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DEGRADATION KINETICS OF VITAMIN C AND β- CAROTNE IN MANGO JUICE

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ABSTRACT

Kinetics study on Vitamin C and beta-carotene degradation in mango juice was examined. Ten (10) mango fruits (Mangifera Indica) of the common cultivar were selected for analysis; the fruits were allowed to reach approximately 75% of full ripeness. Sixteen (16) samples of the mango juice were pasteurized at temperatures of 60ºC, 70 ºC, 80 ºC and 90 ºC for 10, 20, 30, 40 minutes respectively, and kept under refrigerated conditions at 10 ºC. The pH values at these periods ranged from 4.43-4.47. Results showed that both Vitamin C and beta carotene concentrations decreased with time following a zero order kinetic model. The highest R^2 coefficient was 0.9955 in Vitamin C, while that of beta- carotene was 0.9872. The Arrhenius plots (Ink versus 1/T) showed the calculated activated energy E_a =12.192KJ/mol for Vitamin C. while the activation energy E_a = 19.097KJ/mol for beta-carotene. Hereto, heat treatment of mango juice should be carried out under low temperature conditions at short given intervals to retain the vitamin c and beta-carotene contents after juicing, during processing.

Keywords: Degradation, Vitamin c, Beta-carotene, Kinetic

INTRODUCTION

Mango, often referred to as the king of tropical fruits, is an important fruit crop cultivated in tropical regions (**Boghrma *et al.*, 2000**). The mango drupe- consisting of mesocarp (edible fleshy part) and endocarp (large woody, flatten pit). Apart from their importance in enhancing nutrition and food security, the mango fruits are increasingly being cultivated also for commercial purposes. Different cultivars of mango fruits are sold and consumed at different stages of maturity. These differences in cultivar, and post-harvest handling procedures may influence the carotenoid content in these fruits (**Rodriguez-amaya, 2001**). Mangoes, most probably contribute in alleviating vitamin A deficiency, whose prevalence is very high (**Mwaniki *et al.*, 2001**). The vitamin content depends upon the variety and maturity of the fruit. When the mango is green, the amount of vitamin C is higher, as it ripens the amount of beta-carotene (vitamin A) increases. Mangoes are also rich in other non-provitamin A carotenoid. These have diverse roles and benefits for human health including antioxidant activity, cell communication, immune function enhancement and UV skin protection (**Palozza and Krinsky, 1992**). Vitamin C also known as ascorbic acid, functions as a water-soluble antioxidant and as a cofactor in various enzyme systems, such as those involved in the synthesis of connective tissue components and neurotransmitters. Beta-carotene is the pigment that gives mangoes their color. The human body can convert beta-carotene into vitamin A, which is necessary for vision, immunity and skin health. Mangoes offer a good source of beta-carotene.

Food processing significantly lowers the quality of fruits and vegetables where in this study, mango fruit juice is concerned. Micronutrients are particularly affected, among them; beta-carotene and vitamin C, temperature, occurrence of oxygen, the fruit composition and structure are known to affect vitamin C and beta-carotene loss significantly. However, the methods used to obtain kinetic parameters are of major importance in providing data to improve the outstanding and monitoring of vitamin C and beta-carotene retention during the processing mango juice and even at storage.

MATERIAL AND METHODS

Materials

Fresh Mango fruits (mangifera indica L.) were procured from Gboko market in Benue state. Green mature fruits were allowed 75 % ripeness. The stages of maturity were determined using firmness, skin colour and total soluble solids (**Vasqueze-Caicedo *et al.*, 2003**).

Mango Juice Preparation

Fresh mango fruits were washed, peeled and peeled into layers with a stainless steel knife. The slices were piled and blended with electric powered blender to get a homogeneous pulp. The final pulp volume was 1500ml .500ml of water was added to bring the mixture to a juice consistency. Residual pulps were removed by filtering to finally obtained clean juice using muslin clothe. The juice was poured into 100ml plastic container and pasteurized in a water bath at 60 ºC, 70 C, 80 ºC and 90 ºC for 10, 20, 30, 40 minutes respectively. After pasteurization, the product is allowed to cool and refrigerated at 10 °C.

Methods

Vitamin C Determination

The titration method described by **AOAC (2004)** was adopted. 10ml of distilled water was measured using pipette and transferred into a beaker. 5 ml of juice sample was measured and diluted with distilled water contained in the beaker 2.5 ml of metaphophoric acid and make up to 50ml with distilled water. Using the pipette, 10ml of the mixture transferred into conical flask and 1ml of acetic acid added. The mixture was titrated against a prepared stansated solution of 2,6-dichlorophenol indophenol DCPIP dye solution, until a distinct pink colour

persisted for 5 minutes. The tire value was recorded and used as raw data to calculate the concentration of vitamin C in mango fruit juice.

$$\text{Vitamin C} = \frac{\text{Dye concentration X titre value} \times 100}{\text{Volume of sample}}$$

Where Dye concentration = 0.002g and Volume of sample =5ml.

