EFFECT OF OSMOTIC DEHYDRATION PRETREATMENTS AND DRYING TEMPERATURE ON DRYING RATE AND QUALITY OF MANGO CHIPS

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ABSTRACT

Osmotic dehydration pretreatments combined with further drying have been considered a good method of processing fruits and vegetables as it improves their organoleptic properties and makes them safe for storage. In this study, a 3^3 factorial experiment in Randomized Complete Block Design was used to investigate the effect of osmotic solution concentration (45% w/w, 55% w/w and 65% w/w), osmotic process duration (30 min, 60 min and 90 min) and drying temperatures (60˚C, 70˚C and 80˚C) on drying rate and quality of dried mango chips. Results revealed that osmotic dehydration pretreatments had significant effect on drying rate and quality of mango chips at $P \leq 0.05$. Osmotic solution concentration reduced the loss of quality (vitamin A and C) with the mean value not dropping below 6.461mg/100g and 80.661mg/100g respectively. However, osmotic process duration and drying temperature increased the drying rate at reduced the drying time. The drying rate however did not drop below 0.416g/hr. Further studies can be carried out on the optimization in order to know the best process conditions suitable for this work.

KEYWORDS: Osmotic dehydration, quality, drying rate, mango (*Mangifera indica L*)

1 INTRODUCTION

Mango (*Mangifera indica L.*) is one of the favoured fruits in the tropical and subtropical regions. It has an excellent flavour, attractive fragrance, delicious taste and high nutritional value that have made it one of the best fruits (Pal, 1998). The fruit is very much relished for its succulent, exotic flavour and delicious taste (Godson, 2008). Mangoes are rich source of beta - carotene, a provitamin A carotenoid that is converted to vitamin A in the body. Vitamin A is an essential nutrient required for normal growth, reproduction, vision and boost body's immunity. Mangoes are also important source of Vitamin C (essential nutrient) which is necessary for normal collagen breakdown and prevents a health disorder called scurvy. It also serves as a cofactor for some enzymes in the body and it is a powerful water soluble antioxidant that prevents free radical damage to cells (Godson, 2008). The species, which belongs to the family Anacardiaceae is native to Asia, particularly eastern India, Burma and Andaman Islands from where it spread to other parts of the world. But while the Persians introduced it to East Africa in the 10th Century, the Portuguese were responsible for its introduction to West Africa in the 16th Century (Morton, 1987).

Figure 1: Fresh Mango Fruits

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 tropical fruits and vegetables such as banana, sapota, pineapple, mango, and leafy vegetables etc. with retention of initial fruit and vegetables characteristics viz., colour, aroma and nutritional compounds (Pokharkar & Prasad, 1998). It is less energy intensive than air or vacuum drying processes 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 (osmotic concentration) and subsequent dehydration in a dryer where moisture content is further reduced to make the product shelf stable (Ponting, 1973).

Drying is an ancient method of preservation of food and this involves the removal of majority of the moisture normally present in the food by evaporation, or in other cases freeze drying by sublimation under vacuum to yield a dried product. This occurs under controlled conditions of temperature and pressure (Mazza and LeMaguer, 1980). This definition excludes the processes which involves the mechanical extraction of water out of food such as membrane concentration, gravity concentration, and mechanical separation and baking, as these normally removes less water as compared to drying (Treybal, 1980). During drying, water is removed in the form of vapour as heat is supplied to the food material; therefore, heat and mass transfer occur simultaneously. It requires a safe place to spread the food where dry air in large quantities can pass over and beside thin pieces (DeLong, 1979). Drying is achieved by the direct use of energy produced by the sun or from other means of heating such as electricity and fuel, of all these, sun is the most abundant and economical (Treybal, 1980).

Drying is a simple, low-cost way to preserve food that might otherwise spoil. Drying removes water and thus prevents fermentation or the growth of moulds. It also slows the chemical changes that take place naturally in foods, as when fruit ripens. Surplus grain, vegetables, and fruit preserved by drying can be stored for future use. People have been drying food for thousands of years by placing the food on mats in the sun. This simple method, however, allows the food to be contaminated by dust, airborne moulds and fungi, insects, rodents, and other animals. Furthermore, open air-drying is often not possible in humid climates (DeLong, 1979). The objective of this study is to study the effects of pre-drying treatments and drying conditions on drying rate and quality attributes of mango chips. This information should elucidate the problems involved in mango drying and will be useful to establish parameters for industrial drying of mango chips.

2. MATERIALS AND METHODS

2.1 Experimental Equipment and Materials

The following equipments and materials were used for the experiment: electric oven (NAAFCO BS OVH – 102) having a dimension of 66.0cm x 66.0cm x 88.5cm with a load 2.4kw 10 amps, digital weighing balance(CAMRY EHA251) calibrated in grams with 0.1g accuracy, thermometer, stainless steel tray and knife, distil water, sugar and mangoes.

Figure 2: Mango Chips in Oven Drying

2.2 Experimental Design

A 3^3 factorial experiment in a Randomized Complete Block Design (RCBD) was used to investigate some process variables on drying rate and qualities (vitamin A and C) of mango chips. The process variables are: osmotic solution concentration at these levels (45% w/w, 55% w/w and 65% w/w), osmotic process duration (30 min, 60 min and 90 min) and drying temperature (60˚C, 70˚C and 80˚C). All the experimental runs tested and measured in three replicates were 81. The experiment was carried out in the processing laboratory of Agricultural and Biosystems Engineering Department, Faculty of Engineering and Technology, University of Ilorin, Ilorin, Kwara State, Nigeria. All the experiments were conducted in the month of May, 2014 and the average relative humidity of the laboratory was about 28% throughout the period of the osmotic dehydration process.

