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Determination of Cashew Fruit Juice Quality Retention Using Factorial Design Method under Non Refrigerated Storage

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ABSTRACT

Ascorbic acid is the least stable of all fruit juice nutrients, including cashew apple juice. The concentration of ascorbic acid is an index to the retention of the original nutritive quality value. The maximum shelf lives of red and yellow samples of cashew apple juice were estimated and the quality value models based on the deteriorative factors were developed. Data were got from 3^4 full factorial experiments conducted in three replicates with the order randomized. Multivariate regression analyses were used for combining the variables. The models developed for red and yellow samples of cashew fruit juice showed that pH and duration of storage for red sample and temperature, pH and duration of storage for yellow sample were the major parameters that govern the shelf -life and characterization qualities of cashew fruit juice respectively. The experiment 78 of red sample maintained 329.38 mg/100 ml of ascorbic acid level at storage temperature of 29.7 ^{0}C, 10.56 ^{0}Brix value, pH of 3.32 and a maximum storage duration of 6 days while yellow sample maintained 364.79 mg/100 ml of ascorbic acid level at storage temperature of 29.7 ^{0}C, 10.59 ^{0}Brix value, pH of 3.12 and maximum storage duration of 6 days. Based on these facts, it was concluded that red sample of cashew fruit juice deteriorates slightly faster than yellow sample of cashew fruit juice.

Index Terms – Determination, Cashew Juice, Quality Retention, Factorial Design, Refrigerated Storage.

1. INTRODUCTION

Fruit juice is becoming a more important drink in Nigeria's diversified food industry. However, there is on avoidable decline in quality in the course of processing, distribution and storage of fresh fruit juice. The loss in quality occurs due to the sensitivity of ascorbic acid content of juices to some storage and environmental condition [1]

Therefore, it is the duty of the juice manufacturers to ensure that quality losses in juices are minimal. The manufacturer should monitor the factors that control the ascorbic acid level under production, distribution and storage conditions. Losses of ascorbic acid or deterioration of other biological values in fruit juices during storage and distribution has no or little information available as to the rate of these deteriorations. To get the extent of deterioration of nutrients during storage and distribution of cashew fruit juice, knowledge of the reaction rates as a function of the deteriorative factors is needed [2].

Cashew fruit juice is tasteful food beverage which provides energy and contains considerable amount of important vitamins (especially vitamin C) and minerals. The problems associated with freshly harvested fruits such as deterioration have increased the technologies of making the fruits accessible to people living in the urban areas in their processed forms [3]. Cashew fruit has a high rate of deterioration due to prone attack by insects, rodents and microorganisms such as yeast and mould which makes the fruit unavailable to the people in other parts of the country. Akinwale (2000), analyzed some physico-chemical properties of some tropical fruits and found out that cashew apple juice contained the highest amount of vitamin C with 203.5 mg/100 ml which is more than 300 % higher pasteurization which will inhibit the activities of enzymes as well as control the harsh taste of the juice.

The physio-chemical parameters of samples of cashew apple juice showed that the highest nutritional potential of the fruit in terms of ascorbic acid were sugar, organic acids, dry matter and ash. In addition, several other compounds with antioxidant capacity such as carotenoids flavonoids, phenolic acids, tannins, and anacardic acids have already been identified. Cashew apple is rich in nutrients, but cannot consume much because of its astringency. The identification of organic acids in fruit juice is very important because it provides useful information about the nutritive content of the product. Their presence affects the chemical and sensory characteristics of these physiochemical parameters like pH, total acidity, microbial stability, softness, overall acceptability and can provide important information on product shelf life and on how to improve some selected technological processes [5]. Cashew apple juice contains thiamine, niacin, riboflavin and some level of vitamin A. It contains good source of minerals such as copper, zinc, sodium, potassium, calcium, iron, phosphorous and magnesium [6]. In addition to these minerals, the juice also contains sulphur, silicon, chlorine, aluminium and bromine [7]. Ascorbic acid is one of the major vitamins that should be continuously checked in the course of processing and storage of fruit juice. Its level is usually the basis for judging fruit juice quality. The recommended values of ascorbic acid for different fruit juice were shown in Table 1.

Fruit Juice	Ascorbic Acid (mg/100ml)	
	Maximum	Minimum
Orange	80	20
Pineapple	25	8
Cashew	510	126
Mango	80	20
Grape fruit	65	35
Lemon	70	30
Lime	40	5

Table 1 Recommended Juice Quality

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

The spoilage of cashew fruit juice during processing, distribution and storage has received inadequate attention under non-refrigerated storage. The problem in predicting the quality of cashew fruit juice under specific storage conditions and duration is due to unavailability of nutrient deterioration profile. The main objective of this research work is to determine the effect of storage temperature, total soluble solid (brix value), pH and duration of storage on the ascorbic acid level of cashew fruit juice using factorial design method under non refrigerated storage. Mathematical models of the samples of juice quality based on these deteriorative factors were developed.

