

Post-storage qualities of pre-treated dried red bell pepper

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Abstract

Keywords:

Red bell pepper
Storage
Pre-treatment
Vitamin
Qualities

Article history:

Received 05.09.2015
Received in revised
form 27.10.2015
Accepted 24.12.2015

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Introduction. Fresh red bell pepper is highly perishable. Hence, it can be pre-treated, dried and stored for shelf life extension. In the storage facility, stored products' nutrients may depreciate and may be subjected to microbial activities.

Materials and methods. Glass ware desiccator, Lovibond colour reference standard (ISO 9002 AOCS tintometer, Pt-Co (platinum – cobalt) colour 30 reference), incubator (Model no: DHG 1923A), measuring cylinders, conical flasks, pipette, burette, separating funnel, test tubes and petri dishes; and samples of pre-treated dried red bell pepper. Nutritional analysis and bacterial load determination of samples were done respectively in the laboratory. Statistical analysis of all data obtained was done.

Results and discussion. From the table of analysis of variance, only colour had all its inputs and their various interactions not significant at $p \leq 5\%$ while all the inputs and their various interactions had significant effect on vitamin C. The results also showed that the percentage drop in the values of vitamins A and C before and after storage at various levels of process conditions were 53.10% and 53.40% respectively. The bacteria load was not above 6×10^6 cfu/ml which is within the accepted range (10^7 cfu/ml and 10^8 cfu/ml) for ready-to-eat vegetables. There was also a better retention of colour (deep yellow) in the stored pre-treated dried samples well above untreated samples with deep brown colour. T-test done showed that there was significant difference between the amount of vitamins A and C before and after storage. All the above observations from the results could be due to various factors like environmental conditions and type of the storage medium, nature of fresh samples during growth and at the time of harvest, and handling operations before, during and after processing and storage, processing conditions of samples before storage, duration of samples in storage medium and so on. Regression equations were developed for vitamins A and C, bacteria load and colour. Only vitamin A equation did not predict well.

Conclusions. The stored pre-treated dried samples of red bell pepper were microbiologically and nutritionally safe for consumption after 20 months in storage. They also showed better colour (deep yellow). The regression equations developed can be used to predict vitamin C, bacteria load and colour.

Introduction

Bell peppers (also known as sweet peppers) are plump, bell-shaped vegetables featuring either three or four lobes. They are native to Mexico, Central America and Northern sides of South America and are available in various colours such as green, red, yellow, orange and more rarely, white, rainbow (between stages of ripening) and purple[1]. Red bell peppers are rich in vitamin C and vitamin A. Since red bell peppers are high in vitamin A, they support healthy eyesight, especially night vision. They also have the ability to heal fever and cold, cure diabetes, control the cholesterol level in the body [2], heal sores and bruises and enhance food digestion [1,3]. Generally, fresh red bell pepper is highly perishable; hence, depending on the effectiveness of the storage facility and other factors, stored products' nutrients may depreciate and may be subjected to microbial activities.

Osmotic dehydration pre-treatment is the partial removal of water from food products by immersing the food in a hypertonic solution [4]. Osmotic dehydration favours colour and flavour retention, improves texture and rehydration properties and the process is simple and economical [5]. Pre-treatment is done to preserve flavour and colour, minimise nutrient loss, stop enzyme action and extend shelf life of red bell pepper. However, while in storage, pre-treated dried red bell pepper may deteriorate in quality and quantity due to various factors like environmental conditions and type of the storage medium, nature of fresh samples during growth and at the time of harvest, and handling operations before, during and after processing and storage, processing conditions of samples before storage, duration of samples in storage medium and so on.

