chamber is 60 cm and the one connected to the blower is 20 cm. This heating chamber is equipped with electrical heating coil of 1.8 kW. The blower consists of forward curved blades in casing and an electric motor of rating 0.373 kW with a speed regulator to control the speed of the heated air. It is connected directly to the heating chamber of the dryer. Other details of the dryer are in Olaniyan and Omoleyomi (2013).

2.2 Experimental design

A 4^3 factorial experiment in Randomized Complete Block Design (RCBD) was used in this study to investigate the effect of pretreatment conditions on the drying rate and some post-drying quality attributes (vitamin C, vitamin A and ash content) of red bell pepper such as osmotic process duration (A), osmotic solution concentration (B), and osmotic solution temperature (℃). The osmotic process duration investigated were 60 min, 90 min, 120 min and 150 min. Osmotic solution concentrations were 5% (w/w), 10% (w/w), 15% (w/w) and 20% (w/w) while the osmotic solution temperatures were 30℃, 40℃, 50℃ and 60℃. Each treatment combination was replicated three times. All experimental runs that were individually tested and measured were 192.The experiment was conducted in the Chemical Engineering Laboratory of University of Ilorin, Ilorin, Nigeria. The average room temperature was about 30℃ and the average relative humidity was around 65%.

2.3 Experimental procedure

2.3.1 Sample pretreatment

The samples were re-graded to get better quality samples free from defects. The fresh samples of better grades were washed in clean water; they were later de-seeded and then cut into pieces along their longitudinal axes with the use of a short stainless steel knife on a stainless steel tray. After these, 50g of each sample was measured by an electronic sensitive weighing balance(OHAUS 30001) and were soaked in a hypertonic salt (NaCl) solution of four different concentrations: 5% (w/w), 10% (w/w), 15% (w/w) and 20% (w/w). The samples were then placed inside the water baths that had earlier been pre-set to the required osmotic solution temperatures (30℃, 40℃, 50℃ and 60℃). The mass ratio of sample to solution was 1:4. The samples were left inside the water baths for 60 min, 90 min, 120 min and 150 min respectively.

At the end of the pretreatment time, the samples were taken out of water baths, and rinsed under flowing water in order to get rid of adsorbed solute (salt). They were then arranged on the drying trays and left for about 20 min under a fan in order to get rid of surface water which has the tendency of prolonging the drying time. After the surface water had dried, the samples were re-weighed on the sensitive electronic balance again. In this experiment, after the osmotic dehydration, reductions in masses of samples were noticed(less than 50g that was introduced for osmotic dehydration). As a result of this, a uniform sample mass of 40g was used for each treatment combination, and properly re-arranged on the drying trays for drying.

2.3.2 Drying procedure

During the last stage of sample pre-treatment, the dryer was connected to the power source and switched. The drying temperature (60℃) was pre-set on the temperature regulator (thermocouple). It was left for some times until its inside temperature reached the pre-set value;

during this period, the inside temperature of the dryer was also checked occasionally with a portable mercury-in-glass thermometer in order to ensure that the value displayed on the screen of the thermocouple was the actual inside condition of the dryer.

The properly pre-treated samples (40g each) on the labeled trays were carefully placed inside the dryer. The masses of the samples were then taken hourly until a moisture content of less than 10% (w.b.) was reached.

2.4 Output parameters

2.4.1 Drying rate

Drying rate is the quantity of moisture removed from product per unit time during a drying operation. The drying rate was estimated using the equation below:

$$d=\frac{d_m}{d_t}=\frac{m_i-m_f}{t} \tag{1}$$

where: d is drying rate in g/h; d_m is change in mass sample in g; d_t is change in time in h; m_i is initial mass sample in g; m_f is final mass sample in g; and t is time in h.

2.4.2 Post-drying qualities

The post-drying qualities of red bell pepper were determined using AOAC (1990) procedures at the Chemistry Laboratory of University of Ilorin, Ilorin, Nigeria. The post-drying qualities determined were vitamin C, vitamin A and ash content.

2.4.3 Statistical analysis

The data obtained from the experiment were subjected to statistical Analysis of Variance (ANOVA) at P≤0.05 in SPSS 16.0 statistical computer software package. A further analysis to compare the means of result among different levels of experimental conditions was also carried out with Duncan’s New Multiple Range Test(DNMRT).