2. MATERIALS AND METHOD

Cashew apple fruits samples, which include Red and Yellow samples, were obtained from local cashew plantation plot at Nkplogwu in Uzo Uwani Local government of Enugu State, Nigeria. These samples were used to represent cashew fruits in Nigerian market with respect to the species and ecological conditions of the country. Cashew fruits juice were extracted from cashew apple using mechanical screw press and the obtained juice were filtered using sterilize muslin cloth. 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 juice extracted from them are presented in Table 2.

Experimental sample	Variety/source	Properties of juice freshly extracted		
		Vitamin C	Brix value	pH
Fruit Juice	Red	484.10mg/100ml	11.38^{0}Brix	4.48
Fruit Juice	Yellow	495.65mg/100ml	11.40^{0}Brix	4.60

Table 2 Experimental Samples

2.1. Experimental Design Method

A four-variable three level factorial experiment was used to form the framework for designing the juice multifactor experiments. With three levels four variables, a complete design was made which led to a total of 81 runs. In the 3^4 full factorial experiment the low, intermediate and high levels of the factors were represented as "-", "0"and "+", respectively. The levels of the four factors were formed using temperature, total soluble solid, pH and duration of storage as represented in standard order as x_1, x_2, x_3 and x_4.

2.2. Conduct of Experiment

The experiments were conducted in randomized order with four variable three level factorial at three replicates using the design plan (matrix) given in Table 3. The plus, zero and minus signs in the matrix columns showed how to combine the factors in each experimental run. For example, the first run indicated that all the four factors were put in low levels, the second run sets factors x_1 at high level while all the other factors remained at intermediate and low levels. The coded levels of the factors formed and the results of each sample experiments are given in Table 4.

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

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	$x_1x_2x_3$	$x_1x_2x_4$	$x_1x_3x_4$	$x_2x_3x_4$	$x_1x_2x_3x_4$
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 3 Design Matrix for 3^4 Full Factorial Experiment

Level of Factors	Code	Juice Sample	Independent variables			
			Temperate (x_1)	Total soluble solid (x_2)	pH (x_3)	Duration of storage (x_4)
Based level	x	Red	34.15^{0}C	10.31^{0}Brix	3.91	11days
		Yellow	34.15^{0}C	10.64^{0}Brix	3.86	11days

Interval of Variation	ΔX_i	Red	4.45^0C	0.82^0Brix	0.60	5days
		Yellow	4.45^0C	1.04^0Brix	0.75	5days
High level	+	Red	38.60^0C	11.13^0Brix	4.51	16days
		Yellow	38.60^0C	11.68^0Brix	4.61	16days
Intermediate	0	Red	34.40^0C	10.56^0Brix	3.99	11days
		Yellow	34.40^0C	10.59^0Brix	3.98	11days
Low level	-	Red	29.70^0C	9.50^0Brix	3.32	6days
		Yellow	29.70^0C	9.61^0Brix	3.12	6days

Table 4: Factors and their Coded Levels

2.3 Statistical Analysis and Development of Model

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

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

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

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

$$\text{The maximum dispersion} = S_{u\max}^2 \qquad 4$$

Where

r = replication, y_{uv} = value of each ascorbic acid measure, $\bar{y}_u$ = mean of the experimental observation, S_u^2 = dispersion

The G-test (Cochran G-criteria) was used to find out the possibility of carrying out regression analysis. It was also used to check the maximum accuracy of the replication output factors. The test showed the homogeneity of dispersion of the replicate experiments. The calculated G-value was computed using the formula below:

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

The calculated G-value was compared with an appropriate table value. The condition of homogeneity was got using the relation:

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

Where, N = Number of experimental runs, r = Number of replicate, α = Level of significance

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

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

The formula was used to estimate average sample variance. The experimental error was got by:

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

The mean effect was estimated by

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

Where x_0 was the chosen signs in the x_0 column of the design matrix. The four main effects were estimated by

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

Where x_i were the chosen signs in the x_I columns of the design matrix. The six two-factor interactions were estimated by

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

Where x_{ij} were the chosen signs in the x_{ij} columns of the design matrix. The four three-factor interactions were estimated by

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

Where x_{ijkl} were the chosen signs in the x_{ijkl} columns of the design matrix.

The one four-factor interactions were estimate d by

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

Where x_{ijkl} were the chosen signs in the x_{ijkl} columns of the design matrix

Forming the confidence interval and checking the hypotheses about individual regression coefficients in the regression model are frequently used in assessing their statistical significance [9]

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

b's $\pm$ t {α, N(r-1} $S_{b's}$

i.e b's $\pm$ Δb's 14

Where, $S_{b's}$ = 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

We used 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 contain 99% of the variable measurements in the population.