Storing of food has several advantages which include: enabling a better balanced diet throughout the year, preserving pantry food, such as spices or dry ingredients like rice and flour for eventual use in cooking; preparedness for catastrophes, emergencies and periods of food scarcity or famine, and protection from animals or theft [6]. Storage also protects the quality of perishable and semi-perishable products from deterioration and helps in the stabilization of prices by adjusting demand and supply [7]. An in depth literature search revealed that much work has not been done on the post-storage qualities and characteristics of osmotic dehydrated (as a pre-treatment) coupled with hot air dried products, especially, red bell pepper. Therefore, the main objective of this research was to study the post-storage qualities of pre-treated dried red bell pepper with reference to; osmotic process duration, osmotic solution temperature and osmotic solution concentration. The specific objectives were to: (i) investigate the effect of these osmotic process conditions on the nutritional qualities (vitamin A and vitamin C), sensory quality (colour) and bacteria load; (ii) compare the nutritional level of pre-treated dried red bell pepper in terms of vitamin C and vitamin A before and after storage; and (iii) develop regression equations for predicting the vitamin C, vitamin A, colour and bacteria load of pre-treated dried red bell pepper after storage.

Materials and methods

Experimental equipment and materials. The following equipment were used for the study: glass ware desiccator, Lovibond colour reference standard (ISO 9002 AOCS tintometer, Pt-Co (platinum – cobalt) colour 30 reference), incubator (Model no: DHG 1923A), measuring cylinders, conical flasks, pipette, burette, desiccator, separating funnel, test tubes and petri dishes. The main materials used were 192 samples of pre-treated and 20 untreated (control) dried red bell pepper.

Storage of pre-treated dried samples. Samples (pre-treated dried red bell pepper) were stored for 20 months in a glass ware desiccator in accordance with a 4^3 factorial experiment in Randomized Complete Block Design (RCBD) used for the pre-treatment of samples and final drying at 60°C. This experimental design was used by [8] to carry out the osmotic dehydration pre-treatment of samples before drying it in a convective hot air dryer fabricated by [9]. The osmotic dehydration pre-treatment factors taken into consideration were osmotic process duration (A), osmotic solution concentration (B) and osmotic solution temperature (C). The osmotic process duration used 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°C, 40°C, 50°C and 60°C. The moisture content of all samples before storage was not greater than 8 % (db). Also, the mean values of vitamin C and vitamin A contents of the samples before storage were 124.63 mg/100g 1.41 mg/100g respectively. The average ambient conditions of the storage environment were 28°C temperature and 46.50 % relative humidity.

Quality analysis. Vitamin A and vitamin C were analysed in the Chemistry Laboratory of the University of Ilorin, Kwara State, Nigeria using [10] standard. The bacterial load determination was done at the Microbiology Laboratory of University of Ilorin, Ilorin, Nigeria according to the procedure in the Laboratory manual of Microbiology by [11].

Colour evaluation was done using Lovibond colour reference standard with Platinum – Cobalt colour 30 reference and the results were expressed as Y, BY, B and DY, where Y was used to denote yellow, BY was used to denote brownish yellow, B for brown and DY denoted deep yellow.

Statistical analysis. All the data obtained from the laboratory were introduced into SPSS 20.0.0 software package. Statistical Analysis of Variance (ANOVA) was used to check the significance of the results. Duncan's New Multiple Range Test (DNMRT) was also used to separate means and to rank the mean values of outputs at different levels of process conditions. The data obtained for vitamin A and vitamin C were subjected to T-test to compare the amount of vitamin A and vitamin C present before and after storage. A significant level (p value) of 5% was used at all cases.

The equation used for the T-test is shown in equations 1-3 [12].

$$T = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{S_p^2}{n_1} + \frac{S_p^2}{n_2}}} \quad (1)$$

where:

Combinet variance

$$S_p^2 = \frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2} \quad (2)$$

Variance

$$S^2 = \frac{\sum (x - \bar{x})^2}{n - 1} \quad (3)$$

Number of samples n = 64.

Null Hypothesis (H_0). There is no significant difference in the amount of vitamin A and vitamin C of pretreated dried red bell pepper before storage and after storage.