3 Results and discussion

3.1 ANOVA of process conditions on drying rate and post-drying quality attributes of red bell pepper

The result of the statistical analysis of variance (ANOVA) of data obtained from the experiment is presented in Table 1.From the table, it is seen that all the process conditions and their respective interactions had no significant effect on the drying rate. However, this observation is not the same for all the post-drying quality attributes; some process conditions and their interactions had significant effect while others did not show significant effect. In the case of vitamin A, only the interaction of osmotic process duration and osmotic solution concentration had no significant effect on vitamin A content of red bell pepper after drying at p≤0.05. Eroglu and Yildiz (2010)could as a result report these observations; that combinations of some pretreatment factors of osmotic dehydration would have effect on the output of the process in some ways. In addition, since process conditions used for osmotic dehydration of red bell pepper were not insulation, the tendency for the process to affect the responses (nutritional, sensory and mass transfer kinetic properties) of the product positively or otherwise before, during and after hot air drying is possible. The implication of this is that, proper attention must be given to those conditions and interactions that had significant effect on output parameters when the drying of red bell pepper is to be done.

Table 1 Analysis of Variance (ANOVA) of the effect of process conditions on the drying rate and post-drying quality attributes of red bell pepper: A-Osmotic Process Duration; B-Osmotic Solution Concentration; C-Osmotic Solution Temperature

SV	DF	SS	MS	F	P>F
Drying rate, g/h					
A	3	16.458	5.486	1.109	0.348
B	3	8.011	2.670	0.540	0.656
C	3	3.041	1.014	0.205	0.893
A X B	9	5.361	0.596	0.120	0.999
A X C	9	16.601	1.845	0.373	0.946
B X C	9	4.806	0.534	0.108	0.999
A X B X C	27	23.737	0.879	0.178	1.000
Error	128	628.450	4.948		
Total	191	706.465			
VitaminC, mg/100g					
A	3	2304.464	768.155	12.860	0.001*
B	3	385.569	128.523	2.152	0.097
C	3	1589.609	529.870	8.871	0.001*
A X B	9	1456.898	161.878	2.710	0.006*
A X C	9	4978.271	553.141	9.261	0.001*
B X C	9	1400.356	155.595	2.605	0.009*
A X B X C	27	4216.369	156.162	2.614	0.001*
Error	128	7585.845	59.731		
Total	191	23917.381			

SV	DF	SS	MS	F	P>F
Vitamin A, mg/1 0 0 g					
A	3	0.005	0.002	2.931	0.036*
B	3	0.004	0.001	2.609	0.044*
C	3	0.006	0.002	3.407	0.020*
A X B	9	0.009	0.001	1.897	0.058
A X C	9	0.027	0.003	5.446	0.001*
B X C	9	0.023	0.003	4.667	0.001*
A X B X C	27	0.033	0.001	2.271	0.001*
Error	128	0.069	0.001		
Total	191	0.176			
Ash content, %					
A	3	0.014	0.005	0.372	0.773
B	3	0.260	0.087	6.941	0.001*
C	3	0.145	0.048	3.880	0.011*
A X B	9	0.144	0.016	1.279	0.255
A X C	9	0.356	0.040	3.164	0.002*
B X C	9	0.340	0.038	3.021	0.003*
A X B X C	27	0.707	0.026	2.095	0.003*
Error	128	1.587	0.012		
Total	191	3.553			

Note: * Significantly different at P≤0.05.

3.2 Effect of osmotic process duration (min), osmotic solution temperature and osmotic solution concentration on the drying rate of red bell pepper

The effect of process conditions on drying rate is shown in Figure 3. The figure shows that lower combinations of process conditions caused the drying rate to increase but later reduced with higher combinations of process conditions. This observation could be due to the presence of more moisture in the product with lower levels of osmotic dehydration process or increase in permeability of product as reported by Chavan and Amarowicz (2012).Also, the observation is in agreement with the findings reported by Kumar et al.(2012), that osmotic dehydration led to increase in drying rate of litchi pulp. Similarly, Olaniyan and Omoleyomi (2013) reported that osmotic dehydration of okra in sugar solution caused the drying rate to increase when the temperature of drying was above 50 ℃. In another development, Ade-Omowaye et al.(2001) got an increase in the drying rate of red paprika with higher mass and heat transfer coefficients. Higher moisture in product is what usually cause increase in drying rate at the beginning of drying.

