Development of a model to predict shelf life of yellow variety of cashew juice at non refrigerated storage

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Abstract: There is an inevitable decline in quality value of ascorbic acid in storage and distribution of cashew apple juice. The quality value and optimum shelf life of yellow sample of cashew apple juice were determined and the quality value model based on the deteriorative factors was developed. The coefficient of correlation (R^2) of the dependent variable (ascorbic acid or vitamin C) and independent variables (temperature, total soluble solid (TSS), pH and duration of storage) in the regression models of the sample was 0.988. Data were drawn from 3^4 full factorial experiments performed in three replicates with the order of the replicates randomized. A multivariate regression analysis was used for combining the variables. The model developed revealed that temperature, pH and duration of storage with some other interactions were the major factors that influence the shelf -life and also determine the character and qualities of cashew fruit juice. The developed models further revealed that 38.6 ^OC storage temperature, 11.68 ^{O}Brix value, pH of 4.61, and storage duration of 16 days of yellow sample retained ascorbic acid levels at 218.11 mg mL^{-1} on maximum shelf life. Equation 34 expresses the regression model for determining the shelf life of yellow sample of cashew fruit juice.

Keywords: Development, Yellow Cashew Juice, Shelf-Life, Refrigerated, Storage

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1 Introduction

Cashew apple juice, tropical fruit rich in vitamin C and sugars has an interesting market potential (Assunção and Mercadante, 2003). It is reported that cashew apple juice contains 5times as high vitamin C as citrus juice and 10 times as pineapple juice (Akinwale, 2000; Azam-Ali and Judge, 2001). Cashew apple juice contains niacin, thiamine, riboflavin and precursors of vitamin A. It is also found to be good source of minerals such as sodium, copper, zinc, potassium, calcium, phosphorous, iron and magnesium (Lowor and Agyente-Badu 2009). Cashew apple is either taken as fresh or as processed in form of products such as canned fruits, juices, syrups, candies, toffees, pickles, jams, chutneys, ice creams, distilled products vinegar, and marmalade. The wastage of cashew apples in the farm or field is majorly attributed to low shelf life and rapid microbial attack. Unlike other fruit juice, the juice extracted from cashew apple cannot be consumed without further processing, due to its characteristic astringent taste, which causes biting sensation of the tongue and throat. In order to reduce astringency and to retard spoilage, it is important to find out a suitable method for the processing and preservation of cashew apple juice (Talasila et al, 2011).

Currently, only six percent of cashew apple production is exploited, since the farmer can only guarantee the sale of cashew nuts. The quality of nuts detached from the immature cashew fruit, is unacceptable for

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commercialization. The ripe cashew apple can be consumed directly or used for jam, for the production of fruit juice or for making alcoholic beverages. The development of machines for processing cashew apple has also been limited by its high degree of perishability and consequent difficulties in handling or moving them from growing locations to distant processing plants (Costa et al., 2003).

Table 1 Recommended Juice Quality

Fruit Juice	Ascorbic Acid (mg mL-1)	
	Maximum	Minimum
Orange	80	20
Pineapple	25	8
Cashew	510	126
Mango	80	20
Grape fruit	65	35
Lemon	70	30
Lime	40	5

Source: (Gunjate & Patwardhan, 1995), (Olorunsogo & Adgidzi, 2010)

Jatto and Adegoke (2010) processed and stored cashew apple juice using aqueous extract of Aframomum danielli and discovered low vitamin C content and sugars after two weeks. Azoubel et al. (2009) used a combined method of storage which includes drying of cashew apples with osmotic dehydration and discovered that osmotic pretreatment was very active in lowering water activity but was not effective in protecting the juice from oxidation.

The cashew fruit juice manufacturers must seek to control the changes which reduce the quality of this product. Therefore, it is important to establish an analytical approach to the chemistry of cashew fruit juice preservation so as to be able to specify the quality of the juice at different storage conditions. The recommended fruit juice quality was shown in Table 1.

The main factors influencing cashew juice quality must be integrated and applied to the various situations during processing, storage and distribution of this cashew juice. The integration or modeling can then deal with quality assurance maximizing cashew fruit juice.

The objective of this research work is to develop a model and determine the shelf life of yellow variety of cashew fruit juice at non refrigerated storage.

2 Materials and method

The yellow sample of cashew fruits juice were extracted by mechanical screw press from cashew apple fruits obtained from local cashew plantation plot at Opi in Nsukka Local government of Enugu State, Nigeria. The experiments were conducted in Bio Process Laboratory in Agricultural and Bioresource Engineering Department of Enugu State University of Science and Technology, Enugu, Nigeria. The cashew fruit samples and the initial composition of the juices extracted from them are presented in Table 2.

Table 2 Experimental samples

Experimental sample	Variety/source	Properties of juice freshly extracted		
		Vitamin C	Brix value	pH
Fruit Juice	Yellow	495.65mg mL^{-1}	11.40^0Brix	4.60

The extracted juices were filtered using sterilize muslin cloth and both the fruit juice and cake were weighed and recorded. Some samples of cashew fruits juices were separated and introduced in 60cL container each, using total of 243 containers for determination of varying values of pH and total soluble solid used, while others were used to determine the pH, total soluble solid and ascorbic acid at fresh stage. The variation in the values of pH and total soluble solid were carried out by diluting 50cL fresh juice with 15 mL and 25mL of distilled water respectively. The variations in the values of temperature were carried out using inside and outside building structure.

2.1 Experimental Design Method

A four-variable three level factorial experiment provide the framework for designing the juice multifactor experiments. With four variables three levels, a complete design leads to a total of 81 runs. In the 3^4 full factorial experiment the low, intermediate and high levels of the factors are coded as "-", "0"and "+", respectively. The levels of the four factors which include temperature, total soluble solid(TSS), pH and duration of storage are represented in standard order as x_1, x_2, x_3 and x_4.

2.2 Conduct of experiment

Four variable three level factorial experiments were conducted in a randomized order in three replicates according to the design plan (matrix) given in Table 3. The plus, zero and minus signs in the columns indicate how to combine the factors in each experimental run. For example, the first run puts all the four factors at their low levels, the second run sets factors x_1 at high level while all the other factors will be keep at intermediate and low levels. The coded levels of the factors and the results of each sample experiments are given in Table 4.