Alternate hypothesis (H_1). There is significant difference in the amount of vitamin A and vitamin C of pretreated dried red bell pepper before and after storage.

Decision Rule:

Reject H_0 if calculated t- value is $\geq$ Table or critical value.

Accept H_1 if calculated t-value is $\geq$ Table or critical value.

Vitamin A. Number of samles before storage n_1 and after storage n_2 :

$$n_1=n_2=64$$

Mean before storage:

$$\bar{x}_1 = 1.41$$

Mean after storage:

$$\bar{x}_2 = 0.66$$

Variance before storage:

$$S_1^2 = 0.000587$$

Variance after storage:

$$S_2^2 = 0.000798$$

Vitamin C. Number of samles before storage n_1 and after storage n_2 :

$$n_1=n_2=64$$

Mean before storage:

$$\bar{x}_1 = 124.63$$

Mean after storage:

$$\bar{x}_2 = 58.08$$

Variance before storage:

$$S_1^2 = 86.49$$

Variance after storage:

$$S_2^2 = 4.84$$

Developments of regression equations. In developing the regression equations, about 80% of the data obtained were introduced into SPSS 20.0.0 software package and the rest of the data were used for testing the regression equations. The regression equations developed were tested with respect to their p-values and difference between the predicted and observed values of outputs.

Results and discussion

Results of analysis of variance (ANOVA). The results of analysis of variance (ANOVA) showing the effect of osmotic process duration, osmotic solution temperature and osmotic solution concentration on vitamin C, vitamin A, bacteria load and colour is presented in Table 1. It can be inferred from Table 1 that only colour had all its inputs and their various interactions not significant at $p \leq 5\%$ while all the inputs and their various interactions had significant effect on vitamin C. The implication of this observation is that all the process conditions and their interactions did not cause a noticeable effect on the colour of the pretreated dried product after storing them for 20 months.

Table 1

Results of Analysis of Variance for Outputs

Inputs				Interactions			
Outputs	A	B	C	A×B	A×C	B×C	A×B×C
Bacteria Load, 10 ⁶ cfu/ml	0.00*	0.00*	0.00*	0.01*	0.51	0.00*	0.00*
Vitamin C, mg/100g	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*
Vitamin A, mg/100g	0.00*	0.00*	0.00*	0.00*	0.00*	0.14	0.00*
Colour	0.64	0.42	0.20	0.36	0.61	0.73	0.47

*Significant at P ≤ 5%

A - Osmotic Process Duration (minutes), B- Osmotic Solution Concentration , %(w/w),

C- Osmotic Solution Temperature, °C.

Effect of osmotic process duration, osmotic solution concentration and osmotic solution temperature on bacteria load. The effect of osmotic process conditions on bacteria load is shown in Figure 1. The highest bacteria load (6×10⁶cfu/ml) was at 90 minutes osmotic process duration, 60°C osmotic solution temperature and 20 % w/w osmotic solution concentration and the lowest bacteria (1.20×10⁶cfu/ml) was at these combinations; 30°C osmotic solution temperature, osmotic solution concentration 10% w/w and osmotic process duration 90 minutes. It has been reported that bacteria or other microorganisms require nutrients for growth; hence the irregularities in the bacteria load could be as a result of the difference in the amount of nutrients present in the various samples [13]. Also, [14] proposed 10⁸cfu/ml of aerobic psychotropic bacteria and 10⁷cfu/g for lactic acid bacteria as the limiting criteria for ready-to-eat vegetables. The result obtained for bacteria load is within these limiting criteria.