The errors in each regression coefficient is the same in the experiment and was determined by

$$S_{bo} = Sb_i \ldots\ldots\ldots\ldots\ldots\ldots Sb_{ijklm} = \frac{S(r)}{\sqrt{Nr}}. \qquad 15$$

$$\text{Where } S_{bi}^2 = \frac{S_y^2}{N} \qquad 16$$

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

$$t_0 = \frac{b_0}{S_{b0}},\ t_i = \frac{b_i}{S_{bi}},\ t_w = \frac{b_{ij}}{S_{bij}} \bullet\bullet\ \mathrm{t}_{\mathrm{ijklm}} = \frac{\{\mathrm{b}_{\mathrm{ijklm}}\}}{\mathrm{S}_{\mathrm{bijklm}}} \qquad 17$$

The test was done by comparing the calculated t-values with the appropriate critical table values. A coefficient of regression was statically significant at

$$t_{cal} > t\{\alpha, N(r-1)\} \qquad 18$$

The coefficient that was statistically insignificant (i.e $t_{cal} < t_{table}$), were left out of the regression model [10]. Insignificance of an effect do not necessarily mean that those particular factors or interaction were unimportant. It only means that response was unaffected if the factor was varied over the range considered (i.e. from -1 to +1or 0 in coded units).

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 $\bar{Y}_1, \bar{Y}_2, \ldots\ldots\ldots\bar{Y}_N$ and the fitted or predicted values $\hat{Y}_1, \hat{Y}_2, \ldots\ldots\ldots\hat{Y}_N$ were the residuals which were given by $e_u = \bar{Y}_u - \hat{Y}_u; \quad u = 1,2,\ldots\ldots\ldots 81$ 19

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 experiment sums of squares for the effects were calculated from the contrasts used in estimating the effects. In the 3^k full factorial design with replicates, the regression sum of squares for any effects were computed with equation 20.

$$SS_R = \frac{r}{N}(contrast)^2 \qquad 20$$

Which has a single degree of freedom. Consequently, the major effects and the interactions were calculated using equations 21 to 24.

$$SS_{bi} = \frac{r}{N}\sum_{u=1}^{N}\left(x_i \bar{Y}_u\right)^2 \qquad 21$$

Where x_i were the chosen signs in the x_i column of the design matrix.

For the two-factor interactions

$$SS_{bij} = \frac{r}{N}\sum_{u=1}^{N}\left(x_{ij} \bar{Y}_u\right)^2; i = \qquad 22$$

Where x_{ij} were the chosen signs in the x_{ij} column of the design matrix. For the three-factor interactions

$$SS_{bijk} = \frac{r}{N}\sum_{u=1}^{N}\left(x_{ijk} \bar{Y}_u\right)^2; i\ \ j\ \ k \qquad 23$$

Where x_{ijk} were the chosen signs in the x_{ijk} columns of the design matrix For the four-factor interactions

$$SS_{bijkl} = \frac{r}{N}\sum_{u=1}^{N}\left(x_{ijkl}\,\bar{Y}_u \right)^2 ;i \;\; j \;\; k \;\; l \qquad 24$$

Where xijkl were the chosen signs in the x_{ijkl} columns of the design matrix.

Note that $N = 3^k$.

The total sum of squares was calculated using

$$SS_T = \sum_{u=1}^{N.r} Y^2 uv - \sum_{u=1}^{N.r} (Yuv)^2 / N.r \qquad 25$$

The error sum of squares was got by;

$$SS_E = SS_T = -\sum SS_R \qquad 26$$

$$i.e\; SS_E = SS_T - SS_{bj.} + \ldots + SS_{bij} + \ldots. + SS_{bijklm} \;[10] \qquad 27$$

The appropriate statistics for the F-test was computed using

$$F_{cal} = \frac{MS_R}{MS_E} = \frac{SS_R / df_R}{SS_E / N(r-1)} \qquad 28$$

Where df_R = the degree of freedom regression

The null hypothesis was determined by the formula below

$$F_{cal} > F\{\alpha, df_R, N(r-1)\} \qquad 29$$

The conclusion was that the coefficient model contributed significantly to the regression [10]. The complete analyses of variance were summarized using the above conclusion. The adequacy of the model was further checked. The method used for validating the model adequacy was 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 was calculated using

$$SS_{(ad)}^2 = \frac{r}{N-\lambda}\sum_{u=1}^{N}\left(\bar{y}_u - \hat{y}_u\right)^2 = \frac{r}{df_{ad}}\sum_{u=1}^{N}\left(\bar{y}_u - \hat{y}_u\right)^2 \qquad 30$$

Where λ = number of inadequate coefficients.

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

$$F_{cal} = \frac{S_{(ad)}}{S_{(y)}^2} \qquad 31$$

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

$$F_{cal} \le F\{\alpha, N-\lambda, N(r-1)\} \qquad 32$$

The regression model was adequate because the above condition was satisfied.

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 red and yellow cashew fruits juice samples were presented in Tables 5and 6, The mean, dispersion, sum of the dispersion and maximum dispersions were determined from the data generated on the samples. The dependent variable "y"'s 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 both samples of cashew fruit juice were presented in table 7.