Table 3 Design Matrix for 3^4 Full Factorial Experiment

Run	x_0	x_1	x_2	x_3	x_4	x_1x_2	x_1x_3	x_1x_4	x_2x_3	x_2x_4	x_3x_4	$x_1x_2x_3$	$x_1x_2x_4$	$x_1x_3x_4$	$x_2x_3x_4$	$x_1x_2x_3x_4$
1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1
2	+1	0	+1	+1	+1	0	0	0	+1	+1	+1	0	0	0	+1	0
3	+1	-1	+1	+1	+1	-1	-1	-1	+1	+1	+1	-1	-1	-1	+1	-1
4	+1	+1	0	+1	+1	0	+1	+1	0	0	+1	0	0	+1	0	0
5	+1	0	0	+1	+1	-2	0	0	0	0	+1	-2	-2	0	0	-2
6	+1	-1	0	+1	+1	0	-1	-1	0	0	+1	0	0	-1	0	0
7	+1	+1	-1	+1	+1	-1	+1	+1	-1	-1	+1	-1	-1	+1	-1	-1
8	+1	0	-1	+1	+1	0	0	0	-1	-1	+1	0	0	0	-1	0
9	+1	-1	-1	+1	+1	+1	-1	-1	-1	-1	+1	+1	+1	-1	-1	+1
10	+1	+1	+1	0	+1	+1	0	+1	0	+1	0	0	+1	0	0	0
11	+1	0	+1	0	+1	0	-2	0	0	+1	0	-2	0	-2	0	-2
12	+1	-1	+1	0	+1	-1	0	-1	0	+1	0	0	-1	0	0	0
13	+1	+1	0	0	+1	0	0	+1	-2	0	0	-2	0	0	-2	-2
14	+1	0	0	0	+1	-2	-2	0	-2	0	0	0	-2	-2	-2	0
15	+1	-1	0	0	+1	0	0	-1	-2	0	0	-2	0	0	-2	-2
16	+1	+1	-1	0	+1	-1	0	+1	0	-1	0	0	-1	0	0	0
17	+1	0	-1	0	+1	0	-2	0	0	-1	0	-2	0	-2	0	-2
18	+1	-1	-1	0	+1	+1	0	-1	0	-1	0	0	+1	0	0	0
19	+1	+1	+1	-1	+1	+1	-1	+1	-1	+1	-1	-1	+1	-1	-1	-1
20	+1	0	+1	-1	+1	0	0	0	-1	+1	-1	0	0	0	-1	0
21	+1	-1	+1	-1	+1	-1	+1	-1	-1	+1	-1	+1	-1	+1	-1	+1
22	+1	+1	0	-1	+1	0	-1	+1	0	0	-1	0	0	-1	0	0
23	+1	0	0	-1	+1	-2	0	0	0	0	-1	+2	-2	0	0	+2
24	+1	-1	0	-1	+1	0	+1	-1	0	0	-1	0	0	+1	0	0
25	+1	+1	-1	-1	+1	-1	-1	+1	+1	-1	-1	+1	-1	-1	+1	+1
26	+1	0	-1	-1	+1	0	0	0	+1	-1	-1	0	0	0	+1	0
27	+1	-1	-1	-1	+1	+1	+1	-1	+1	-1	-1	-1	+1	+1	+1	-1
28	+1	+1	+1	+1	0	+1	+1	0	+1	0	0	+1	0	0	0	0
29	+1	0	+1	+1	0	0	0	-2	+1	0	0	0	-2	-2	0	-2
30	+1	-1	+1	+1	0	-1	-1	0	+1	0	0	-1	0	0	0	0
31	+1	+1	0	+1	0	0	+1	0	0	-2	0	0	-2	0	-2	-2
32	+1	0	0	+1	0	-2	0	-2	0	-2	0	-2	0	-2	-2	0
33	+1	-1	0	+1	0	0	-1	0	0	-2	0	-2	-2	0	-2	-2
34	+1	+1	-1	+1	0	-1	+1	0	-1	0	0	-1	0	0	0	0
35	+1	0	-1	+1	0	0	0	-2	-1	0	0	+1	-2	-2	0	-2
36	+1	-1	-1	+1	0	+1	-1	+1	-1	0	0	+1	0	0	0	0
37	+1	+1	+1	0	0	+1	0	0	0	0	-2	0	0	-2	-2	-2
38	+1	0	+1	0	0	0	-2	-2	0	0	-2	-2	-2	0	-2	0
39	+1	-1	+1	0	0	-1	0	0	0	0	-2	0	0	-2	-2	+2
40	+1	+1	0	0	0	0	0	0	-2	-2	-2	-2	-2	-2	0	0
41	+1	0	0	0	0	-2	-2	-2	-2	-2	-2	0	0	0	0	-2
42	+1	-1	0	0	0	0	0	0	-2	-2	-2	-2	-2	-2	0	0
43	+1	+1	-1	0	0	-1	0	0	0	0	-2	0	0	-2	-2	-2
44	+1	0	-1	0	0	0	-2	-2	0	0	-2	-2	-2	0	-2	0
45	+1	-1	-1	0	0	+1	0	0	0	0	-2	0	0	-2	-2	-2
46	+1	+1	+1	-1	0	+1	-1	0	-1	0	0	-1	0	0	0	0
47	+1	0	+1	-1	0	+1	0	-2	-1	0	0	-1	-2	-2	0	-2
48	+1	-1	+1	-1	0	-1	+1	0	-1	0	0	+1	0	0	0	0
49	+1	+1	0	-1	0	0	-1	0	0	-2	0	0	-2	0	-2	-2
50	+1	0	0	-1	0	-2	0	-2	0	-2	0	+2	0	-2	-2	0
51	+1	-1	0	-1	0	0	+1	0	0	-2	0	0	-2	0	-2	-2
52	+1	+1	-1	-1	0	-1	-1	0	+1	0	0	+1	0	0	0	0
53	+1	0	-1	-1	0	0	0	-2	+1	0	0	0	-2	-2	0	-2
54	+1	-1	-1	-1	0	+1	+1	0	+1	0	0	-1	0	0	0	0
55	+1	+1	+1	+1	-1	+1	+1	-1	+1	-1	-1	+1	-1	-1	-1	-1
-56	+1	0	+1	+1	-1	0	0	0	+1	-1	-1	0	0	0	-1	0
57	+1	-1	+1	+1	-1	-1	-1	+1	+1	-1	-1	-1	+1	+1	-1	+1
58	+1	+1	0	+1	-1	0	+1	-1	0	0	-1	0	0	-1	0	0
59	+1	0	0	+1	-1	-2	0	0	0	0	-1	-2	+2	0	0	+2
60	+1	-1	0	+1	-1	0	-1	+1	0	0	-1	0	0	+1	0	0
61	+1	+1	-1	+1	-1	-1	+1	-1	-1	+1	-1	-1	+1	-1	+1	+1
62	+1	0	-1	+1	-1	0	0	0	-1	+1	-1	0	0	0	+1	0