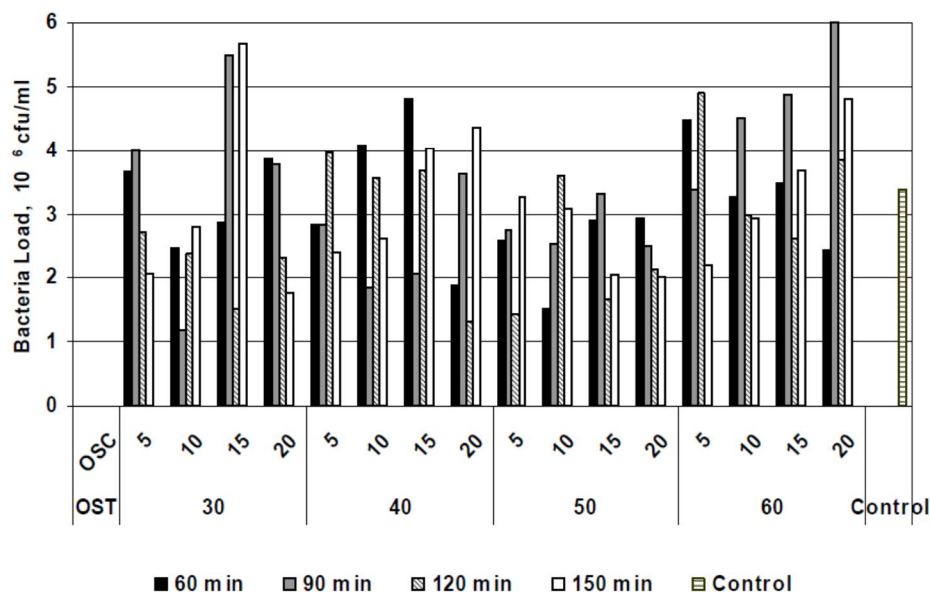


Figure 1. Effect of osmotic process duration, osmotic solution temperature and osmotic solution concentration on bacteria load

Table 2 presents the effect of individual process conditions on the mean values of bacteria load of stored pre-treated dried red bell pepper. The highest mean value of bacteria load (3.71×10^6 cfu/ml) from the table was found to be at 90 min and the lowest mean value (2.63×10^6 cfu/ml) was at 120mins osmotic process duration. Higher mean value of bacteria load was obtained at 40°C osmotic solution temperature and it was also observed that bacteria load decreased as the temperature increased. The product might have absorbed some moisture while in storage thereby increasing the water activity which in turn might have increased the bacteria load. [15] reported that free water or available water as responsible factor for growth of moulds, yeast and bacteria.

Table 2

Duncan's New Multiple Range Test (DNMRT) for the effect of process conditions on bacteria load

Osmotic Process Duration, min	60	90	120	150
Bacteria Load, 10^6 cfu/ml	2.93 ^c	3.71 ^a	2.63 ^c	3.18 ^b
Osmotic Solution Concentration, %(w/w)	5	10	15	20
Bacteria Load, 10^6 cfu/ml	3.09 ^a	2.85 ^b	3.42 ^b	3.09 ^a
Osmotic Solution Temperature, °C	30	40	50	60
Bacteria Load, 10^6 cfu/ml	3.22 ^a	3.34 ^a	2.95 ^b	2.95 ^b

Means with the same alphabet are not significantly different from each other at $p \leq 5\%$

Effect of osmotic process duration, osmotic solution concentration and osmotic solution temperature on vitamin C. Figure 2 shows the effect of osmotic process conditions on vitamin C. The highest amount of vitamin C (63.43mg/100g) was at 40°C osmotic solution temperature, 15%w/w of osmotic solution concentration and at 120 min osmotic process duration while the lowest amount of vitamin C (51.23mg/100g) was found to be at 60°C osmotic solution temperature, 15% w/w osmotic solution concentration and 150 minutes osmotic solution temperature. This observation is in line with what was reported by [16] that exposure to temperature via cooking would not favour vitamin C. Also, [17] reported that there is tendency for vitamin C to degrade steadily during prolonged storage. The fairly high value of the control sample (59.88mg/100g) could mean that the process conditions were not harsh enough to cause a sharp drop in vitamin C.