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	156.65	130.10	138.95	141.90	14.75	-11.80	-2.95	217.56	139.24	8.70	182.75
2	138.95	156.65	179.49	158.36	-19.41	-1.71	21.13	376.748	2.924	446.771	413.075
3	17.80	177.80	165.50	163.70	-15.90	14.10	1.80	252.810	198.81	3.240	227.430
4	112.40	121.25	147.80	127.15	-14.75	5.90	20.65	217.563	34.810	426.423	339.398
5	130.10	130.10	155.65	138.62	-8.52	-8.52	17.03	72.590	72.590	290.021	217.600
6	147.80	156.65	154.56	153.00	-5.20	3.65	1.56	27.04	13.323	2.434	21.398
7	165.50	165.50	192.05	174.35	-8.85	-8.85	17.70	78.323	78.323	313.290	234.968
8	156.65	130.10	156.65	147.8	8.885	-17.7	8.85	78.323	313.290	70.323	234.968
9	177.80	174.35	180.49	177.55	0.25	-3.20	2.94	0.063	10.240	8.644	9.473
10	174.35	200.90	195.02	190.09	-15.74	10.81	4.93	247.748	116.856	24.305	144.454
11	254.00	245.15	216.85	238.67	15.33	6.48	-21.82	235.009	41.990	476.112	376.556
12	174.35	183.20	200.90	185.85	-11.50	-2.65	15.05	132.25	7.023	226.503	182.888
13	236.30	262.83	280.55	259.89	-23.59	2.94	20.66	556.488	8.644	426.836	495.984
14	138.95	147.80	174.35	153.70	-14.75	-5.90	20.65	217.563	34.810	426.423	339.398
15	192.05	183.20	165.50	180.25	11.80	2.95	-14.75	139.240	8.700	217.560	182.750
16	192.05	200.90	174.35	189.10	2.95	11.80	-14.75	8.700	139.240	217.560	182.750
17	177.80	165.50	192.05	178.45	-0.65	-12.95	13.60	0.423	167.703	184.960	176.543
18	85.85	85.85	103.55	91.75	-5.90	-5.90	11.80	34.810	34.810	139.240	104.430
19	236.30	245.15	227.45	236.30	0.00	8.85	-8.85	0.000	78.323	78.323	78.323
20	183.20	183.20	165.50	177.30	5.90	5.90	-11.80	34.810	34.810	139.240	104.430
21	192.05	183.20	191.40	188.88	3.17	-5.68	2.52	10.049	32.262	6.350	24.331
22	183.20	174.35	192.05	183.20	0.00	-8.85	8.85	0.000	78.3223	78.323	78.323
23	73.50	103.55	94.70	90.58	-17.08	12.97	4.12	291.726	168.221	16.974	238.461
24	85.85	85.85	68.15	79.95	5.90	5.90	-11.75	34.810	34.810	138.063	103.841
25	156.65	177.80	138.95	157.80	-1.15	20.00	-18.85	1.323	400.000	355.323	378.323
26	121.25	165.50	156.65	147.85	-26.60	17.65	8.80	707.560	311.523	77.440	548.262
27	112.40	127.50	121.25	120.38	-7.98	7.12	0.87	63.680	50.694	0.7571	57.565
28	94.70	77.00	85.90	85.87	8.83	-8.87	0.03	77.969	78.677	0.0009	78.323
29	147.80	121.25	121.25	130.10	17.70	-8.85	-8.85	313.29	78.323	78.323	234.968
30	85.85	94.70	90.20	90.25	-4.40	4.45	-0.05	19.360	19.803	0.0025	19.583
31	94.70	85.85	103.55	94.70	0.00	-8.85	8.85	0.000	78.323	78.323	78.323
32	103.55	112.40	77.00	97.65	5.90	14.75	-20.65	34.810	217.560	426.423	339.396
33	130.10	138.95	147.80	138.95	-8.85	0.00	8.85	78.323	0.000	78.323	78.323
34	192.05	191.60	174.35	186.00	6.05	5.60	-11.65	36.603	31.360	135.723	101.843
35	103.55	112.95	121.25	112.58	-9.03	0.37	8.67	81.541	0.137	75.169	78.423
36	156.65	174.35	165.00	165.33	-8.68	9.02	-0.33	75.342	81.360	0.109	78.405
37	165.50	156.65	160.20	160.78	4.72	-4.13	-0.58	22.278	17.057	0.336	19.836
38	73.50	103.55	77.00	84.68	-11.18	18.87	-7.68	124.992	356.077	58.982	270.026
39	68.15	76.80	121.25	88.73	-20.58	-11.93	32.52	423.536	142.325	1057.55	811.706
40	147.80	161.45	165.80	158.35	-10.55	3.10	7.45	111.303	9.610	55.503	82.208