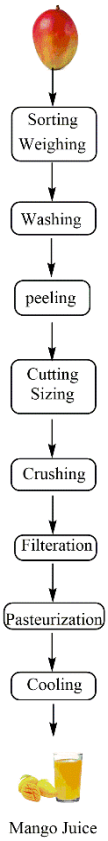


Figure 1 Mango juice extraction process

β- Carotene Determination pipette

Beta –carotene concentration was extracted using hexaneas described by the method of **Craft (2001).** 5mls of the sample was measured into the conical flask, using the pipette. 2ml of sodium chloride added to the sample.10mls of methanol and 20mls hexane were added respectively. Mixture shaken vigorously, using stirrer for 5 minutes and allowed to settle for about 20 minutes. Cleared colour solution was read for absorbency using spectrophotometer at 450nm wave length.

$$\text{Beta carotene} = \frac{\text{Absorbance}}{\text{Specific Extraction} \times \text{Path of cell coefficient} 2a}$$

Where Specific extraction confident= wavelength X molar mass of beta carotene, Path length=1cm, and Molar mass of beta carotene =536.88g

Kinetic Data Analysis for vitamin C and Beta Carotene Degradation in pasteurized Mango Juice

The methods of **Ariahu and Ogunsua (2000)were** adopted. The method used the concentration of vitamin C and Beta carotene versus time. This is used to ascertain vitamin concentration and beta carotene with time function at constant temperature.

The model C=Co-Kt which is Zero order kinetic, C/Co= -Kt which is First order kinetics and C/CO=-KDt which is Second order.

Where
C= concentration of nutrient at time t
Co= Initial concentration of nutrient at time zero
K= reaction rate constant

The kinetic model was fit into **Shin *et al*. (2001)** Equation to obtained a reaction rate. Through Arrhenius equation the regression analysis was related to absolute temperature in kelvin. Thus:

$K=Ko^{-Ea/RT}$

Where, Ko = Frequency pre-exponential factor, Ea = Activation energy.mol-1, R= Universal gas constant 8. 314J.K-1mol-1, T= Absolute temperature, Ea =From the slope of the graph, Ko= intercept of the graph
The decimal reduction time or D –value were related to reaction rate constant by D =2.303/K.

RESULTS AND DISCUSSION

pH Reading

The pH readings obtained from the treated mango fruit juice are given in Table 1. The pH values ranges from 4.43- 4.71. Since pH has an influence on the stability of vitamin C in mango juice. Findings from **FAO/WHO** Expert consultation on human and mineral requirement reveals that the vitamin C will decay if the pH is higher than 4 (**Bangkok-Thailand, 1998).** This result also collaborated with that of **Nagymate and Fodor, (2008).**

Table 1 pH of pasteurized mango juice at different temperatures and time.

	60ºC	**70ºC**	**80ºC**	**90ºC**
10min	4.43	4.57	4.61	4.71
20min	4.48	4.66	4.65	4.69
30min	4.51	4.61	4.66	4.68
40min	4.60	4.64	4.56	4.52

Regression Analysis

Data obtained from vitamin C and beta-carotene degradation, were fitted into zero, first and second order reaction kinetics.

Regression Analysis for the Degradation of vitamin C in Mango Juice

The regression parameters are shown in Table 2. The first and the second order models gave low coefficient of the regression (r^2) between 0.5454 and 0.5368 respectively. The coefficient of regression (r^2) is higher for the zero order models, which is 0.9955. Figures 7-9 show the relationship between concentration of vitamin C and heating time for mango juice.

Table 2 Reaction rate parameters for the degradation of vitamins C in pasteurized mango juice

		Concentration ºC			
Kinetics Models	**Regression Parameters**	60	70	80	90
Zero order $[C=C_0-K_t]$	r^2	0.9955	0.931	0.9168	0.7426
	Intercept	17.28	15.96	15.46	13.7
	Gradient	0.199	0.215	0.277	0.289
First order $Ln(C/C_0)=-K_t$	r^2	0.5322	0.5294	0.5454	0.5384
	Intercept	10.772	10.688	10.676	10.5
	Gradient	0.2788	0.2817	0.2916	0.297
Second order $C/C_0=-KDT$	r^2	0.528	0.527	0.5368	0.5179
	Intercept	9.964	9.908	9.848	9.502
	Gradient	0.2769	0.2793	0.2881	0.2953

Degradation of vitamin C in mango juice

Table 3 depicts the reaction rate, D-value and activation energy evaluated. The D-value was highest in zero order11.57 and lowest in the first order 7.89. The second order had a D-value of 7,99 respectively. For the gradient K, the value was higher for the first order 0.2916, this was followed by the second order 0.288 and lowest for the zero order 0.199.