The effect of individual process conditions on Vitamin C is shown in Table 3. The highest mean value of Vitamin C (58.88mg/100g) was obtained at osmotic solution temperature 30°C and it was observed that Vitamin C decreased as temperature increased. It was seen that there was an increase in the amount of Vitamin C as osmotic process duration increased from 60 minutes to 150 minutes. There was retention in the amount of Vitamin C which agreed with what [18] reported that osmotic dehydration was a means of enhancing the processing of tropical fruits and vegetables with retention of initial fruit and vegetables characteristics in terms of colour, aroma and nutritional compounds.

Effect of osmotic process duration, osmotic solution concentration and osmotic solution temperature on vitamin A. As seen in figure 3, there was a general increase in the amount of vitamin A as osmotic solution temperature increased from 30°C to 60°C. However, the highest amount of Vitamin A (0.73mg/100g) was at 60°C osmotic solution temperature, 5%w/w osmotic solution concentration and 60 min osmotic process duration. The irregularities in the amount of Vitamin A present may be as a result of variables like maturity, variety, pretreatments, temperature, nature and concentration of osmotic agent, geometry of the material, fruit pieces to osmotic solution ratio, physico-chemical properties, additives, structure, pressure as reported by [5].

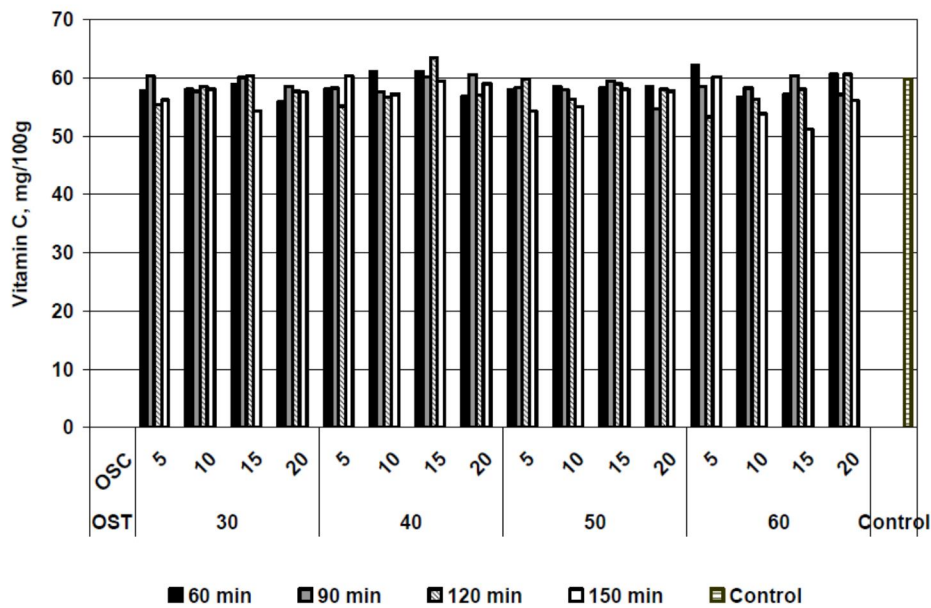


Figure 2. Effect of osmotic process condition, osmotic solution temperature and osmotic solution concentration on vitamin C

Table 3
Duncan's New Multiple Range Test (DNMRT) for the effect of process conditions on vitamin C

Osmotic Process Duration, min	60	90	120	150
Vitamin C, mg/100g	57.51 ^c	58.07 ^b	58.19 ^b	58.31 ^a
Osmotic Solution Concentration, %(w/w)	5	10	15	20
Vitamin C, mg/100g	57.99 ^b	57.54 ^b	58.52 ^a	58.03 ^a
Osmotic Solution Temperature, °C	30	40	50	60
Vitamin C, mg/100g	58.88 ^a	58.61 ^a	57.89 ^b	56.69 ^c