63	+1	-1	-1	+1	-1	+1	-1	+1	-1	+1	-1	+1	-1	+1	+1	-1
64	+1	+1	+1	0	-1	+1	0	-1	0	-1	0	0	-1	0	0	0
65	+1	0	+1	0	-1	0	-2	0	0	-1	0	-2	0	+2	0	+2
66	+1	-1	+1	0	-1	-1	0	+1	0	-1	0	0	+1	0	0	0
67	+1	+1	0	0	-1	0	0	-1	-2	0	0	-2	0	0	+2	+2
68	+1	0	0	0	-1	-2	-2	0	-2	0	0	0	+2	+2	+2	0
69	+1	-1	0	0	-1	0	0	+1	-2	0	0	-2	0	0	+2	+2
70	+1	+1	-1	0	-1	-1	0	-1	0	+1	0	0	+1	0	0	0
71	+1	0	-1	0	-1	0	-2	0	0	+1	0	-2	0	+2	0	+2
72	+1	-1	-1	0	-1	+1	0	+1	0	+1	0	0	-1	0	0	0
73	+1	+1	+1	-1	-1	+1	-1	-1	-1	-1	+1	-1	-1	+1	+1	+1
74	+1	0	+1	-1	-1	0	0	0	-1	-1	+1	0	0	0	+1	0
75	+1	-1	+1	-1	-1	-1	+1	+1	-1	-1	+1	+1	+1	-1	+1	+1
76	+1	+1	0	-1	-1	0	-1	-1	0	0	+1	0	0	+1	0	0
77	+1	0	0	-1	-1	-2	0	0	0	0	+1	+2	+2	0	0	-2
78	+1	-1	0	-1	-1	0	+1	+1	0	0	+1	0	0	-1	0	0
79	+1	+1	-1	-1	-1	-1	-1	-1	+1	+1	+1	+1	+1	+1	-1	-1
80	+1	0	-1	-1	-1	0	0	0	+1	+1	+1	0	0	0	-1	0
81	+1	-1	-1	-1	-1	+1	+1	+1	+1	+1	+1	-1	-1	-1	-1	+1

Table 4 Factors and their Coded Levels for Yellow Cashew Juice Experiment

Level of Factors	Code	Independent variables			
		Temperate (x_1)	Total soluble solid (x_2)	pH (x_3)	Duration of storage (x_4)
Based level	x	34.15^{0}C	10.64^{0}Brix	3.86	11days
Interval of Variation	ΔXi	4.45^{0}C	1.04^{0}Brix	0.75	5days
High level	+	38.60^{0}C	11.68^{0}Brix	4.61	16days
Intermediate	0	34.40^{0}C	10.59^{0}Brix	3.98	11days
Low level	-	29.70^{0}C	9.61^{0}Brix	3.12	6days

2.3 Statistical Analysis and Model Development

Multivariate regression analysis was used in relating the variables. The mean of the replicated observations were given by

$$\text{The mean, } \bar{y}_u = \frac{1}{r}\sum_{v=1}^{r} y_{uv} \quad (1)$$

$$\text{The dispersion, } S_u^2 = \frac{1}{r-1}\sum_{v=1}^{r}(y_{uv} - \bar{y}_u)^2 \quad (2)$$

$$\text{The sum of the dispersion } \sum_{u=1}^{81} S_u^2 \quad (3)$$

$$\text{The maximum dispersion} = S_{u\max}^2 \quad (4)$$

Where, r is the replication, y_{uv} is thevalue of each ascorbic acid measure, $\bar{y}_u$ is the mean of the experimental observation and S_u^2 is the dispersion.

The G-test (Cochran G-criteria) is used to ascertain the possibility of carrying out regression analysis. It is used to check if the output factors of the replication have maximum accuracy of the replication. The test verifies the homogeneity of dispersion of the replicate experiments. The calculated G-value is given as:

$$G_{cal} = \frac{S_{u\max}^2}{\sum_{u=1}^{N} S_u^2}; N = 81 \quad (5)$$

The calculated G-value is compared with an appropriate table value. The condition of homogeneity is given as:

$$G_{cal} < G_{[\alpha, N, (r-1)]} \quad (6)$$

where, N is the number of experimental runs, r is the number of replicate and α is the level of significance

The dispersion, taken as mean-squared-error, is given as:

$$S_{(y)}^2 = \frac{1}{N}\sum_{u=1}^{N} S_u^2 \quad (7)$$

It is the average sample variance estimate. The experimental error is given as:

$$S_{(y)} = \sqrt{S_{(y)}^2} \quad (8)$$

The mean effect was estimated by

$$b_0 = \frac{1}{N}\sum_{u=1}^{N}\left(x_0 \bar{y}_u\right); u = 1, 2, ...81 \quad (9)$$

where,x_0 was the coded signs in the x_0 column of the design matrix

The four main effects were estimated by

$$b_i = \frac{1}{N}\sum_{u=1}^{N}\left(x_i \bar{y}_u\right); i = 1, 2, 3, 4; \quad (10)$$

where x_i were the coded signs in the x_I columns of the design matrix.

The six two-factor interactions were estimated by

$$b_{ij} \frac{1}{N}\sum_{u=1}^{N}\left(x_{ij} \bar{y}_u\right); i \neq j;; u = 1, 2, ...81 \quad (11)$$

where x_{ij} were the coded signs in the x_{ij} columns of the design matrix.