2.3 Experimental Procedure

Fresh and ripe matured mangoes were purchased from local market in Ilorin, Kwara State, Nigeria for the purpose of this work. The ones without blemish were chosen, washed with clean water, peeled on stainless steel tray using sharp stainless knife and the pulp separated from the pit (stone).The separated pulp was sliced to 5mm thickness (chips). The slices were weighed (50g) and transferred into different prepared osmotic solution concentrations of sugar syrup 45% (w/w), 55% (w/w) and 65% (w/w)] for 30 min, 60 min and 90 min osmotic process durations according to experimental design layout. The pretreated slices were removed after the completion of osmotic process durations, washed with running water and drained. The weight of each sample was taken after osmotic dehydration. A constant weight of 40g each was introduced into the oven for further drying at different drying temperatures of 60˚C, 70˚C and 80˚C and the weight of each sample was taken at an interval of one hour until a safe moisture content for the mango chips was reached (8% - 16%(wb)). Thermometer was used to check constantly the preset temperature inside the oven to ensure that there was significant no change in temperature.

2.4 Output Parameters

2.4.1 Drying Rate

This is the rate of moisture removal per time during the drying process. It can be obtained by determining the moisture content of samples as drying progresses. Mathematically expressed as:

$$DR = \frac{W1 - W2}{t} \quad (1)$$

Where: w_1 = Weight of product before drying (g), w_2 = Weight of product after drying (g)
t = Drying time (hr), DR = Drying rate (g/hr).

2.4.2 Qualities Determination

The qualities (vitamin A and C) were determined in the Chemistry Laboratory of the University of Ilorin, Kwara State, Nigeria using AOAC procedure of 1990.

2.5 Statistical Analysis

The data obtained from the experiment were subjected to statistical Analysis of Variance (ANOVA) at $P \leq 0.05$ 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

Table 1 shows the results of the analysis of variance (ANOVA) of the effect of osmotic solution concentration, osmotic process duration and drying temperature on drying rate and quality of mango chips. It can be seen from the table that all the process variables and some of their interactions had significant effect on drying rate and quality of the mango chips at $P \leq 0.05$.

Table 1: Results of the Analysis of Variance (ANOVA) of the Effect of Process Conditions on the Drying Rate and Quality of Mango Chips: A-Osmotic Solution Concentration; B-Osmotic Process Duration; C-Drying Temperature

SV	DF	SS	MS	F	P>F
Drying Rate (g/hr)					
A	2	42.864	21.432	19.169	0.002*
B	2	29.018	14.509	12.977	0.010*
C	2	361.196	180.598	161.537	0.000*
A X B	4	1203.416	300.845	269.100	0.020*
A X C	4	2.200	0.550	0.492	0.320
B X C	4	1.504	0.376	0.336	0.628
A X B X C	8	3.300	0.413	0.369	0.260
Error	54	60.365	1.118		
Total	80	1703.863			
Vitamin A (mg/100g)					
A	2	62.460	31.230	20.600	0.100*
B	2	73.527	18.764	12.377	0.001*
C	2	441.183	220.592	145.509	0.002*
A X B	4	103.416	25.854	17.054	0.020*
A X C	4	2.750	0.688	0.454	0.420
B X C	4	1.880	0.470	0.310	0.526
A X B X C	8	3.300	0.413	0.272	0.160
Error	54	81.857	1.516		
Total	80	770.373			
Vitamin C (mg/100g)					
A	2	52.296	26.148	4.500	0.000*
B	2	53.527	26.764	4.605	0.003*
C	2	541.179	270.560	46.560	0.008*
A X B	4	203.416	50.854	8.750	0.020*

A X C	4	2.750	0.688	0.118	0.320
B X C	4	1.880	0.470	0.081	0.326
A X B X C	8	3.300	0.413	0.071	0.267
Error	54	313.857	5.812		
Total	80	1172.205			

*Significantly different at $P \leq 0.05$

3.1 Effect of Osmotic Solution Concentration on Drying Rate and Quality of Mango Chips

The result of Duncan's New Multiple Range Test (Table 2)revealed that drying rate decreased and later increased as the osmotic solution concentration increased from 45% w/w to 65% w/w with the mean values as shown in the table. This effect could be due to uneven distribution of hot air to samples in the conventional oven used in drying. However, vitamin A and C increased with increase in osmotic solution concentration. The mean values of vitamin A and C did not drop below 6.461mg/100g and 80.661mg/100g respectively at 65% w/w osmotic solution concentration.

Table 2: Effect of Osmotic Solution Concentration on Drying Rate and Quality of Mango Chips*

Osmotic Solution Concentration (% w/w)		**45**	**55**	**65**
Drying Rate (g/hr)		20.105^{c}	18.151^{b}	25.261^{a}
Vitamin A (mg/100g)		2.104^{b}	3.706^{b}	6.461^{a}
Vitamin C (mg/100g)		45.205^{c}	61.151^{b}	80.661^{a}

*In each row, means with the same letters are not significantly different ($P \leq 0.05$) using Duncan' Multiple Range Test