Table 3 Reaction rate K, D –value and Ea for Vitamin C degradation in mango juice

Parameter	**Kinetic models**		
	Zero order	**first order**	**Second Order**
	C=C0 –Kt	[In (C/Co)=-kt]	[C/C0=-kDT]
K	0,199	0.2916	0.2881
D-value	11.573	7.898	7.994

Activation Energy 12.192, Key: K =gradient, D –values=decimal reduction

Figures 2-4 depicts the kinetic Vitamin C concentration versus time considering different kinetic models.

Time (minutes)

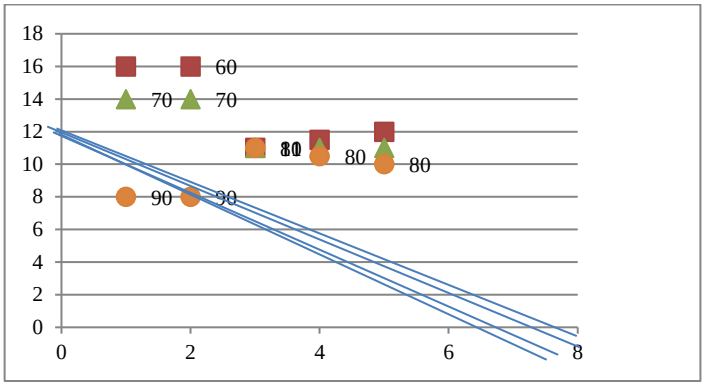
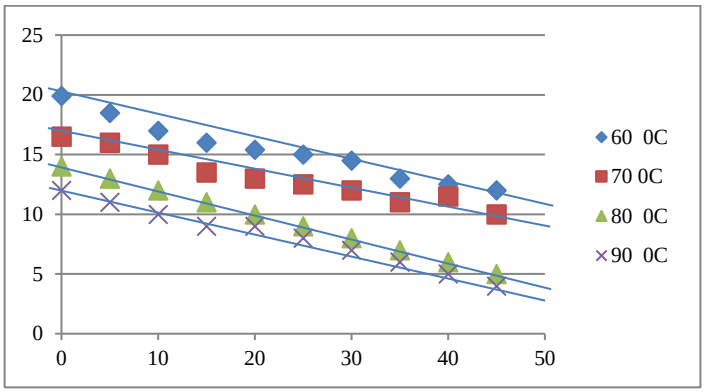
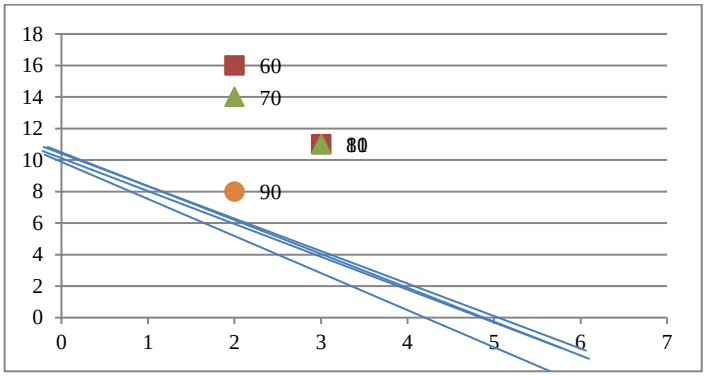


Figure 2 Graph of vitamin C concentration versus Time. Zero order (C =C0-Kt), Series 1= 60 ˚C, Series 2= 70 °C, Series 3=80 °C, Series 4=90 °C. Y-axis (Concentration of vitamin C mg/ml)



Time (min)

Figure 3 Graph of vitamin C concentration versus Time. First order (C/C0 =-Kt), Series 1= 60 °C, Series 2= 70 °C, Series 3=80 °C, Series 4=90 °C, Y-axis (Concentration of vitamin C mg/ml)



Time (min)

Figure 4 Graph of vitamin C concentration versus Time. Second order (C/Co =-KDt), Series 1= 60 °C, Series 2= 70 °C, Series 3=80 °C, Series 4=90 °C, Y- axis (Change in concentration of vitamin C mg/ml).