The four three-factor interactions were estimated by

$$b_{ijk} = \frac{1}{N}\sum_{u=1}^{N}\left(x_{ijk} \bar{y}_u\right); i \neq j \neq k;\ u = 1, 2, ...81 \quad (12)$$

where,x_{ijkl}were the coded signs in the x_{ijkl}columns of the design matrix

The one four-factor interactions were estimated by

$$b_{ijkl} = \frac{1}{N}\sum_{u=1}^{N}\left(x_{ijkl} \bar{y}_u\right); i \neq j \neq k \neq l; u = 1, 2, ...81 \quad (13)$$

where,x_{ijkl}were the coded signs in the x_{ijkl} columns of the design matrix

Construction of confidence interval and testing of hypotheses about individual regression coefficients in the regression model are frequently used in assessing their statistical significance (Robert et al., 2003).

Confidence interval for the regression coefficients with confidence coefficient “α” was of the general form.

$$b's \pm t\ \{\alpha, N(r-1)\}\ S_{b's} \quad (14)$$

$$\text{i.e } b's \pm \Delta b's \quad (15)$$

where, $S_{b's}$ is the estimated standard error in regression coefficients

*b’s.t {α, N(r-1}*are appropriate tabulated criteria with *N(r-1)* degree of freedom.

For our purpose, we were contented with a level of significance of 5% (i.e α = 0.05), with this we established confidence limits for 99% of the variable measurements, using a 95% confidence interval. That was, approximately 95 out of every 100 similarly constructed confidence intervals will contain 99% of the variable measurements in the population.

For full factorial experiments, errors in each regression coefficient is the same and was determined by

$$S_{bo} = Sb_i ....Sb_{ijklm} = \frac{S(r)}{\sqrt{Nr}} \quad (16)$$

$$\text{where } S_{bi}^2 = \frac{S_y^2}{N} \quad (17)$$

where S(y) = the experimental error. The statistical significance of the regression coefficients were tested by

$$t_0 = \frac{b_0}{S_{b0}}, \quad t_i = \frac{b_i}{S_{bi}}, \ t_w = \frac{b_{ij}}{S_{bij}} ...\ t_{ijklm} = \frac{\{b_{ijklm}\}}{S_{bijklm}} \quad (18)$$

The test was carried out by comparing these calculated t-values with the appropriate critical table values. A coefficient of regression is statically significant if and only if

$$t_{cal} > t\{\alpha, N(r-1)\} \quad (19)$$

If any coefficient is statistically insignificant (i.e$t_{cal} < t_{table}$), such a coefficient is left out of the regression model (Douglas, 2001). Insignificance of an effect does not necessarily mean that the particular factors or interaction is unimportant. It only implies that response is unaffected if the factor is varied over the range considered (i.e. from -1 to +1or 0 in coded units). For example, it could be that the factor or interaction is very important, but that a change over the range considered has no effect on the response. Using only the statistically significant regression coefficients, we then define the fitted (or predicted) model as;

$$y = \left[b_0 \pm ....\right] \quad (20)$$

The calculation of the above expression at the levels x_1 ……x_{in} of the independent variables provide the fitted values. The respective differences between the mean experimental observations $\bar{Y}_1, \bar{Y}_2, \ldots \bar{Y}_N$ and the fitted or predicted values $\hat{Y}_1, \hat{Y}_2, \ldots \hat{Y}_N$ were the residuals which were given by

$$e_u = \bar{Y}_u - \hat{Y}_u; \quad u = 1,2, \ldots 81 \quad (21)$$

Thus, the model can be used to generate the predicted values in the range of the observations studies (i.e.. over the range of the factor levels chosen). The residuals are useful in examining the adequacy of the least squares fit.

The observed values ($\bar{Y}_u$), the fitted values ($\hat{Y}_u$) the residuals ($e_u = \bar{y}_u - \hat{y}_u$) and the squares of the residuals $e^2{}_u = \left(\bar{y}_u - \hat{y}_u\right)^2$ are presented in results. The residuals are the deviations of the measured values $\bar{y}_u$ from their predicted counterparts Y_u..

The sums of squares for the effects were computed from the contrasts used in estimating the effects. In the 3^k factorial design with replicates, the regression sum of squares for any effects were computed with Equation 22.

$$SS_R = \frac{r}{N}(contrast)^2 \tag{22}$$

and has a single degree of freedom. Consequently, the main effects and the interactions were computed using Equations 23 to 26.

$$SS_{bi} = \frac{r}{N}\sum_{u=1}^{N}\left(x_i \bar{Y}_u\right)^2 \tag{23}$$

where,x_i were the coded signs in the x_i column of the design matrix.

For the two-factor interactions:

$$SS_{bij} = \frac{r}{N}\sum_{u=1}^{N}\left(x_{ij} \bar{Y}_u\right)^2 \tag{24}$$

where,x_{ij} were the coded signs in the x_{ij} column of the design matrix.

For the three-factor interactions:

$$SS_{bijk} = \frac{r}{N}\sum_{u=1}^{N}\left(x_{ijk}\bar{Y}_u\right)^2 \tag{25}$$

where,x_{ijk} were the coded signs in the x_{ijk}columns of the design matrix

For the four-factor interactions

$$SS_{bijkl} = \frac{r}{N}\sum_{u=1}^{N}\left(x_{ijkl}\bar{Y}_u\right)^2 \tag{26}$$

where,x_{ijk} were the coded signs in the x_{ijkl} columns of the design matrix.

note that $N = 3^k$.