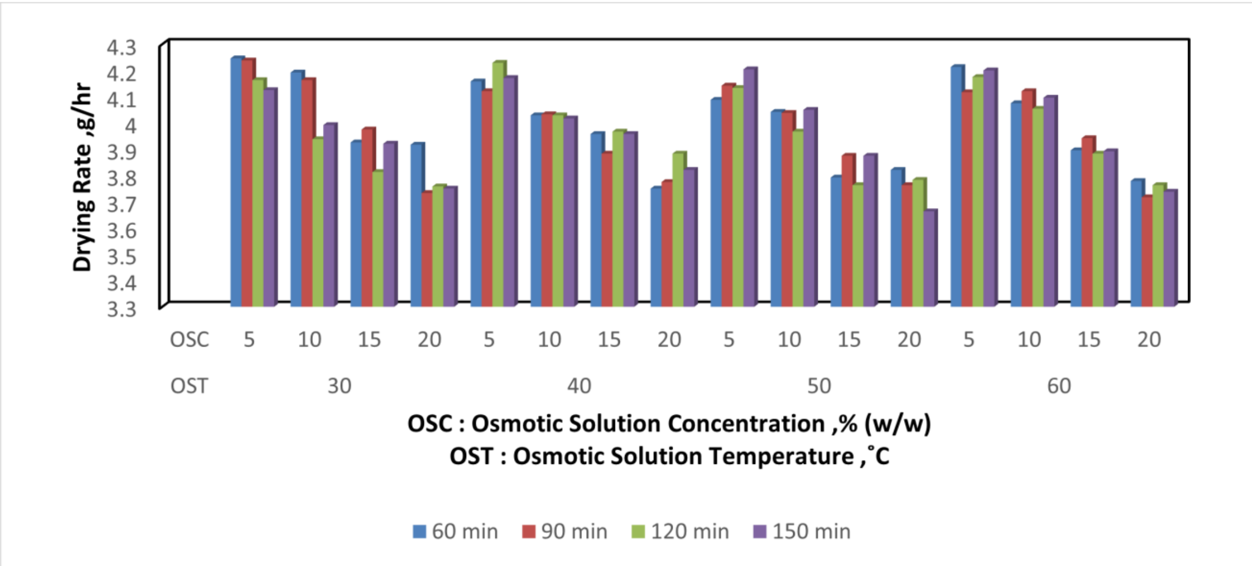

Figure 3 Effect of osmotic process duration (min), osmotic solution temperature and osmotic solution concentration on the drying rate of red bell pepper

3.3 Effect of osmotic process duration (min), osmotic solution temperature and osmotic solution concentration vitamin C content of red bell pepper

The effect of process conditions on vitamin C content of dried red bell pepper is shown in Figure 4. The figure shows that increase in all the process conditions made the vitamin C content of most of the samples to be slightly above 120 mg/100g but Famurewa et al.(2006) got a greater value of 125 mg/100g when a single osmotic solution concentration of 60Brix and osmotic solution temperature of 40 ℃ was used to pre-treat red bell pepper in sugar solution before drying. However, obvious higher values of vitamin C (above 140 mg/100g) were noticed at osmotic process duration of 30 min and osmotic solution concentration of 20% w/w. The reason for the latter observation could be attributed to occasional variations (like maturity level and physiological variations) in the internal structures of samples. On this observation also, Chavan and Amarowicz (2012) listed maturity level and product variety as some of the factors that could influence osmotic dehydration process. Furthermore, any condition that affects the osmotic dehydration process would likely pose some effects on the post-drying qualities of products.

Table 2 presents the effect of individual process conditions on the mean values of vitamin C content of dried red bell pepper. The table shows that increase in the levels of process conditions caused the vitamin C content to maintain mean values of not less than 120 mg/100g. The reduction in values could be due to osmotic dehydration processes, which lead to leaching out of product's solutes (vitamins, minerals etc.) reported by Tiwari and Jalali (2004) and Karthiayani (2004).