41	77.00	103.55	121.25	100.60	-23.60	2.95	20.65	556.960	8.703	426.423	490.043
42	77.00	68.15	74.45	73.20	3.80	-5.05	1.25	14.440	25.503	1.563	20.753
43	147.80	161.45	165.80	158.35	-10.55	3.10	7.45	111.303	9.610	55.503	82.208
44	218.60	217.17	227.45	221.07	-2.47	-3.90	6.38	6.101	15.210	40.704	31.008
45	59.30	71.60	103.55	78.15	-18.85	-6.55	25.40	355.323	42.903	645.160	521.693
46	138.95	121.25	147.80	136.00	2.95	-14.75	11.80	8.703	217.563	139.240	182.753
47	174.35	165.50	191.60	177.15	-2.80	-11.65	14.45	7.840	135.723	208.803	176.183
48	227.45	192.05	209.75	209.75	17.70	-17.70	0.00	313.290	313.290	0.000	313.290
49	245.15	218.60	227.45	230.40	14.75	-11.80	-2.95	217.563	139.240	8.703	182.753
50	103.55	112.95	121.25	112.58	-9.03	0.37	8.67	81.541	0.137	75.169	78.423
51	227.45	217.17	218.60	221.07	6.38	-3.90	-2.47	40.704	15.210	6.101	31.007
52	262.85	254.00	236.30	251.05	11.80	2.95	-14.75	139.240	8.700	217.560	182.750
53	218.60	217.17	227.45	221.07	-2.47	-3.90	6.38	6.101	15.210	40.704	31.008
54	174.35	165.50	156.65	165.50	8.85	0.00	-8.85	78.323	0.000	78.323	78.323
55	200.90	191.60	209.75	200.75	0.15	-9.15	9.00	0.023	83.723	81.000	82.373
56	218.60	217.17	227.15	220.97	-237	-3.80	6.18	5.617	14.440	38.192	29.125
57	254.00	254.00	245.15	251.05	2.95	2.95	-5.90	8.703	8.703	34.810	26.108
58	289.40	315.95	192.05	301.20	-11.80	14.75	-2.95	139.240	217.560	8.703	182.753
59	209.75	216.85	218.60	215.07	-5.32	1.78	3.53	28.302	3.168	12.461	21.965
60	183.20	192.05	191.40	188.88	-5.68	3.17	2.52	32.262	10.049	6.350	24.331
61	121.25	127.45	130.10	126.27	-5.02	1.18	3.83	25.200	1.392	14.669	20.630
62	156.65	138.95	160.20	151.93	4.72	-12.98	8.27	22.278	168.480	68.393	129.535
63	165.50	174.35	156.65	165.50	0.00	8.85	-8.85	0.000	78.323	78.323	78.323
64	192.05	191.40	183.20	188.88	3.17	2.52	-5.68	10.049	6.350	32.262	24.331
65	280.55	282.60	298.25	287.13	-6.58	-4.53	11.12	43.296	20.521	123.654	93.736
66	286.75	289.40	298.25	291.47	-4.72	-2.07	6.78	22.278	4.285	45.968	36.266
67	156.65	161.45	138.95	152.35	4.30	9.10	-13.40	18.490	82.810	179.560	140.430
68	127.45	147.80	121.25	132.17	-4.72	15.63	-10.92	22.278	244.297	119.246	192.911
69	85.85	68.15	103.55	85.85	0.00	-17.70	17.70	0.000	313.290	313.290	313.290
70	161.45	156.65	147.80	155.30	6.15	1.35	-7.50	37.823	1.823	56.250	47.948
71	156.65	165.50	121.25	147.80	8.85	17.70	-26.55	78.323	313.290	704.903	548.258
72	174.35	174.35	138.95	162.53	11.82	11.82	-23.58	139.712	139.712	556.016	417.720
73	192.05	183.20	174.35	183.20	8.85	0.00	-8.85	78.323	0.000	78.323	78.323
74	254.00	245.15	245.15	248.10	5.90	-2.95	-2.95	34.810	8.703	8.703	26.108
75	183.20	191.40	192.05	188.88	-5.68	2.52	3.17	32.262	6.350	10.049	24.331
76	280.55	298.25	277.45	285.42	-4.87	12.83	-7.97	23.717	164.609	63.521	125.923
77	218.60	183.20	192.05	197.95	20.65	-14.75	-5.90	426.423	217.563	34.810	339.398
78	333.65	322.90	351.35	335.97	-2.32	-13.07	15.38	5.382	170.825	236.544	206.376
79	262.85	277.45	254.00	264.77	-1.92	12.68	-10.77	3.686	160.782	115.993	140.230
80	307.10	298.25	289.40	298.25	8.85	0.00	-8.85	78.323	0.000	78.323	78.323
81	286.75	280.55	277.45	281.58	5.17	-1.03	-4.13	26.729	1.061	17.057	22.423

Table 5 Ascorbic Acid Content of Red Cashew Fruit Juice, mg/100 ml

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
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