The total sum of squares was found by

$$SS_T = \sum_{u=1}^{N.r} Y^2uv - \sum_{u=1}^{N.r}(Yuv)^2 / N.r \tag{27}$$

The error sum of squares was given as;

$$SS_E = SS_T = -\sum SS_R \tag{28}$$

$$i.e\ SS_E = SS_T - SS_{bj.} + ... + SS_{bij} + ...SS_{bijklm} \text{ (Douglas, 2001)} \tag{29}$$

In multiple linear regressions, testing the significance or contribution of individual coefficient is accomplished by testing the null hypothesis H_0: $b_i = 0$. The appropriate statistics for the F-test is

$$F_{cal} = \frac{MS_R}{MS_E} = \frac{SS_R / df_R}{SS_E / N(r-1)} \tag{30}$$

Where df_R = the degree of freedom regression

The null hypothesis will be rejected if

$$F_{cal} > F\{\alpha, df_R, N(r-1)\} \tag{31}$$

With the conclusion that the coefficient contributes significantly to the regression (Douglas, 2001). The complete analyses of variance were summarized using the conclusion. The adequacy of the model was further checked. A method of validating the model adequacy is to calculate the dispersion of adequacy for the replicate experiment and compared the magnitude with the variance estimate given by the mean squared error. The dispersion of adequacy for the replicate experiment is given

$$SS^2_{(ad)} = \frac{r}{N-\lambda}\sum_{u=1}^{N}\left(\bar{y}_u - \hat{y}_u\right)^2 = \frac{r}{df_{ad}}\sum_{u=1}^{N}\left(\bar{y}_u - \hat{y}_u\right)^2 \tag{32}$$

where λ = number of inadequate coefficients.

The adequacy of the regression model was estimated by Fisher's criteria (F-test).

$$F_{cal} = \frac{S_{(ad)}}{S_{(y)}^2} \tag{33}$$

where, $S^2_{(y)}$ is the variance estimate given by the mean squared error. The calculated F-value was compared with the appropriate table value. The condition of adequacy is

$$F_{cal} \leq F\{\alpha, N-\lambda, N(r-1)\} \tag{34}$$

If this condition is satisfied, then we can conclude that the fitted (or predicted) regression model is adequate.

3 Results and discussion

The data generated, which consists of the 81 runs that were replicated of three observations of the dependent variable 'y' of yellow cashew fruits juice samples are presented in Table 5, The mean, dispersion, sum of the dispersion and maximum dispersions were determined from the data generated on the samples. The dependent variables 'y' were the values of ascorbic acid level obtained at random mixture of the samples. The summary of mean experimental observations, fitted values, residuals and squares of residuals for samples of cashew fruit juice were presented in Table 6.

Table 5 Ascorbic Acid Content of Yellow Cashew Fruit Juice (mg mL^{-1})

Run	Y_{u1}	Y_{u2}	Y_{u3}	Y_u	Y_{u1}- Y_u	Y_{u2} Y_u	Y_{u3} Y_u	$(Y_{u1}$- $Y_u)^2$	$(Y_{u2}$- $Y_u)^2$	$(Y_{u3}$- $Y_u)^2$	SU
1	192.05	209.75	201.09	200.96	-8.91	8.79	0.13	79.388	77.264	0.017	78.3350
2	183.20	179.49	183.20	181.96	1.24	-2.47	1.24	1.538	6.101	1.538	4.589
3	174.35	183.20	177.78	178.44	-4.09	4.76	-0.66	16.728	22.650	0.436	19.911
4	121.25	121.25	122.06	121.52	-0.27	-0.27	0.52	0.073	0.073	0.270	0.865
5	147.80	155.65	165.50	156.32	8.52	-0.67	9.18	72.590	0.449	84.272	78.656
6	147.80	165.50	154.56	155.95	-8.15	9.55	-1.39	66.423	91.203	1.932	79.779
7	289.40	280.55	286.75	285.57	3.83	-5.02	1.18	14.669	25.200	1.392	20.631
8	271.70	262.85	267.75	267.43	4.27	-4.58	0.32	18.233	20.976	0.102	19.66
9	183.20	180.49	183.20	182.30	0.90	-1.81	0.90	0.810	3.276	0.810	2.448
10	165.50	156.65	160.75	160.97	4.53	-4.32	-0.22	20.521	18.662	0.048	19.595
11	147.80	147.80	144.60	146.73	1.07	1.07	-2.13	1.145	1.145	4.537	3.414
12	227.45	217.17	200.90	215.17	12.28	2.00	-14.27	150.798	4.00	203.633	179.216
13	209.75	218.60	216.85	215.07	-5.42	3.53	1.78	29.376	12.461	3.168	22.503
14	147.80	165.50	161.30	158.20	-10.40	7.30	3.10	108.160	53.290	9.610	85.530
15	165.50	156.65	160.20	160.78	4.72	-4.13	-0.58	22.278	19.057	0.0336	19.836
16	192.05	200.60	192.05	194.90	-2.85	5.70	-2.85	8.128	32.490	8.123	24.368
17	200.90	191.60	174.35	188.95	11.95	2.65	-14.6	142.803	7.023	213.160	181.493
18	77.00	73.50	68.15	72.88	4.12	0.62	-4.73	16.974	0.384	22.373	19.866
19	227.45	211.40	218.65	219.17	8.28	-7.77	-0.52	68.558	60.373	0.270	64.601
20	192.05	174.35	187.80	184.73	7.32	-10.38	3.07	53.582	107.744	9.425	85.376
21	192.05	192.05	191.40	191.83	0.22	0.22	-0.43	0.049	0.048	0.185	0.141
22	369.05	354.05	351.35	358.15	10.90	-4.10	-6.80	118.810	16.810	46.240	90.930
23	59.30	77.00	71.60	69.30	-10.00	7.70	2.30	100.000	59.290	5.290	82.290
24	49.60	50.45	23.90	41.32	8.28	9.13	-17.42	68.558	83.357	303.456	227.686
25	183.20	192.05	186.60	187.28	-4.08	4.77	-0.68	16.646	22.753	0.462	19.931
26	174.35	174.35	171.40	173.37	0.98	0.98	-1.97	0.960	0.960	3.881	2.901
27	130.10	127.45	121.25	126.27	3.83	1.18	-5.02	14.663	1.392	25.200	20.628
28	32.75	34.05	23.90	30.23	2.52	3.82	-6.33	6.350	14.592	40.069	30.506
29	121.25	103.55	112.95	112.58	8.67	-9.03	0.37	75.169	81.541	0.137	78.424
30	32.75	32.75	30.90	32.13	0.62	0.62	-1.23	0.384	0.384	1.513	1.140
31	23.90	36.90	41.60	34.13	-10.23	2.77	7.47	104.653	7.673	55.801	84.063
32	77.00	68.15	74.45	73.20	3.80	-5.05	1.25	14.440	25.503	1.563	20.753
33	130.10	126.60	121.25	125.98	4.12	0.62	-4.73	16.974	0.384	22.373	19.866
34	156.65	150.80	138.95	148.80	7.85	2.00	-9.85	61.623	4.000	97.023	81.323
35	64.90	77.00	50.45	64.12	0.78	12.88	-13.67	0.608	165.894	186.869	176.685
36	121.25	156.65	141.95	139.95	-18.70	16.70	2.00	349.690	278.890	4.000	316.290
37	174.35	172.90	174.35	173.87	0.48	-0.97	0.48	0.230	0.941	0.230	0.700
38	32.75	32.75	40.10	35.20	-2.45	-2.45	4.90	6.003	6.003	24.010	18.008
39	68.15	70.55	77.00	71.90	-3.75	-1.35	5.10	14.063	1.823	26.010	20.948
40	103.55	124.05	121.25	116.28	-12.73	7.77	4.97	162.053	60.373	24.701	123.563
41	74.60	77.00	77.00	76.20	-1.60	0.80	0.80	2.560	0.640	0.640	1.920