Regression Analysis for the degradation of Beta-carotene in mango juice.

The regression parameters are shown in Table 3. The first and second order models gave a low coefficient of regression (r^2) between 0.9974 and 0.9941 respectively. The coefficient of regression (r^2) is higher for the zero order models, which is 0.9976 figures 10-12 show the relationship between concentration of beta-carotene and heating time for the mango juice.

Kinetic degradation of Beta carotene in Mango juice.

Table 4 depicts the reaction rate. The D-value was highest in the second order76.76 and lowest in the zero order 20.38. The first order had a D-value of 46.06 respectively. For the gradient K, the value was higher for the second order 23.1, this was followed by the first order 13.86 and lowest for the zero order 6.13

Table 3 Reaction rate parameters for the degradation of β-carotene in pasteurized mango juice

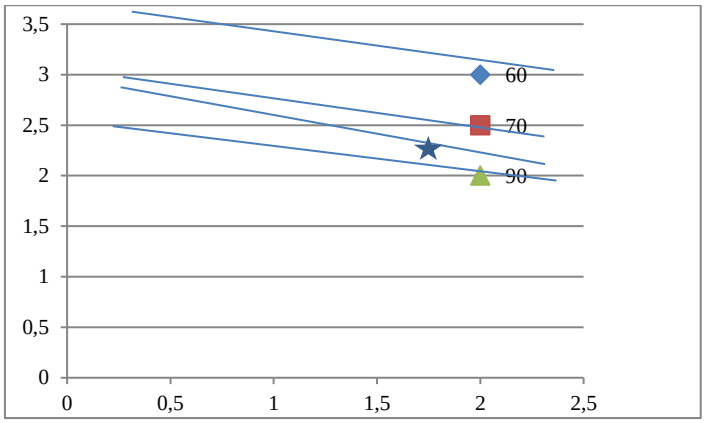
Kinetics Models	Regression Parameters	Concentration ºC			
		60	70	80	90
Zero order $[C=C_0-K_t]$	r^2	0.9872	0.9839	0.9976	0.8586
	Intercept	2.655	2.07	1.6	1.6
	Gradient	0.0113	0.0053	0.0082	0.0107
First order $Ln(C/C_0)=-K_t$	r^2	0.9839	0.9809	0.9974	0.8416
	Intercept	0.982	0.7295	0.627	0.491
	Gradient	0.0048	0.0028	0.005	0.0084
Second order $C/C_0=-KDT$	r^2	0.978	0.975	0.9941	0.8211
	Intercept	0.3725	0.4815	0.531	0.5945
	Gradient	0.002	0.0014	0.003	0.0065

Table 4 Reaction rate K, D –value and Ea for Vitamin C degradation in mango juice

Parameter	Kinetic models		
	Zero order	first order	Second Order
	C=C0 –Kt	[In (C/Co)=-kt]	[C/C0=-kDT]
K	0.0113	0.005	0.003
D-value	20.38	46.06	76.76

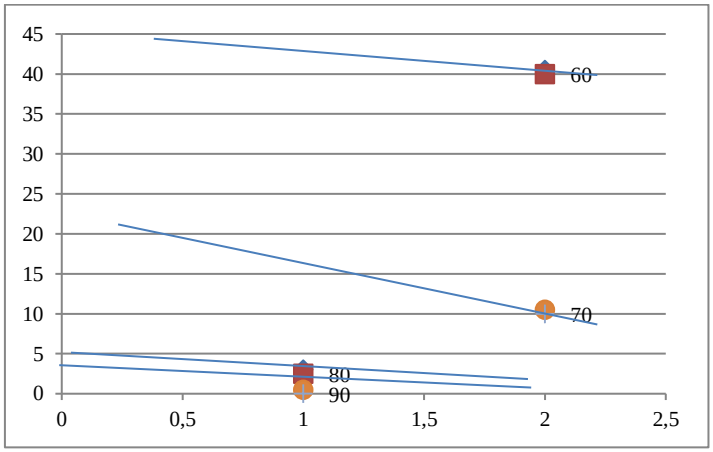
Activation Energy 19.9099 KJ/mol, **Key:** K =gradient, D –values=decimal reduction

Figures 5-7 depicts the kinetic Beta-carotene concentration versus time considering different kinetic models.