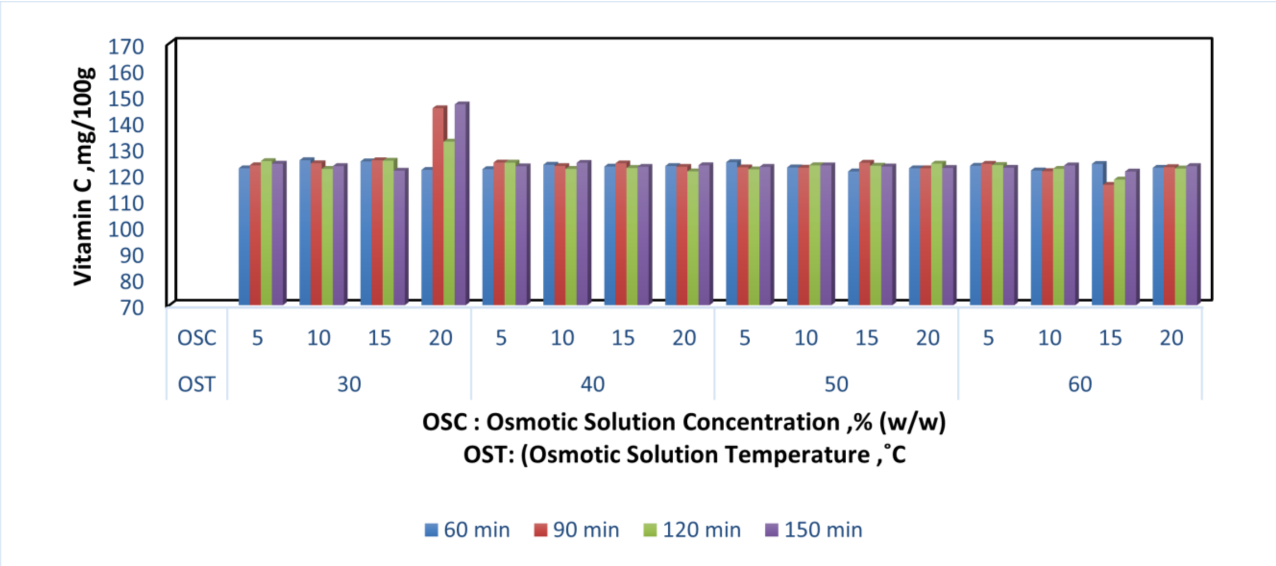

Figure 4 Effect of osmotic process duration (min), osmotic solution temperature and osmotic solution concentration vitamin C content of red bell pepper

The reduction in nutrient via leaching during osmotic dehydration could be due to the non-selective nature of cell membrane of fruits and vegetables. The highest mean value (130.58 mg/100g) and lowest mean value (121.87 mg/100g) of vitamin C were obtained at 60 min and 30 min of osmotic process duration respectively. Higher mean value of vitamin C was obtained at osmotic solution temperature 60 ℃, this observation negates the common expectation that increase in temperature of process would likely lead to drop in the values of heat sensitive nutrients like vitamin C. However, this observation is in agreement with that reported by Chavan and Amarowicz (2012) that higher temperature of above 60 ℃ would destroy cell membrane of products.

Table 2 Effect of process conditions on the post-drying quality (vitamin C) of red bell pepper

Osmotic process duration, min	**60**	**90**	**120**	**150**
Vitamin C, mg/100g	130.58[a]	123.12[b]	122.91[b]	121.87[b]
Osmotic solution concentration, % (w/w)	**5**	**10**	**15**	**20**
Vitamin C, mg/100g	122.96[a]	124.27[b]	126.88[c]	124.40[b]
Osmotic solution temperature, ℃	**30**	**40**	**50**	**60**
Vitamin C, mg/100g	123.36[a]	122.93[a]	122.62[a]	129.59[b]

Note: *means with the same alphabet are not significantly different from each other at p≤0.05.

3.4 Effect of osmotic process duration (min), osmotic solution temperature and osmotic solution concentration vitamin A content of red bell pepper

The effect of process conditions on the vitamin A content of dried red bell pepper is presented in Figure 5.

From the figure, it is clearly seen that increase in the levels of process conditions led to an irregular response in values of the vitamin A content of dried samples. More than half of the dried samples have vitamin A content of above 1.40 mg/100g. The former observation gave the impression that vitamin A responses is somewhat different from that of vitamin C when osmotic dehydration process is used as pretreatment before hot air drying even; though they are both vitamins. This pattern of response could also be due to some reasons earlier mentioned which were, maturity level(Chavan and Amarowicz, 2012)and physiological variations which could affect the initial nutrient level and other characteristics of fresh red bell pepper. Another possible reason is mass transfer kinetics characteristics during osmotic dehydration process. For this, there could have been some combinations of process conditions which could probably have led to a faster rate or lower rate of water loss than solid gain. A faster rate of water loss could be accompanied by a corresponding leaching of nutrients. Phisut (2012) and Chavan and Amarowicz (2012) reported that high temperature (osmotic solution temperature) and high concentration (osmotic solution concentration) promoted mass transfer during osmotic dehydration and led to a faster osmotic dehydration process.