Run	Y_{u1}	Y_{u2}	Y_{u3}	Y_u	Y_{u1}- Y_u	Y_{u2} Y_u	Y_{u3} Y_u	$(Y_{u1}- Y_u)^2$	$(Y_{u2}- Y_u)^2$	$(Y_{u3}- Y_u)^2$	SU
42	85.85	86.05	68.15	80.02	5.83	6.03	-11.87	33.989	36.361	140.897	105.625
43	156.65	161.45	156,65	158.25	-1.60	3.20	-1.60	2.560	10.240	2.560	7.680
44	286.40	298.25	280.55	288.40	-2.00	9.85	-7.85	4.000	97.023	61.623	81.323
45	69.80	94.70	68.15	77.55	-7.75	17.15	-9.40	60.063	294.123	88.360	221.273
46	103.55	109.60	130.10	114.42	-10.87	-4.82	15.68	118.157	23.232	245.862	193.626
47	174.35	174.35	174.35	174.35	0.00	0.00	0.00	0.000	0.000	0.000	0.000
48	200.90	183.20	191.60	191.90	9.00	-8.70	-0.30	81.000	75.690	0.090	78.390
49	298.25	280.55	282.60	287.13	11.12	-6.58	-4.53	123.654	43.296	20.521	93.735
50	121.25	103.55	106.40	110.40	10.85	-6.65	-4.00	117.723	46.923	16.000	90.323
51	271.70	280.55	280.55	277.60	-5.90	2.95	2.95	34.810	8.703	8.703	26.108
52	200.90	197.40	183.20	193.83	7.07	3.57	-10.63	49.985	12.745	112.997	87.863
53	200.90	200.90	200.90	200.90	0.00	0.00	0.00	0.000	0.000	0.000	0.000
54	147.80	158.40	165.50	157.23	-9.43	1.17	8.27	88.925	1.369	68.393	79.343
55	209.75	183.20	204.60	199.18	10.57	-15.98	5.42	111.725	255.360	29.376	198.231
56	192.05	192.05	179.90	188.00	4.05	4.05	-8.10	16.403	16.403	65.610	49.208
57	333.65	322.90	324.80	327.12	6.53	-4.22	-2.32	42.641	17.808	5.382	32.916
58	342.50	342.50	345.80	343.60	-1.10	-1.10	2.20	1.210	1.210	4.840	3.630
59	209.75	209.75	209.75	209.75	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60	165.50	165.50	149.80	160.27	5.23	5.23	-10.47	27.353	27.353	109.621	82.163
61	138.95	129.65	121.25	129.95	9.00	-0.30	-8.70	81.000	0.090	75.690	78.390
62	156.65	156.65	152.75	155.35	1.30	1.30	-2.60	1.690	1.690	6.760	5.070
63	156.65	165.50	150.45	157.53	-0.88	7.97	-7.08	0.774	63.521	50.126	57.211
64	181.45	183.20	174.35	179.67	1.78	3.53	-5.32	3.168	12.46	28.302	21.966
65	262.85	271.70	265.25	266.60	-3.75	5.10	-1.35	14.063	26.010	1.823	20.948
66	289.40	277.45	262.85	276.57	12.83	0.88	-13.72	164.609	0.774	188.238	176.811
67	165.50	159.40	165.50	163.47	2.03	-4.07	2.03	4.121	16.565	4.121	12.403
68	130.10	138.95	128.40	132.48	-2.38	6.47	-4.08	5.664	41.861	16.646	32.086
69	85.85	68.90	94.70	83.15	2.70	-14.25	11.55	7.290	203.063	133.403	171.878
70	165.50	165.50	160.70	163.90	1.60	1.60	-3.20	2.560	2.560	10.240	7.680
71	145.20	156.65	130.10	143.98	1.22	12.67	-13.88	1.488	160.529	192.654	177.336
72	156.65	165.50	149.80	157.32	-0.67	8.18	-7.52	0.449	66.912	56.550	61.956
73	192.05	174.35	209.75	192.05	0.00	-17.70	17.70	0.000	313.290	313.290	313.290
74	254.00	254.00	262.82	256.95	-2.95	-2.95	5.90	8.703	8.703	34.810	26.108
75	165.50	192.05	174.35	177.30	-11.80	14.75	-2.95	139.240	217.563	8.703	182.753
76	236.30	254.00	262.85	251.05	-14.75	2.95	11.80	217.563	8.703	139.240	182.753
77	174.35	192.05	179.90	182.10	-7.75	9.95	-2.20	60.063	99.003	4.840	81.953
78	360.20	351.35	369.05	360.20	0.00	-8.85	8.85	0.000	78.323	78.323	78.323
79	236.30	245.15	262.85	248.10	-11.80	-2.95	14.75	139.240	8.703	217.63	182.753
80	298.25	298.25	282.60	293.03	5.22	5.22	-10.43	27.248	27.248	108.785	81.640
81	315.95	322.90	333.65	324.17	-8.22	-1.27	9.48	67.568	1.613	89.870	79.526

The fitted or predicted model for yellow (Equation 35) sample becomes.