The effect of osmotic solution concentration on drying rate and quality was also determined using histogram as seen in Figures 3–5. From the figures, it is clear that increase in osmotic solution concentration caused a noticeable decrease the drying rate which at 80˚C drying temperature, also at this same drying temperature, the drying rate maintained a uniform value of about 0.2g/hr for all osmotic solution concentrations at osmotic process duration 60 min. Furthermore, there was nearly constant rate of drying and sharp increase at 65% (w/w) at 30 min osmotic process duration for 60˚C drying temperature. This effect could be due to the presence of dissolved solids in the sugar syrup that has been transferred into the sample which contributed to slow drying rate (Dennis, 1993). Also, the hygroscopic nature of the sugar could influence the final moisture content of the dried product by lowering the rate of drying in the pre-treated samples. In addition crystallization of these solutes especially sugars could minimize the rate of heat transfer during drying (Mazza and LeMaguer, 1980). The Figure explained particularly at 80˚C that as osmotic solution concentration increases, the better the retention of Vitamin A which is also confirmed by DNMRT (Table 4.12) that the maximum value of Vitamin A is at 65% w/w osmotic solution concentration with a mean value of 6.4611mg/100g. This situation that occurred is one of the advantages of carrying out osmotic dehydration on products before drying to a shelf stable moisture content in a dryer (Pokharkar & Prasad, 1998). The effect of osmotic process duration on vitamin C is also shown. According to the Figure, there was no regular pattern in the effect of osmotic process duration on vitamin C content, but the highest value of above 53 mg/100g was obtained at 45 % w/w with drying temperature 60˚C in 90 min osmotic process duration.

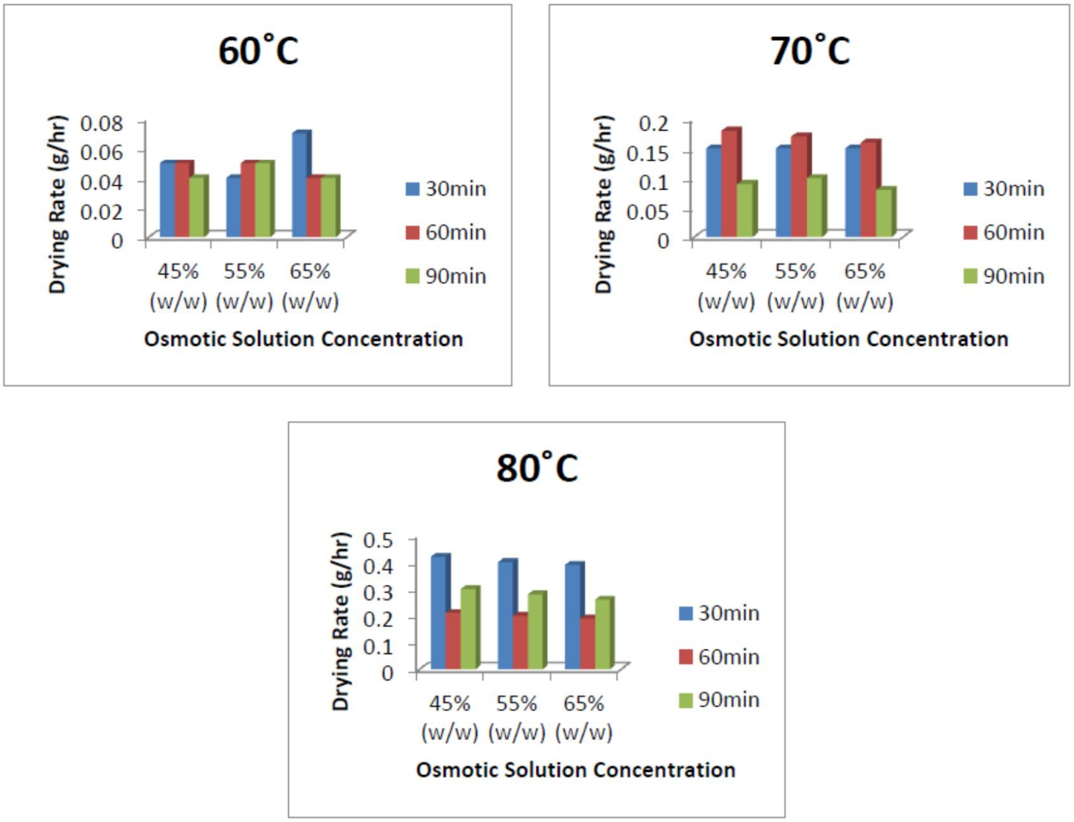
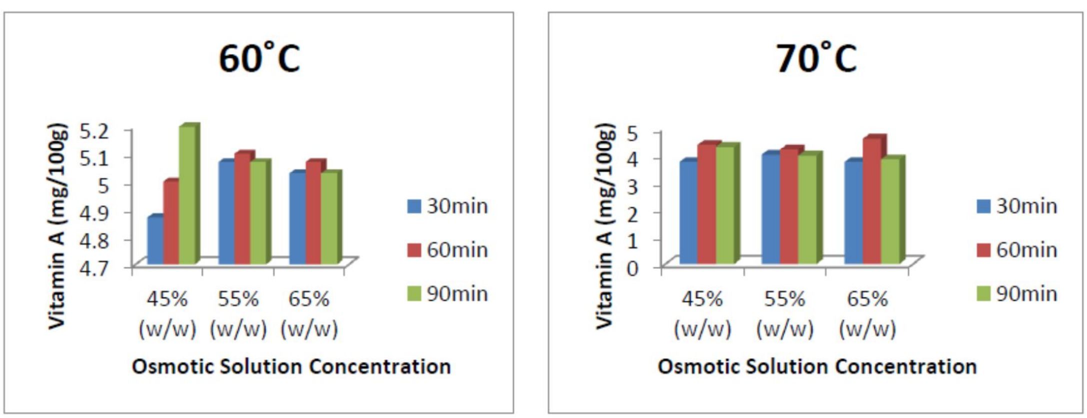


Figure 3: Effect of Osmotic Solution Concentration on Drying Rate at different Osmotic Process Duration for Drying Temperatures of 60, 70 and 80˚C.