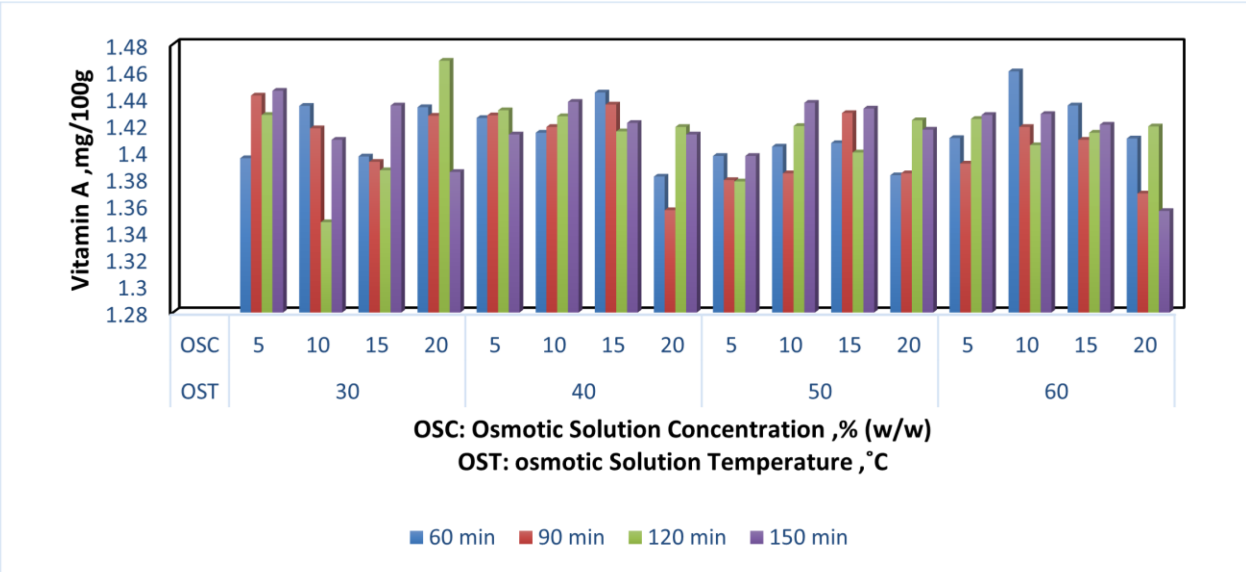

Figure 5 Effect of osmotic process duration (min), osmotic solution temperature and osmotic solution concentration on vitamin A content of red bell pepper

Table 3 shows the effect of individual level of process conditions on vitamin A content. The table shows that, the mean values of vitamin A did not drop below 1.40 mg/100g with increase in levels of each of the process condition. The highest values of vitamin A (1.42mg/100g) were achieved at osmotic process duration of 90 min; osmotic solution concentration of 20% (w/w) and osmotic solution temperatures of 40℃ and 50℃. There is better retention of nutrients of dried samples at these process conditions; which is in agreement with what was reported by Bekele and Ramaswamy (2010) that osmotic dehydration used to cause improvement in product quality.

Table 3 Effect of process conditions on the post-drying quality (vitamin A) of red bell pepper

Osmotic process duration, min	**60**	**90**	**120**	**150**
Vitamin A, mg/100g	1.41[a]	1.42[b]	1.40[c]	1.41[a]
Osmotic solution concentration, % (w/w)	**5**	**10**	**15**	**20**
Vitamin A, mg/100g	1.41[a]	1.40[b]	1.41[a]	1.42[c]
Osmotic solution temperature, ℃	**30**	**40**	**50**	**60**
Vitamin A, mg/100g	1.41[a]	1.42[b]	1.42[b]	1.40[c]

Note: *means with the same alphabet are not significantly different from each other at p≤0.05.

3.5 Effect of osmotic process duration (min), osmotic solution temperature and osmotic solution concentration on the ash content of red bell pepper

The effect of process conditions on the ash content of red bell pepper is shown in Figure 6. The figure shows that increase in process conditions caused the ash content of most samples to be above 8.0 mg/100g. Also, in most cases, the osmotic process duration of 150 min had the highest values of ash contents. Products could vary in tissue compactness, initial insoluble and soluble solids, intercellular spaces and enzymatic activities(Chavan and Amarowicz, 2012). All the factors mentioned would probably cause variations in the inorganic residue (ash) after water and organic has been removed.