Table 6 Ascorbic Acid Content of Yellow Cashew Fruit Juice, mg/100 ml

Run No	$\bar{y}_u$	$\hat{y}_u$	$\ell_u = \left(\bar{y}_u - \hat{y}_u\right)$	$\ell_u^2 = \left(\bar{y}_u - \hat{y}_u\right)^2$	$\bar{y}_u$	$\hat{y}_u$	$\ell_u = \left(\bar{y}_u - \hat{y}_u\right)$	$\ell_u^2 = \left(\bar{y}_u - \hat{y}_u\right)^2$
	Red Sample of Cashew Juice				Yellow Sample of Cashew Juice			
1	141.90	171.64	-29.74	884.47	200.96	218.17	-17.21	296.18
2	158.36	157.63	0.73	0.53	181.96	183.83	-1.87	3.50
3	163.70	166.12	-2.42	5.86	178.44	188.45	-10.01	100.20
4	127.15	130.65	-3.50	12.25	121.52	120.77	0.75	0.56
5	138.62	138.78	-0.16	0.03	156.32	154.39	1.93	3.73
6	153.00	149.41	3.59	12.89	155.95	154.81	1.14	1.30
7	174.80	174.22	0.58	0.34	285.57	280.05	5.52	30.47
8	147.81	146.80	1.01	1.02	267.43	277.13	-9.70	94.09
9	177.55	178.56	-1.01	1.02	182.30	180.79	1.51	2.28
10	190.09	191.17	-1.08	1.17	160.97	159.17	1.80	3.24
11	238.67	239.59	-0.92	0.85	146.73	150.95	-4.22	17.81
12	185.85	184.43	1.42	2.02	215.17	222.88	-7.71	59.44
13	259.89	258.07	1.82	3.31	215.07	212.96	-2.11	4.45
14	153.70	154.64	-0.94	0.88	158.20	157.99	0.21	0.04
15	180.25	179.09	1.17	1.37	160.78	161.04	-0.26	0.07
16	189.10	188.52	0.58	0.34	194.90	190.92	3.98	17.84
17	178.45	178.12	0.33	0.11	188.95	191.87	-2.92	8.53
18	91.75	88.86	2.89	8.35	72.88	73.61	-0.73	0.533
19	236.30	235.39	0.91	0.83	219.17	220.68	-1.48	2.19
20	177.30	176.05	1.25	1.56	184.73	183.05	1.68	2.82

21	188.88	186.12	2.76	7.62	191.83	192.43	-0.6	0.36
22	183.20	183.64	-0.44	0.19	358.15	361.72	-3.57	12.74
23	90.58	91.26	-0.68	0.46	69.30	68.84	0.46	0.212
24	79.95	77.13	2.82	7.95	41.32	40.11	1.21	1.46
25	157.80	156.83	0.97	0.94	187.28	179.93	7.35	54.02
26	147.85	149.61	-1.76	3.10	173.37	174.56	-1.19	1.42
27	120.38	119.90	0.48	0.23	126.27	119.79	6.48	41.99
28	85.87	84.00	1.87	3.50	30.23	33.11	-2.88	8.29
29	130.10	132.56	-2.46	6.06	112.58	114.76	-2.18	4.75
30	90.25	92.51	-2.26	5.11	32.13	41.07	-8.94	79.92
31	94.70	93.61	1.09	1.19	34.13	35.84	-1.71	2.92
32	97.65	95.36	2.29	5.24	73.20	72.77	0.43	0.18
33	138.95	140.79	-1.84	3.39	125.98	125.66	0.32	0.10
34	186.00	185.24	0.76	0.58	148.80	151.23	-2.43	5.90
35	112.58	111.06	1.52	2.31	64.12	60.89	3.23	10.43
36	165.33	163.04	2.29	5.24	139.95	137.41	2.54	6.45
37	160.78	160.48	0.30	0.09	173.87	180.89	-7.02	49.28
38	84.68	83.12	1.56	2.43	35.20	36.89	-1.69	2.86
39	88.73	88.82	-0.09	0.008	71.90	77.84	-5.94	35.28
40	158.35	157.48	0.87	0.76	116.28	119.68	-3.40	11.56
41	100.60	99.02	1.58	2.50	76.20	77.81	-1.61	2.59
42	73.20	74.23	-1.03	1.06	80.02	79.29	0.73	0.53
43	158.35	159.80	-1.45	2.10	158.25	161.09	-2.84	8.07
44	221.07	220.13	0.94	0.88	288.40	290.66	-2.26	5.11
45	78.15	78.82	-0.67	0.45	77.55	74.98	2.57	6.60
46	136.00	135.98	0.02	0.0004	114.42	118.93	+4.51	20.34
47	177.15	176.09	1.06	1.13	174.35	177.82	-3.47	12.04
48	209.75	212.68	-2.93	8.58	191.90	189.24	2.66	7.08
49	230.40	229.39	1.01	1.02	287.13	288.74	-1.61	2.59
50	112.58	114.58	-2.00	4.00	110.40	122.27	-1.87	3.50
51	221.07	224.01	-2.94	8.64	277.60	276.91	0.69	0.48
52	251.05	256.14	-5.09	25.91	193.83	200.23	-6.40	40.96
53	221.05	224.78	-3.73	13.91	200.90	202.97	-2.07	4.28
54	165.50	165.70	-0.20	0.04	157.23	149.84	7.39	54.61
55	200.75	199.72	1.03	1.06	199.18	201.81	-2.63	6.92
56	220.97	223.22	-2.25	5.06	188.00	179.75	8.25	68.06
57	251.05	254.82	-3.77	14.21	327.12	325.83	1.29	1.66
58	301.20	303.97	-2.77	7.67	343.60	344.01	-0.41	0.17
59	215.07	223.71	-8.64	74.65	209.75	211.89	-2.14	4.58
60	188.88	189.61	-0.73	0.53	160.27	161.95	-1.68	2.82
61	126.27	125.01	1.26	1.59	129.95	128.60	1.35	1.88
62	151.93	153.05	-1.12	1.25	155.35	154.72	0.63	0.40
63	165.50	166.94	-1.44	2.07	157.53	155.47	2.06	4.24
64	188.88	190.81	-1.93	3.72	179.67	177.02	2.65	7.02
65	287.13	286.66	0.47	0.22	266.60	267.65	-1.05	1.10
66	291.47	290.81	0.66	0.44	276.57	280.93	-4.36	19.01
67	152.35	151.44	0.91	0.83	167.47	169.88	-6.41	41.09
68	132.17	131.18	0.99	0.98	132.48	136.71	-4.23	17.89
69	85.85	85.22	0.63	0.40	83.15	86.74	-3.59	12.89
70	155.30	154.37	0.93	0.86	163.90	170.64	-6.74	45.43
71	147.80	145.90	1.90	3.61	143.98	140.85	3.13	9.80