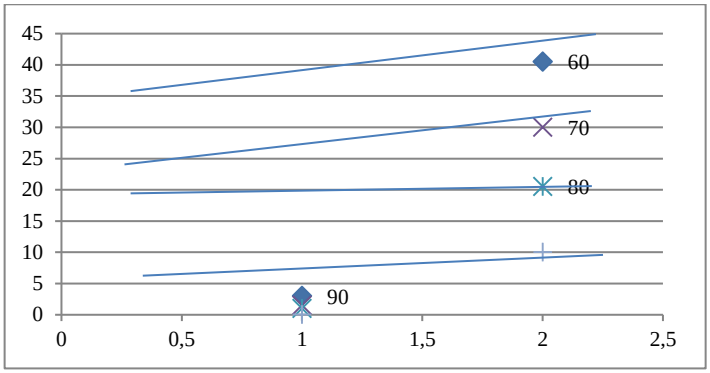
Time (min)

Figure 5 Graph of beta- carotene concentration against Time. zero order (C -C0=Kt), Series 1= 60 °C, Series 2= 70 °C, Series 3=80 °C, Series 4=90 °C, y-axis (β-carotene Concentration in mol/ml)



Time (min)

Figure 6 Graph of beta- carotene concentration against Time. First order [In(C/C0) = -Kt], Series 1= 60 °C, Series 2= 70 °C, Series 3=80 °C, Series 4=90 °C, y- axis (β-carotene Concentration in mol/ml)



Time (Min)

Figure 7 Graph of beta- carotene concentration against Time. Second order in [C /C0=-KDt], Series 1= 60 °C, Series 2= 70 °C, Series 3=80 °C, Series 4=90 °C, y-axis (β-carotene Concentration in mol/ml)

Calculation of activation energy (E_a)

Activation energy (E_a) was estimate d from the reaction rate constant (K) and multiplied by the universal gas constant (R= 8.314KJ/mol). Arthenius plot (lnk vs 1/T) for vitamin C and beta-carotene degradation in mango juice is given in Figure 8 and 9 respectively.

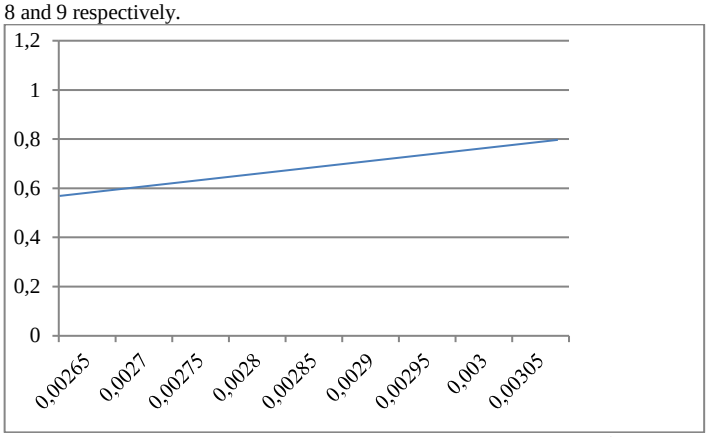


Figure 8 Arrehenuis plot equation lnk versus1/T FOR Degradation of vitamin C in pasteurised mango juice, y=-1466.4x+5.974, R^2=0.9653, Ea= 12.192kj/mol.

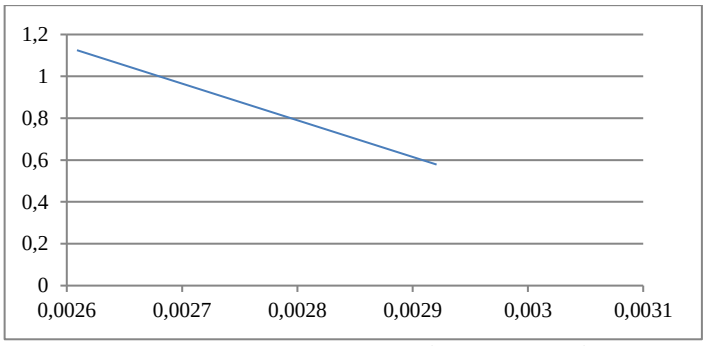


Figure 9 Arrehenuis plot equation lnk versus1/T for Degradation of beta carotene in pasteurised mango juice, y=-1466.4x+5.974, R^2=0.9653, Ea= 12.192kj/mol

CONCLUSION

Kinetics of vitamin C and beta-carotene degradation in mango fruit juice were evaluated. Results showed that the concentration of vitamin C and beta-carotene were affected by storage temperature and processing time, vitamin C and beta-carotene degrade faster at higher temperature and longer processing time. Results show that the highest coefficient of regression (r^2) is 0.9955 for vitamin C degradation and 0.9872 for beta-carotene degradation respectively. The activation energy (E_a) for vitamin C in the pasteurized mango juice is calculated to be 12.192 KJ/mol, while that of beta-carotene is 19.097KJ/mol.

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