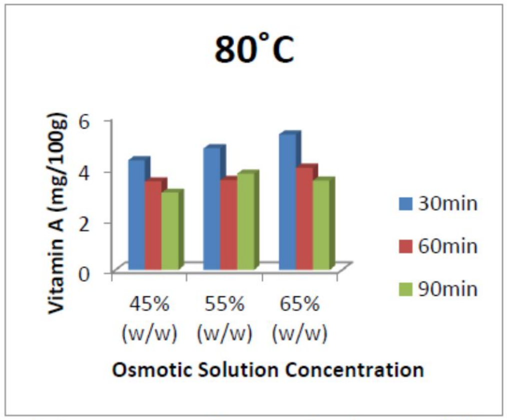


Figure 4: Effect of Osmotic Solution Concentration on Vitamin A at different Osmotic Process Duration for Drying Temperatures of 60, 70 and 80˚C

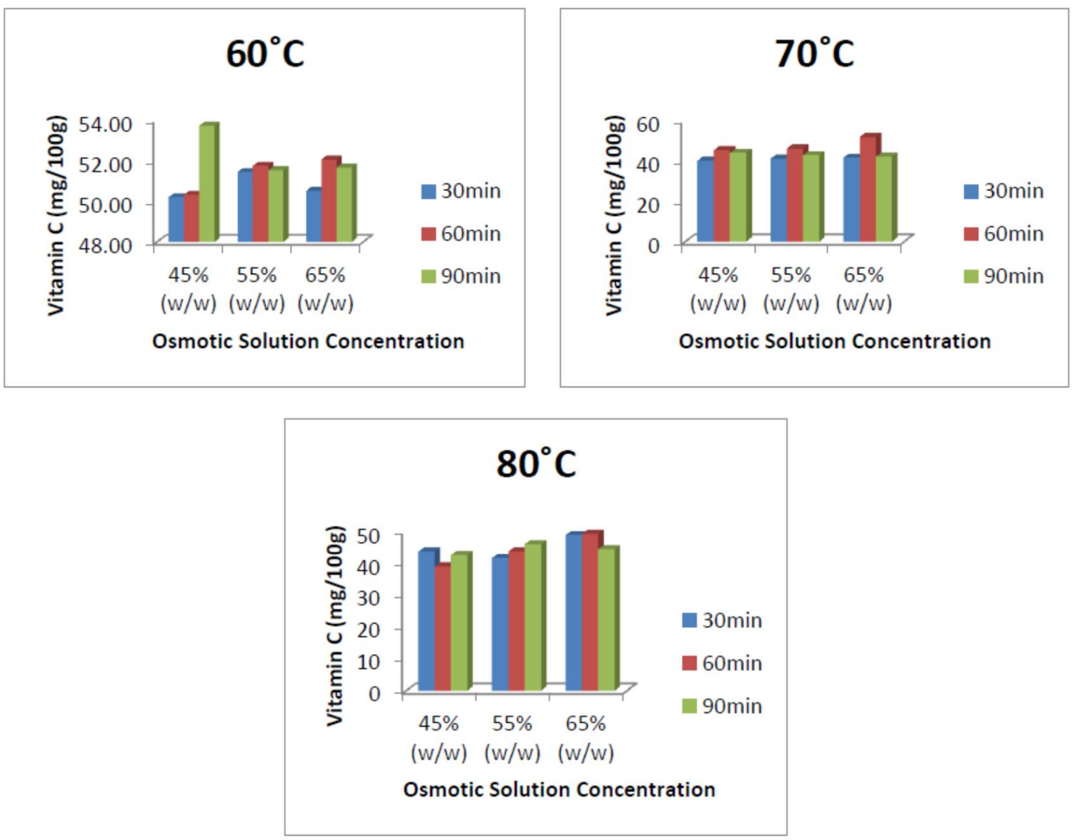


Figure 5: Effect of Osmotic Solution Concentration on Vitamin C at different Osmotic Process Duration for Drying Temperatures of 60, 70 and 80˚C

3.2 Effect of Osmotic Process Duration on Drying Rate and Quality of Mango Chips

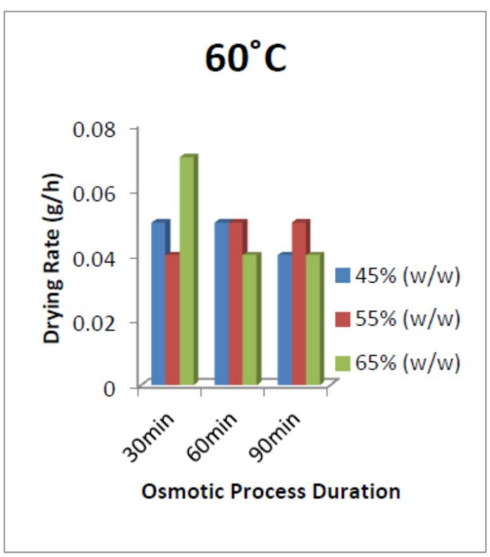
The result of Duncan's New Multiple Range Test (Table 3) showed that as the osmotic process duration increased from 30 min to 90 min, the drying rate increased as well with mean values as revealed in the table. This can be expected because increase in osmotic process duration leads to increase in water loss but the rate at which it increases decreases with time as reported by Tiwari and Jalali (2004) which could contributes to high drying rate. The reverse however was the case for vitamin A and C. As the osmotic process duration increased, the values of vitamin C decreased successively but vitamin A increased and later decreased to a mean value of 4.148mg/100g at 90 min osmotic process duration. But the rate of decrease was not really significant as the value of decrease for vitamin C did not drop below approximately 1.30mg/100g and less than 1.0mg/100g for vitamin A.