72	162.53	161.41	1.12	1.25	157.32	148.64	8.68	75.34
73	183.20	182.50	0.70	0.49	192.05	189.17	2.88	8.29
74	248.10	247.66	0.44	0.19	256.95	249.93	7.02	49.28
75	188.88	188.26	0.62	0.38	177.30	174.59	2.71	7.34
76	285.42	283.61	1.81	3.28	251.05	250.66	0.39	0.15
77	197.95	198.48	-0.53	0.28	182.10	180.15	1.95	3.80
78	335.97	329.33	6.64	44.09	360.20	364.79	-4.59	21.07
79	264.77	264.12	0.65	0.42	248.10	238.84	9.26	85.75
80	298.25	301.19	-2.94	8.64	293.03	289.03	4.00	16.00
81	281.58	280.84	0.74	0.55	324.17	331.19	-7.02	49.28
		TOTAL	=	1244.54		TOTAL	=	1707.37

Table 7 The Mean Experimental Observations Fitted Values, Residuals and Squares of Residuals for both samples of Cashew Fruit Juice

The fitted or predicted models for red and yellow (equation 33 and 34) samples become.

$$y_u = 207.11 - 15.96x_3 - 18.76x_4 - 39.54x_{12} - 48.21x_{13} - 54.35x_{14} - 30.32x_{23} - 36.24x_{24} - 26.24x_{34} - 66.06x_{123} - 50.10x_{124} - 51.14x_{134} - 65.94x_{234} - 51.87x_{1234} + 13.25x_3^2 + 32.95x_4^2 - 18.35x_1^2x_{23} + 10.56x_1^2x_{24} - 11.20x_1^2x_{234} - 12.42x_2^2x_{13} - 12.7x_3^2x_1 - 11.68x_3^2x_2 - 19.93x_3^2x_4 - 23.25x_3^2x_{14} + 20.5x_4^2x_2 + 11.52x_4^2x_3 - 11.33x_4^2x_{12} + 12.85x_4^2x_{13} - 20.54x_4^2x_{123} - 37.77x_1^2x_2^2 + 12.95x_1^2x_3^2 + 39.68x_3^2x_4^2 + 10.07x_1^2x_2^2x_4^2 + 19.69x_1^2x_3^2x_4^2 + 9.93x_1^2x_2^2x_3 + 10.12x_1^2x_2^2x_4 + 13.68x_1^2x_2^2x_{34} + 12.92x_1^2x_3^2x_4 - 20.27x_1^2x_3^2x_{24} - 21.83x_1^2x_4^2x_3 - 17.49x_1^2x_4^2x_{23} + 13.36x_2^2x_3^2x_1 + 47.15x_2^2x_3^2x_4 - 11.62x_2^2x_4^2x_1 - 26.02x_2^2x_4^2x_3 - 16.29x_2^2x_4^2x_{13} - 10.56x_3^2x_4^2x_2 + 19.32x_1^2x_2^2x_3^2x_4 + 46.54x_1^2x_3^2x_4^2x_2 - 9.96x_2^2x_3^2x_4^2x_1 \quad 33$$

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

3.1. Discussion

It was seen from equations 33 and 34 that only two main effects which include pH (with coefficient b_3 = -15.96) and duration of storage (with coefficient b_4 = -18.76) with other interactions in the model have significant influence on the level of the ascorbic acid on the red cashew fruit juice sample while 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. These imply that high levels of each of these factors with their interactions led to drastic reduction in the ascorbic acid level of the juice. Comparing the predicted values based on the fitted models with the mean experimental values for the eighty-one experimental runs, as shown in Table 7, it was shown that storage and distribution of experiment 78 with predicted values y_{78} = 329.33 mg/100 ml and y78 = 364.79mg/100 ml maintained the ascorbic acid level of the juice at the highest level for both samples. However, storage and distribution conditions of experiment 18 (with predicted value y_{18} = 88.86 mg/100 ml), experiments 23 and 24 (predicted values y_{23}= 91.26 mg/100 ml, y_{24}, = 77.13 mg/100 ml), experiments 27, 28, 30 31, 32, 35, 38, 39, 41, 42, 45, 50, 61,69 (with respective predicted values of y_{27}