Means with the same alphabet are not significantly different from each other at $p \leq 5\%$

The individual effect of the process conditions on Vitamin A is shown in the Table 4 below. The table shows that the highest mean value of Vitamin A (0.68mg/100g) was at 30°C osmotic solution temperature and it was noticed that the amount of Vitamin A reduced as osmotic solution temperature increased from 30°C to 60°C. The lowest mean value of Vitamin A (0.65mg/100g) is at osmotic solution temperature 60°C. This could be as a result of process temperatures during pre-treatment and final drying operations which could have caused the Vitamin A content to further reduce over the storage period.

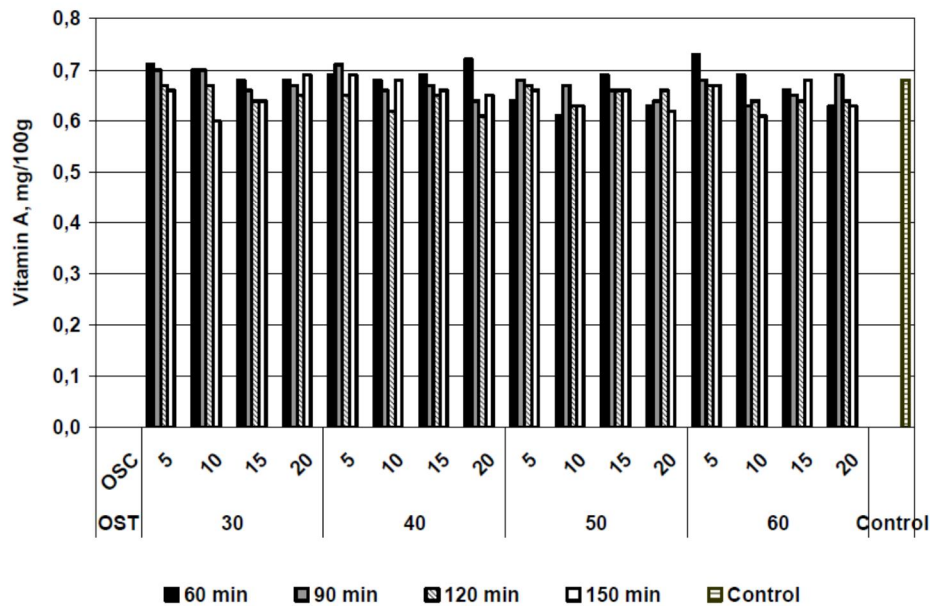


Figure 3. Effect of osmotic process duration, osmotic solution temperature and osmotic solution concentration on Vitamin A

Table 4
Duncan's New Multiple Range Test (DNMRT) for the effect of process conditions on vitamin A

Osmotic Process Duration, min	60	90	120	150
Vitamin A, mg/100g	0.66 ^b	0.67 ^a	0.67 ^a	0.66 ^b
Osmotic Solution Concentration, %(w/w)	5	10	15	20
Vitamin A, mg/100g	0.68 ^a	0.65 ^c	0.66 ^b	0.65 ^c
Osmotic Solution Temperature, °C	30	40	50	60
Vitamin A, mg/100g	0.68 ^a	0.66 ^b	0.65 ^b	0.65 ^c

Means with the same alphabet are not significantly different from each other at $P \leq 5\%$

Effect of osmotic process duration, osmotic solution concentration and osmotic solution temperature on sensory quality (colour). Figure 4 shows the effect of the process conditions on sensory quality. From the figure, the highest color value, 31.83 (DY (deep yellow)) was noticed at osmotic solution temperature 50°C, osmotic solution concentration 20 % w/w and osmotic process duration 120 min. It was also clearly noticed that the control (untreated) samples had the least color value (23.82) denoted as B (brown). This observation is a confirmation of what [5] said that osmotic dehydration is a process that used to increase the sensory qualities (e.g. colour and flavour) of products.