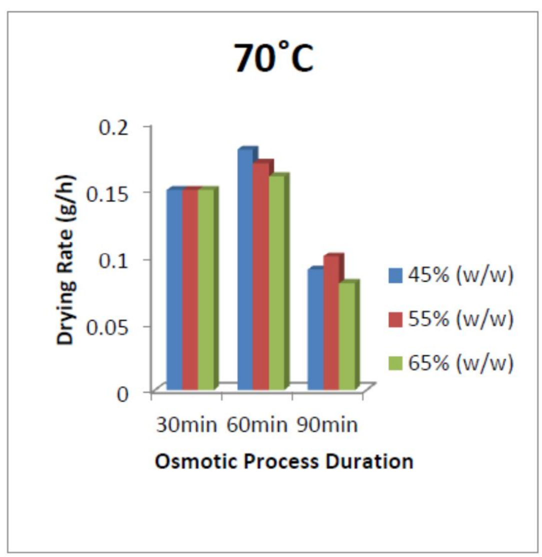
Table 3: Effect of Osmotic Process Duration on Drying Rate and Quality of Mango Chips*

Osmotic Process Duration (min)		**30**	**60**	**90**
Drying Rate (g/hr)		34.047^{c}	40.181^{b}	51.961^{a}
Vitamin A (mg/100g)		4.013^{c}	4.980^{a}	4.148^{b}
Vitamin C (mg/100g)		22.701^{a}	21.598^{b}	20.144^{c}

*In each row, means with the same letters are not significantly different (P≤0.05) using Duncan' Multiple Range Test

The effect of osmotic process duration on drying rate and quality was also examined using histogram as seen in Figures 6-8. From the figures, it is seen that there was no steady pattern in response of drying rate to osmotic process duration. As the osmotic process duration increased from 30mins to 90mins, there was a decrease in the drying rate. The only exceptions are at 70˚C (where there was sharp increase in drying rate at 60min osmotic process duration) and 80˚C (where there was sharp decrease at the same 60min osmotic process duration). These exceptions may be due to factors associated with how the fibre arrangement of individual experimental samples, which also has the tendency of influencing measured responses. The 60˚C drying temperature showed almost a constant drying rate. For vitamin A, there was no regular pattern in the way it was affected, but the drying temperature at 80˚C showed a decreasing value of Vitamin A as osmotic process duration increased. Similarly, there was no regular pattern in the response of vitamin C to change in osmotic process duration.





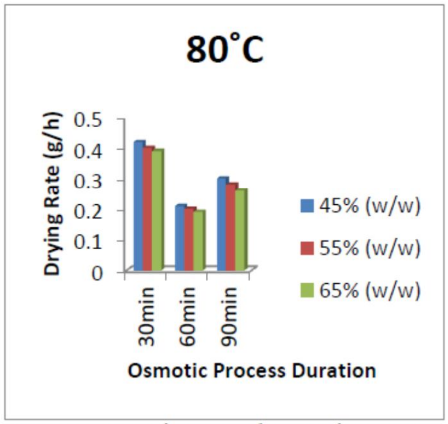


Figure 6: Effect of Osmotic Process Duration on the Drying Rate at different Osmotic Solution Concentration for Drying Temperatures of 60, 70 and 80˚C

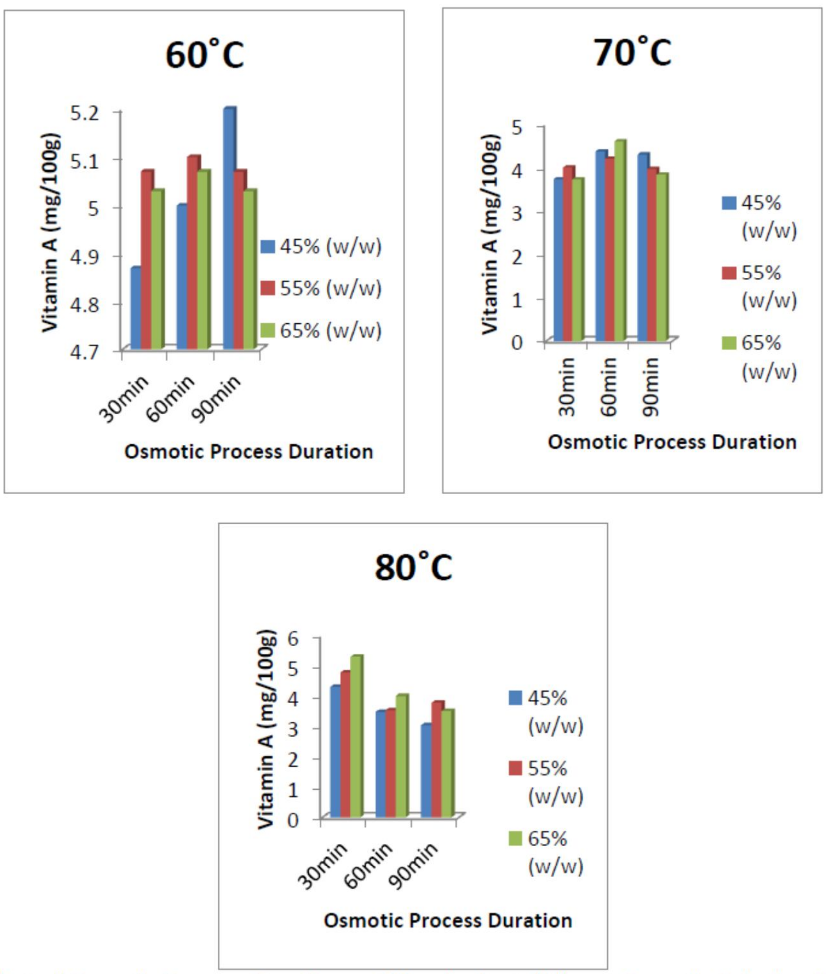


Figure 7: Effect of Osmotic Process Duration on Vitamin A at different Osmotic Solution Concentration for Drying Temperatures of 60, 70 and 80˚C