= 119.90 mg/100 ml, y_{28}= 84 mg/100 ml, y_{30} = 92.51 mg/100 ml, y_{31} = 93.62 mg/100 ml, y_{32} = 95.36 mg/100 ml, y_{35} = 111.06 mg/100 ml, y_{38} = 83.12 mg/100 ml, y_{39} = 88.82 mg/100 ml, y_{41} = 99.02 mg/100 ml, y_{42}, = 74.23 mg/100 ml, y_{45} = 78.82 mg/100 ml, y_{50} = 114.5 mg/100 ml, y_{61} = 125.01 mg/100 ml and y_{69} = 85.22 mg/100 ml) did not meet the minimum quality standard for red sample. Hence 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/100 ml, y_{18} = 73.61 mg/100 ml, y_{23} = 68.84 mg/100 ml, y_{24} = 40.11 mg/100 ml, y_{27} = 119.79 mg/100 ml, y_{28} = 33.11 mg/100 ml, y_{29} = 114.76 mg/100 ml, y_{30} = 41.07 mg/100 ml, y_{31} = 35.84 mg/100 ml, y_{32} = 72.77 mg/100 ml, y_{33} = 125.60 mg/100 ml, y_{35} = 60.89 mg/100 ml, y_{38} = 36.89 mg/100 ml, y_{39} = 77.84 mg/100 ml, y_{40} = 119.68 mg/100 ml, y_{41} = 77.81 mg/100 ml, y_{42} = 79.29 mg/100 ml, y_{45} = 74.98 mg/100 ml, y_{46} = 118.93 mg/100 ml,y_{50} = 112.27 mg/100 ml and y_{69} = 86.74 mg/100 ml did not meet the minimum requirement of ascorbic acid level of cashew juice for yellow sample (Table 1).

The optimum condition was experiment that fall within 200 – 240 mg/100 ml of ascorbic acid level. The experiments that fall within specifications from red sample were 11, 19, 44, 48, 49, 51, 53, 56 and 59 (predicted values were y_{11} = 239.59 mg/100 ml, y_{19} = 235.39 mg/100 ml, y_{44} = 220.13 mg/100 ml, y_{48} = 212.68 mg/100 ml, y_{49} = 229.39 mg/100 ml, y_{51} = 224.01 mg/100 ml, y_{53} = 224.78 mg/100 ml, y_{56} = 223.22 mg/100 ml and y_{59} = 223.71 mg/100 ml) while y_1 = 218.17 mg/100 ml, y_{12} = 222.88 mg/100 ml, y_{13} = 212.96 mg/100 ml, y_{19} = 220.68 mg/100 ml, y_{52} = 200.23 mg/100 ml, y_{53} = 202.97 mg/100 ml, y_{55} = 201.81 mg/100 ml, y_{59} = 211.89 mg/100 ml and y_{79} = 238.84 mg/100 ml fall in yellow sample. Models developed (equations 33 and 34) showed that 31 insignificant regression coefficients of red samples and 20 insignificant regression coefficients of yellow samples were recorded at 5 percent after checking the adequacy of the produced models. The positive signs against the coefficients of the main and interactions in these models showed that the levels of ascorbic acids were raised by increasing the level of factors from low to intermediate and to high levels while negative signs against the coefficients of the main and interactions showed that the levels of ascorbic acids were reduced from low to intermediate and to high levels.

4. CONCLUSIONS

The results of the experiment and the developed models showed that pH and duration of storage for red sample and temperature, pH and duration of storage for yellow sample were the major parameters that govern the shelf life and also important factors for characterizing the quality of the samples of the juice. These quality variables enabled the prediction of shelf-life of the juice under non-refrigerated storage and distribution conditions. The 3^4 full factorial experimental design technique revealed the following optimal non-refrigerated storage and distribution conditions. The experiment of Red sample of cashew fruit juice revealed that temperature of 34.4 ^{0}C, 11.13 ^{0}Brix value, pH of 3.99 and maximum of 16 days storage duration maintained the highest optimum level of ascorbic acid at 239.59 mg/100 ml while yellow sample shown that temperature of 29.7 ^{0}C, 11.68 ^{0}Brix value, pH of 3.98 and maximum of 16 days storage duration maintained the highest optimum level of ascorbic acid at 222.88 mg/100 ml.

The optimum condition of the ascorbic acid in the experiment was used to determine the shelf-life of red and yellow samples of cashew fruit juice. The red and yellow samples of cashew juice recorded seventeen and twenty-one experiments that did not meet minimum quality requirement of ascorbic acid level and both samples showed nine experiments that fall within the optimum level of ascorbic acid. Equations 33 and 34 express the fitted models for predicting shelf life of red and yellow samples of cashew fruit juice. The statistical analysis of the experimental data showed that the samples of cashew fruits juice models were adequate for shelf life prediction. Since the models were 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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