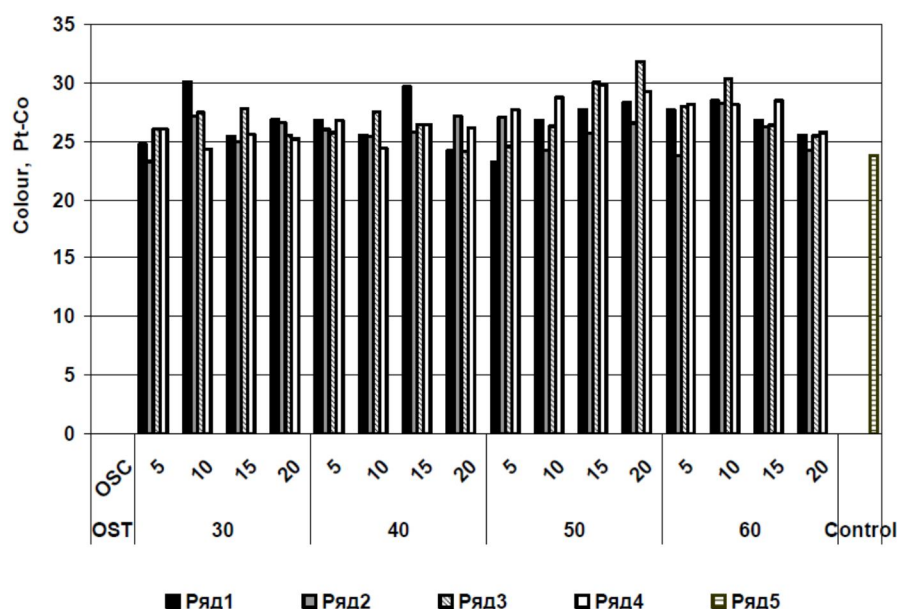


Figure 4. Effect of osmotic process duration, osmotic solution temperature and osmotic solution concentration on colour

T- test result. The T-test for the amount of vitamin C was calculated to be 55.71 while that of vitamin A was calculated to be 161.23. From the T-test table [12], at degree of freedom (df) 63 and level of significance (α) 5%, the table value (critical value) of vitamin C was gotten to be 1.99 while the table value (critical value) of vitamin A was found to be about 1.96. From the aforementioned, the calculated values for both vitamin C and vitamin A were greater than their table values hence, H_0 (null hypothesis) was rejected and H_1 (alternative or research hypothesis) was accepted. This means there is a significant difference in the amount of vitamin C and vitamin A present in the pretreated dried red bell pepper before storage and the amount after storage. This could be as a result of environmental conditions of the storage medium like temperature and relative humidity, maturity level of samples before pre-treatment, side effect of handling during the experiment or ageing of samples in storage. All these observations were in line with what was reported by [17] that vitamins have the tendency of steadily degrading during prolonged storage. The percentage drop in the amount of vitamin C and vitamin A of pre-treated dried red bell pepper before and after storage was 53.40% and 53.10% respectively

Regression equations. Equations 4 – 7 present the regression equations developed for vitamin C (VIT C), vitamin A (VIT A), Bacteria Load (BL) and Colour (COL) with respect to the input factors: A(Osmotic Process Duration)), B(Osmotic Solution Concentration) and C(Osmotic Solution Temperature).

$$\text{VIT C} = 60.141 + 0.130A + 0.560B - 0.374C, \text{ P-value} = 0.006, R^2 = 0.60 \quad (4)$$

$$\text{VIT A} = 415.462 - 3.770A - 7.542B + 3.769C, \text{ P-value} = 0.005, R^2 = 0.55 \quad (5)$$

$$\text{BL} = 3.637 - 0.001A + 0.012B - 0.012C, \text{ P-value} = 0.007, R^2 = 0.66 \quad (6)$$

$$\text{COL} = 24.032 - 0.001A + 0.030B + 0.049C, \text{ P-value} = 0.003, R^2 = 0.88 \quad (7)$$