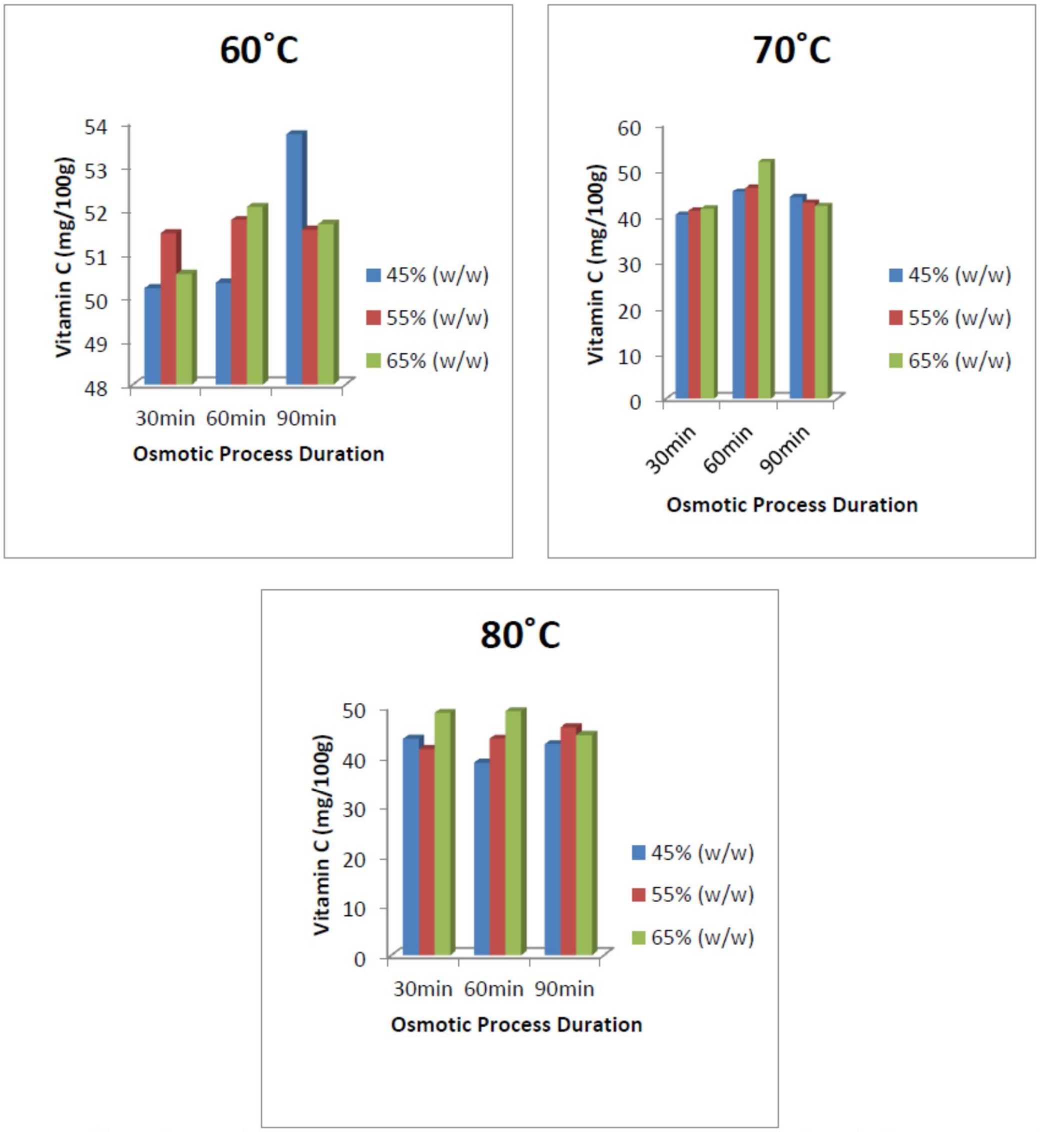


Figure 8: Effect of Osmotic Process Duration on Vitamin C at different Osmotic Solution Concentration for Drying Temperatures of 60, 70 and 80˚C

3.3 Effect of Drying Temperature on Drying Rate and Quality of Mango Chips

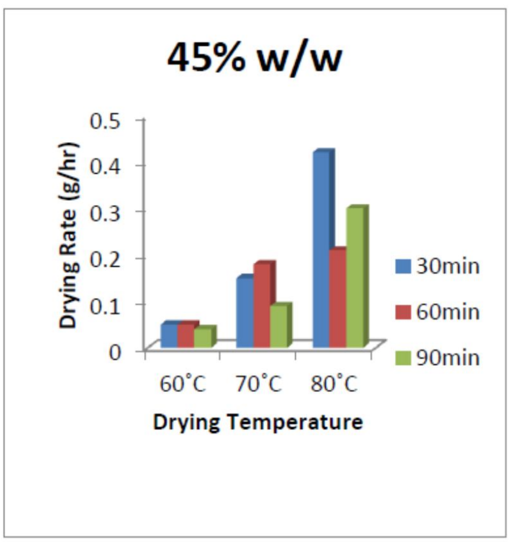
The result of Duncan's New Multiple Range Test (Table 4) revealed that increase in drying temperature resulted in increased drying rate with a mean value of 36.661g/h at 80˚C drying temperature all test at $P \leq 0.05$. This could be expected as the moisture diffusion from product to its surface for evaporation to occur will be faster at high temperature which could eventually lead to high drying rate. Increase in drying temperature caused a decrease and later an increase in vitamin A with mean value of 4.068mg/100g at 80˚C drying temperature. This result however showed that there was no much difference in the value of vitamin C for 60 and 70˚C but falls at 80˚C with mean value of 20.143mg/100g. This reduction in vitamins could be due to sensitivity of these qualities to temperature.