Table 4 presents the response of ash content to different levels of process conditions. Increase in osmotic process duration did not cause all the mean values of ash content to be significantly different from each other. Different trends occurred for osmotic solution concentration and osmotic solution temperature. In all cases, the mean values of ash content did not fall below 8.0%. This mean value (8.0%) is slightly below the value of ash content of 8.77% that was obtained by Famurewa et al.(2006) when the osmotic dehydration of red bell pepper was done in sugar solution before hot air drying. Increase in ash content is obvious at some conditions; this is in agreement with the results reported by Olaniyan and Omoleyomi (2013) for the ash content of okra.

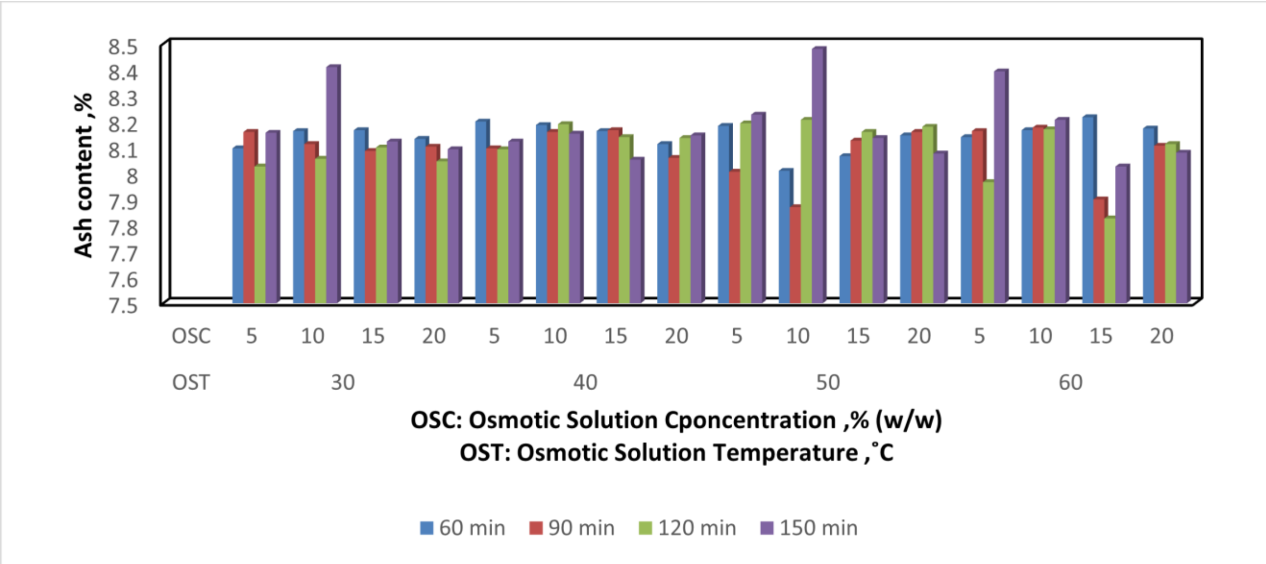

Figure 6 Effect of osmotic process duration (min), osmotic solution temperature and osmotic solution concentration on ash content of red bell pepper

Table 4 Effect of process conditions on the post-drying quality (ash content) of red bell pepper

Osmotic process duration, min	**60**	**90**	**120**	**150**
Ash content, %	8.13^{a}	8.14^{a}	8.14^{a}	8.12^{a}
Osmotic solution concentration, % (w/w)	**5**	**10**	**15**	**20**
Ash content, %	8.15^{a}	8.09^{b}	8.10^{c}	8.18^{d}
Osmotic solution temperature, ℃	**30**	**40**	**50**	**60**
Ash content, %	8.14^{a}	8.17^{b}	8.10^{c}	8.11^{c}

Note: *means with the same alphabet are not significantly different from each other at $p \leq 0.05$.

4 Conclusions

All the levels of osmotic dehydration pretreatment conditions considered, as well as their interactions were not significant on drying rate of red bell pepper with drying temperature of 60℃; although the drying rate decreased with increase in the levels of process conditions. In addition, increase in process conditions did not cause the mean values of vitamin C, vitamin A and ash content of dried red bell pepper to drop below 120 mg/100g, 1.40 mg/100g and 8.0% respectively. Further studies should be done on the storability, shrinkage and rehydration properties of dried samples, and modeling and optimization of the process.

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