It was observed from equations 4 to 7 that the P-values for the equations developed were low. The low P-values (less than 0.05) is one of the possibilities that all the regression equations developed would suitably explain the characteristics of the pre-treated dried red bell pepper after storage. R^2 value is the coefficient of multiple determination and it is a measure of the amount of reduction in variability of outputs (vitamin A, vitamin C, colour and bacteria load) obtained by using the variables(inputs), that is, osmotic process duration (A), osmotic solution temperature (C) and osmotic solution concentration (B). Some of the equations developed did not have high R^2 values but according to [19], a large value of R^2 does not necessarily implied that a regression model is a good one and a low R^2 value does not mean that the equation is a bad one. Also, R^2 is an index that explains the strength of linear relationship between input and output variables. The not too high R^2 values(except for colour) obtained for some of the regression equations developed showed that there was no strong linear relationship between the input variables (A, B and C) and output variables (vitamin A, vitamin C, colour and bacteria load) of the pre-treated dried red bell pepper after storage. To further check the suitability of all developed regression equations, the difference between predicted and observed outputs was done.

The summary of the difference between predicted and observed values of the outputs is presented Table 5. The table shows that vitamin C, bacteria and colour predicted well as the difference between the observed and predicted were not much. However, vitamin A did not predict well even though it has low P-value because one of the differences between observed and predicted values vitamin A gave an extremely high value of 37.72 mg/100g.

Table 5
Summary of difference between predicted and observed values of vitamin C and vitamin A

Vitamin C(mg/100g)			Vitamin A(mg/100g)		
Observed A	Predicted B	B-A	Observed A	Predicted B	B-A
57.90	59.52	1.62	0.70	0.71	0.01
59.53	58.58	-0.95	0.69	0.69	0.00
59.50	61.38	1.88	0.65	0.70	0.05
57.27	58.74	1.47	0.64	0.68	0.04
53.95	55.00	-1.05	0.70	38.4	37.72
Bacteria Load (10 ⁶ cfu/ml)			Colour		
Observed A	Predicted B	B-A	Observed A	Predicted B	B-A
2.47	3.34	0.87	24.74	25.59	0.85
2.87	3.40	0.53	25.47	25.89	0.42
2.70	3.22	0.52	24.96	25.86	0.93
2.37	3.28	0.91	25.61	25.80	0.19
2.83	3.16	0.33	25.56	26.23	0.67

Conclusions and recommendations

From this study, it can be concluded that all the process conditions (osmotic solution temperature, osmotic solution concentration and osmotic process duration) had significant effect on the nutritional qualities (vitamins A and C) and bacteria load of stored pre-treated dried red bell pepper but not on sensory quality (colour) at $p \leq 5\%$. The percentage drop in the amount of vitamin C and vitamin A of pre-treated dried red bell pepper before and after storage was 53.40% and 53.10% respectively. Osmotic dehydration pre-treatment retained the sensory quality of red bell pepper. The pre-treated sample had deep yellow colour (DY) which is the closest to red colour (the colour fresh sample) and the control samples (untreated) had a B (brown) colour. The pre-treated dried samples were microbiologically safe for consumption because the highest bacteria load count attained (6×10^6 cfu/ml) was within permissible level required by standard which was given by [14] to be 10^8 cfu/ml of aerobic psychotropic bacteria and 10^7 cfu/ml for lactic acid bacteria as the limiting criteria for ready-to-eat vegetables. The regression equations developed can be used to predict vitamin C, bacteria and colour.

Confirmatory test should be done on the stored products in order to know the specific bacteria that infested the product in storage. Toxicology test should be carried out on the stored products in order to further ascertain their suitability for human consumption. Further validation operation should be carried out on the regression equations developed especially for vitamin A and optimization of the post storage qualities should be done.

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