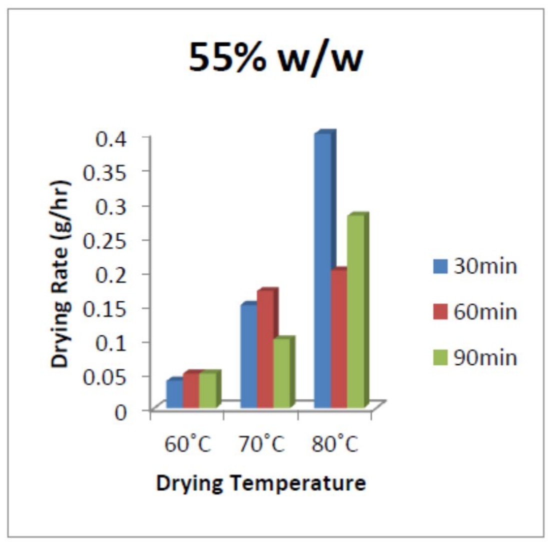
Table 4: Effect of Drying Temperature on Drying Rate and Quality Mango Chips*

Drying Temperature (˚C)	**60**	**70**	**80**
Drying Rate (g/hr)	21.446[c]	27.181[b]	36.661[a]
Vitamin A (mg/100g)	4.081[a]	3.145[c]	4.068[b]
Vitamin C (mg/100g)	32.231[a]	29.698[ab]	20.143[b]

*In each row, means with the same letters are not significantly different ($P \leq 0.05$) using Duncan' Multiple Range Test

The effect of drying temperature on drying rate and quality was also determined using histogram as seen in figures 9-11. From the figures, shown that increase in drying temperatures caused an increase in drying rate; this is usually expected in drying operation because the moisture diffusion from inside of material to the surface for it to evaporate will be faster at higher temperature than at the lower one; this is also seen in Figure 9. Figure 10 showed the effect of drying temperature on vitamin A. The figure gave pictures of slight reduction in of vitamin A values with increase in drying temperatures; this trend is not unusual because higher drying temperatures could lead to loss of essential vitamins. For Vitamin C, increase in drying temperatures caused a decrease in the values of Vitamin C for at various osmotic solution concentrations; however, the drop in Vitamin C values between two adjacent drying temperatures was not sharp. The highest values of Vitamin C (above 50 mg/100g) were obtained at the lowest drying temperature of 60˚C for the three osmotic solution concentrations used. The reason for the drop in value of Vitamin C could most likely be the fact that, at higher drying temperature, there is high tendency of destroying heat sensitive vitamins of which Vitamin C is inclusive.





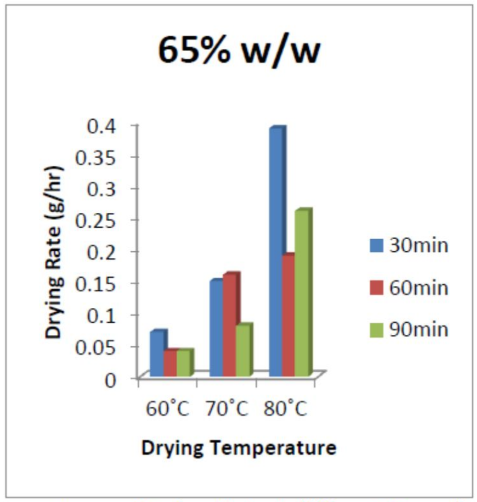


Figure 9: Effect of Drying Temperature on Drying Rate at different Osmotic Process Duration for Osmotic Solution Concentration of 45% w/w, 55% w/w and 65% w/w