$$
\begin{aligned}
y_u = {} & 240.07 + 12.87x_1 - 21.38x_3 - 20.82x_4 - 59.91x_{12} - 65.58x_{13} - 29.62x_{14} - 50.51x_{23} - 59.51x_{24} \\
& - 32.36x_{34} - 96.73x_{123} - 75.64x_{124} - 72.75x_{134} - 99.0x_{234} - 73.67x_{1234} + 12.45x_1^2 + 33.58x_2^2 + 50.36 \\
& x_3^2 + 100.55x_4^2 - 23.58x_1^2x_{23} - 21.71x_1^2x_{24} - 16.75x_1^2x_{234} - 9.44x_2^2x_1 + 10.95x_2^2x_3 + 29.62x_2^2x_4 - 14.45x_2^2x_{13} \\
& - 12.29x_2^2x_{14} + 20.75x_2^2x_{134} - 9.47x_3^2x_1 - 9.95x_3^2x_2 - 14.98x_3^2x_{14} - 9.91x_3^2x_{24} + 28.6x_4^2x_2 + 37.20x_4^2x_3 - \\
& 29.69x_4^2x_{12} - 10.85x_4^2x_{13} - 31.11x_4^2x_{123} + 10.9x_1^2x_2^2 - 48.44x_1^2x_4^2 - 25.29x_2^2x_3^2 + 15.11x_2^2x_4^2 - 52.55x_1^2x_2^2x_3^2 \\
& + 15.29x_1^2x_2^2x_4^2 + 27.65x_1^2x_3^2x_4^2 + 24.15x_2^2x_2^2x_4^2 + 45.35x_1^2x_2^2x_3 + 33.0x_1^2x_2^2x_{34} - 9.95x_1^2x_3^2x_2 + 12.84x_1^2x_3^2x_4 \\
& - 42.67x_1^2x_3^2x_{24} - 43.04x_1^2x_4^2x_3 + 53.65x_1^2x_4^2x_{23} + 50.8x_2^2x_3^2x_4 - 33.36x_2^2x_4^2x_1 - 49.0x_2^2x_4^2x_3 - 25.42x_2^2x_4^2x_{13} \\
& + 23.64x_3^2x_4^2x_1 - 20.64x_3^2x_4^2x_2 + 11.56x_1^2x_2^2x_3^2x_4 + 58.85x_1^2x_3^2x_4^2x_2 - 11.36x_2^2x_3^2x_4^2x_1
\end{aligned}
\tag{35}
$$

Table 6 The Mean Experimental Observations Fitted Values, Residuals and Squares of Residuals for Yellow Cashew Fruit Juice

Run No	$\bar{y}_u$	$\hat{y}_u$	$\ell_u = \left(\bar{y}_u - \hat{y}_u\right)$	$\ell_u^2 = \left(\bar{y}_u - \hat{y}_u\right)^2$
1	200.96	218.17	-17.21	296.18
2	181.96	183.83	-1.87	3.50
3	178.44	188.45	-10.01	100.20
4	121.52	120.77	0.75	0.56
5	156.32	154.39	1.93	3.73
6	155.95	154.81	1.14	1.30
7	285.57	280.05	5.52	30.47
8	267.43	277.13	-9.70	94.09
9	182.30	180.79	1.51	2.28
10	160.97	159.17	1.80	3.24
11	146.73	150.95	-4.22	17.81
12	215.17	222.88	-7.71	59.44
13	215.07	212.96	-2.11	4.45
14	158.20	157.99	0.21	0.04
15	160.78	161.04	-0.26	0.07
16	194.90	190.92	3.98	17.84
17	188.95	191.87	-2.92	8.53
18	72.88	73.61	-0.73	0.533
19	219.17	220.68	-1.48	2.19
20	184.73	183.05	1.68	2.82
21	191.83	192.43	-0.6	0.36
22	358.15	361.72	-3.57	12.74
23	69.30	68.84	0.46	0.212
24	41.32	40.11	1.21	1.46
25	187.28	179.93	7.35	54.02
26	173.37	174.56	-1.19	1.42
27	126.27	119.79	6.48	41.99
28	30.23	33.11	-2.88	8.29
29	112.58	114.76	-2.18	4.75
30	32.13	41.07	-8.94	79.92
31	34.13	35.84	-1.71	2.92
32	73.20	72.77	0.43	0.18
33	125.98	125.66	0.32	0.10
34	148.80	151.23	-2.43	5.90
35	64.12	60.89	3.23	10.43
36	139.95	137.41	2.54	6.45
37	173.87	180.89	-7.02	49.28
38	35.20	36.89	-1.69	2.86
39	71.90	77.84	-5.94	35.28
40	116.28	119.68	-3.40	11.56
41	76.20	77.81	-1.61	2.59
42	80.02	79.29	0.73	0.53
43	158.25	161.09	-2.84	8.07
44	288.40	290.66	-2.26	5.11
45	77.55	74.98	2.57	6.60
46	114.42	118.93	+4.51	20.34
47	174.35	177.82	-3.47	12.04
48	191.90	189.24	2.66	7.08

49	287.13	288.74	-1.61	2.59
50	110.40	122.27	-1.87	3.50
51	277.60	276.91	0.69	0.48
52	193.83	200.23	-6.40	40.96
53	200.90	202.97	-2.07	4.28
54	157.23	149.84	7.39	54.61
55	199.18	201.81	-2.63	6.92
56	188.00	179.75	8.25	68.06
57	327.12	325.83	1.29	1.66
58	343.60	344.01	-0.41	0.17
59	209.75	211.89	-2.14	4.58
60	160.27	161.95	-1.68	2.82
61	129.95	128.60	1.35	1.88
62	155.35	154.72	0.63	0.40
63	157.53	155.47	2.06	4.24
64	179.67	177.02	2.65	7.02
65	266.60	267.65	-1.05	1.10
66	276.57	280.93	-4.36	19.01
67	167.47	169.88	-6.41	41.09
68	132.48	136.71	-4.23	17.89
69	83.15	86.74	-3.59	12.89
70	163.90	170.64	-6.74	45.43
71	143.98	140.85	3.13	9.80
72	157.32	148.64	8.68	75.34
73	192.05	189.17	2.88	8.29
74	256.95	249.93	7.02	49.28
75	177.30	174.59	2.71	7.34
76	251.05	250.66	0.39	0.15
77	182.10	180.15	1.95	3.80
78	360.20	364.79	-4.59	21.07
79	248.10	238.84	9.26	85.75
80	293.03	289.03	4.00	16.00
81	324.17	331.19	-7.02	49.28
		TOTAL	=	1707.37