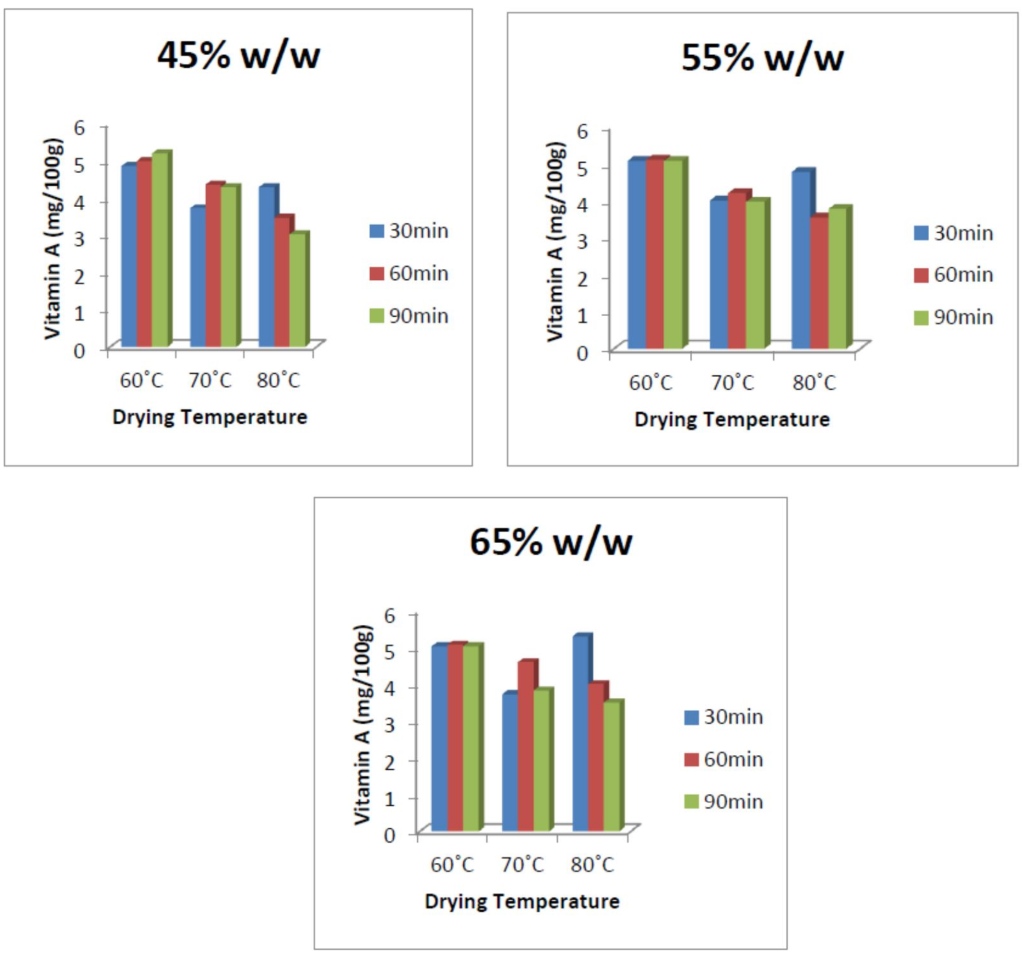


Figure 10: Effect of Drying Temperature on Vitamin A at different Osmotic Process Duration for Osmotic Solution Concentration of 45% w/w, 55% w/w and 65% w/w

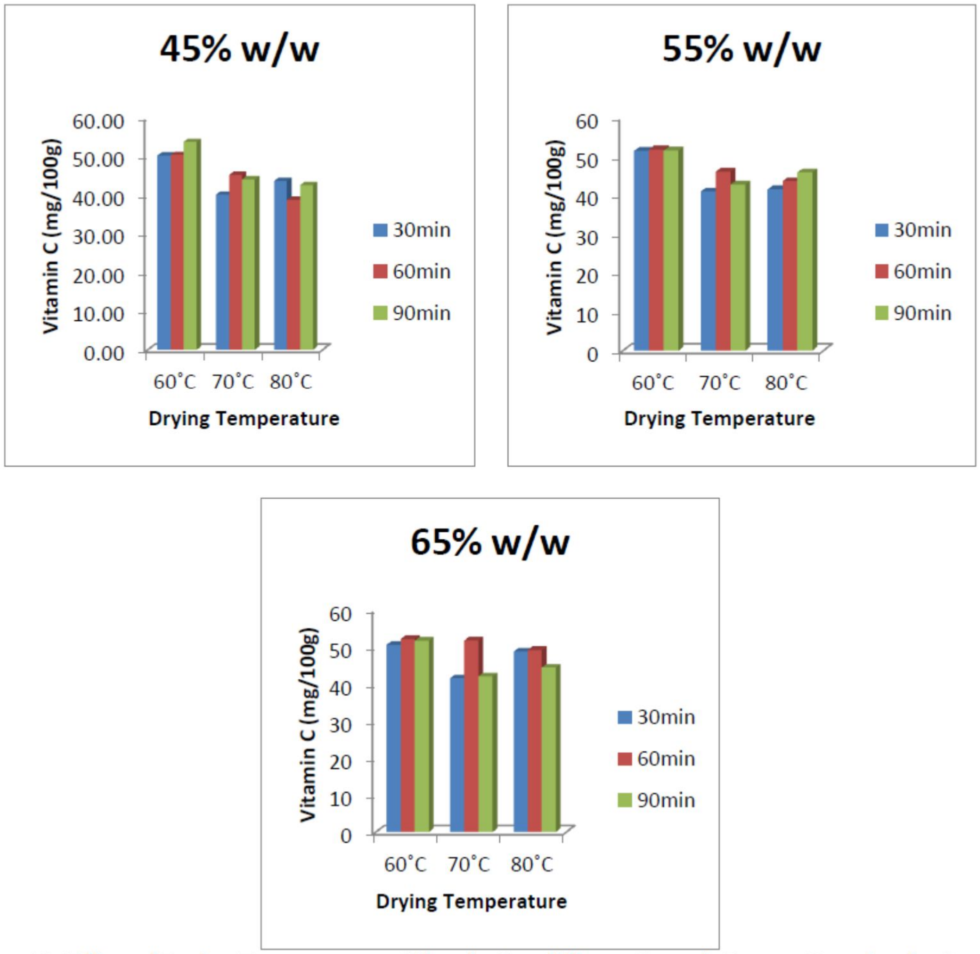


Figure 11: Effect of Drying Temperature on Vitamin C at different Osmotic Process Duration for Osmotic Solution Concentration of 45% w/w, 55% w/w and 65% w/w

4. CONCLUSION

From the study, it can be concluded that all the process conditions considered were significant on drying rate and quality attributes of mango chips. Increase in osmotic solution concentration caused retention of the quality attributes of mango chips whose mean values of vitamin A and C did not drop below 6.461mg/100g and 80.661mg/100g respectively. However, increase in osmotic process duration and drying temperature had slight negative effect on quality attributes of mango chips but led to increase in drying rate whose value did not drop below 0.416g/hr.

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