It was shown from Equation 34 that three main effects which include temperature (with coefficient b_1 = 12.87), pH (with coefficient b_3 = -21.38) and duration of storage (with coefficient b_4 = 20.82) with other interactions in the model have significant influence on the level of the ascorbic acid on the yellow cashew fruit juice sample. This implies that high levels of each of these factors with their interactions led to drastic reduction in the ascorbic acid level of the juice. This does not mean that other factors do not affect the ascorbic acid on storage but within the stipulated time of the experiment it was found that temperature, pH and duration of storage slightly affect the ascorbic acid of juice, as reported by Olorunsogo and Agdidzi (2010). Comparing the predicted values based on the fitted model with the mean experimental values for the eighty-one experimental runs, as shown in Table 6, it was seen that storage and distribution of experiment 78 with predicted valued y_{78} = 364.79mg100 mL^{-1}, maintained the ascorbic acid level of the juice at the highest level. It means that non-refrigerated storage of yellow apple juice for optimum ascorbic acid should be conditioned to 29.70℃ of temperature, 9.610 brix value and 3.12 of pH for maximum of six days for best result as observed by Jatto and Adegoke (2010).

However, storage and distribution conditions, as determined from matrix table and model after fisher's test, of experiments 4, 18, 23,24,27,28,29,30,31,32, 33,35,38,39,40,41,42,45,46,50 and 69 with their respective values of ascorbic acid levels as y_4 = 120.77 mg mL^{-1}, y_{18} =

73.61 mg mL^{-1}, y_{23} = 68.84 mg mL^{-1}, y_{24} = 40.11 mg mL^{-1}, y_{27} = 119.79 mg mL^{-1}, y_{28} = 33.11 mg mL^{-1}, y_{29} = 114.76 mg mL^{-1},y_{30}= 41.07 mg mL^{-1}, y_{31}= 35.84 mg mL^{-1}, y_{32} = 72.77 mg mL^{-1}, y_{33} = 125.60 mg mL^{-1}, y_{35} = 60.89 mg mL^{-1}, y_{38}= 36.89 mg mL^{-1}, y_{39} = 77.84 mg mL^{-1}, y_{40} = 119.68 mg mL^{-1}, y_{41} = 77.81 mg mL^{-1}, y_{42} = 79.29 mg mL^{-1}, y_{45} = 74.98 mg mL^{-1}, y_{46}= 118.93 mg mL^{-1},y_{50} = 112.27 mg mL^{-1}and y_{69}= 86.74 mg mL^{-1} did not meet the minimum optimum quality standard as reported by Gunjate and Patwardhan (1995), Olorunsogo and Adgidzi (2010) (Table 1). The low level of ascorbic acid from those experiment could be wrong combination or interaction of factors used to performed the experimental, Nair (2010). However, the optimum condition of the experiment was used to determine the shelf-life of yellow sample of cashew fruit juice. The experiments that fall within the optimum level (200 – 240 mg ml^{-1}) as determined from matrix table and model after fisher's test were y_1= 218.17 mg mL^{-1}, y_{12} = 222.88 mg mL^{-1}, y_{13}= 212.96 mg mL^{-1}, y_{19} = 220.68 mg mL^{-1}, y_{52} = 200.23 mg mL^{-1}, y_{53} = 202.97 mg mL^{-1}, y_{55}= 201.81 mg mL^{-1}, y_{59}= 211.89 mg mL^{-1}and y_{79} = 238.84 mg mL^{-1}.The computer calculation showed that all the deteriorative factors considered had significant influence on the ascorbic acid of the juice. It does not mean that other factors did not affect ascorbic acid as manually calculated, but it is insignificant in the calculation as reported on the orange, apple and pineapple juices by Olorunsogo and Adgidzi (2010). The yellow apple juice model was validated by plotting regression graph of mean experimental observations against the estimated value and the regression coefficient of determination (R^2) value was 0.988 as determined using gen stat software as against 0.923 of orange juice from Akinwale (2000).

A model developed (Equation 35) showed that 20 insignificant regression coefficients of yellow samples were recorded at 5 percent after checking the adequacy of the regression model. The positive signs against the coefficients of the factors on the main effect and interactions in Equation 35 showed that the levels of ascorbic acids were increased by increasing the level of factors from low to intermediate and to high levels while negative signs against the coefficients of the factors on the main effects and interactions showed that the levels of ascorbic acids were reduced drastically from low to intermediate and to high levels.

4 Conclusions

The experimental results and the developed model of yellow sampled cashew fruit juice showed that temperature, pH and duration of storage were the major parameters that influence the shelf life and also important factors for characterizing the quality of the sample of the juice. These quality variables enabled the prediction of shelf-life of the juice under non-refrigerated storage and distribution conditions. The coefficient of correlation (R^2) of the dependent variable (ascorbic acid or vitamin C) and independent variables (temperature, total soluble solid(TSS), pH and duration of storage) in the regression models of the sample was 0.988. The 3^4 full factorial experimental design technique revealed the following optimal non-refrigerated storage and distribution conditions. The results also revealed that temperature of 38.6 ^{O}C, 11.68 ^{0}Brix value, pH of 4.61 and maximum of 16 days storage duration maintained the highest optimum level of ascorbic acid at 218.11 mg mL^{-1}. The optimum condition of the ascorbic acid in the experiment was used to determine the shelf-life of yellow sample of cashew fruit juice. The sample of cashew juice recorded twenty one experiments that did not get up to optimum minimum quality requirement of ascorbic acid level and also nine experiments that fall within the optimum level of ascorbic acid. Equation 35 expresses the regression model for determining shelf life of yellow sample of cashew fruit juice. The statistical analysis of the experimental data shows that the sample of cashew fruit juice model was adequate for shelf life prediction. Since the model was purely for non-refrigerated storage and distribution conditions, it is recommended comparing cashew fruits juice at different location within Nigeria, using the above experimental and modeling format, to ascertain the deteriorating differences in locations as further studies.

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