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Determination of Cashew Juice specie's Shelf-Life at Natural Storage Using Multivariate Regression Model

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ABSTRACT
There is an inevitable decline in quality value especially the ascorbic acid in preserving cashew apple juice. The maximum shelf life of a red sample of cashew apple juice was estimated and the quality value multivariate regression model was developed. Data were drawn from 3^4 full factorial experiments conducted in three replicates with the order of the replicates randomized. The model developed for the sample of cashew fruit juice revealed that pH and duration of storage with other interactions were the major parameters that govern the shelf-life and characterization qualities of cashew fruit juice. The coefficient of correlation (R^2) of the dependent variable (ascorbic acid) and independent variables (temperature, total soluble solids, pH, and duration of storage) in the model was 0.954. The regression model revealed that temperature of 34.4 ^{O}C, 11.13 ^{O}Brix value, pH of 3.99, 16 days storage duration of the sample maintained ascorbic acid levels of 239.59 mg/100 ml at maximum shelf life. The sample of the juice had 31 insignificant regression coefficients at a 5 percent probability level after checking the adequacy of the predicted model. Equation 34 expresses the fitted model for predicting the shelf life of a red sample of cashew fruit juice which recorded 17 experiments that did not meet the minimum quality requirement of the ascorbic acid level.

Keywords: *Cashew Juice, Natural, Regression Model, Shelf-Life, Species.*

I. INTRODUCTION

Fruit juices have long been noted as excellent sources of ascorbic acid (vitamin C). Ascorbic acid is the least stable of all fruit juice nutrients. It is one of the vitamins that should be routinely assayed in the course of processing and storage of fruit juices. Its level is usually the criterion for judging fruit juice quality. It is readily oxidized and its concentration is an index to the retention of the original nutritive quality values during storage and distribution [6].

The phytochemical and nutritional assessment showed that juice obtained from cashew apple of domestic origin in Western Nigeria is endowed with phytochemicals and nutritional constituents that could play a role in health maintenance [2].

The utilization of cashew juice should be encouraged as a health drink and could be recommended to people with vitamin C deficiency because of its high vitamin C content. Above all, the preservation of cashew apple juice is important because of the seasonality of its production which makes it abundantly available during its season and scarce during off-season [10]. Table 1 shows the recommended values of ascorbic acid for different fruit juice

Table 1: Recommended Juice Quality

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

Source: [4], [7]

Various methods of cashew apple juice preservation and shelf life evaluation have been reported by many scientists. Hot fill and aseptic methods were efficient in maintaining Physico-chemical characteristics of the juice up to twelve months [1]. To predict the degree of deterioration of the nutrient value of cashew fruit juice, knowledge of the loss of this important quality as a function of deteriorative index factors are needed [8]. Through modeling of these various deteriorative factors, cashew juice manufacturer can specify the value of this juice, if the nutrients claims are to be made on the label or advertising associated with the products.

Modeling provides a logical procedure for predicting process outcomes in circumstances other than those that have been observed. Decision modeling aims to determine the optimal decision, define the trade-offs between different outcomes that are inherent in a range of decisions, or predict the probable decisions that will be taken by farmers in a range of practical circumstances. Such models encapsulate knowledge of how a system is constructed of interacting processes and how each process works. They often combine experimental observations, expert knowledge, and logic [5]. The main objective of this work is to develop a model and use the model to predict the shelf life of a red sample of cashew fruit juice under non-refrigerated storage

II. MATERIALS AND METHOD

Cashew fruit juice was extracted by mechanical screw press from samples of red cashew apple fruits obtained from a local cashew plantation plot at Obimo in Nsukka Local government of Enugu State, Nigeria. The experiments were conducted in BioProcess 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	Red	484.10mg/ 100ml	11.38 ^{0}Brix	4.48

A. Experimental Design Method

A four-variable three-level factorial experiment provides 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 solids, pH, and duration of storage are represented in a standard order as x_1, x_2, x_3, and x_4.

B. Conduct of Experiment

Four variable three-level factorial experiments were conducted in a randomized order in three replicates according to the design plan (matrix table). 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 a high level while all the other factors will be kept at intermediate and low levels. The coded levels of the factors and the results of each sample experiments are given in Table 3

C. Statistical Analysis and Model Development

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

Table 3: Factors and their Coded Levels for Red 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	10.31^{0}Brix	3.91	11days
Interval of Variation	ΔX_i	4.45^{0}C	0.82^{0}Brix	0.60	5days
High level	+	38.60^{0}C	11.13^{0}Brix	4.51	16days
Intermediate	0	34.40^{0}C	10.56^{0}Brix	3.99	11days
Low level	-	29.70^{0}C	9.50^{0}Brix	3.32	6days

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

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

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

The maximum dispersion = $S_{u\max}^2$ 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) 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 = Number of experimental runs , r = Number of replicate, α = Level of significance
The dispersion, taken as mean-squared-error, is given as:

$$S^2_{(y)} = \frac{1}{N}\sum_{u=1}^{N} S^2_u. \qquad 7$$

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

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

The mean effect was estimated by

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

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

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

where x_i was 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

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

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

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

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 is frequently used in assessing their statistical significance [9].
The confidence interval for the regression coefficients with confidence coefficient "α" was of the general form.
b's ± t {α, N(r-1} $S_{b's}$
i.e b's ± 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

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 are the same and were determined by

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

where $S^2_{bi} = \frac{S^2_y}{N}$ 16

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

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

17
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{α, N (r – 1)} 18
if any coefficient is statistically insignificant **(i.e t_{cal} < $_{table}$),** such a coefficient is left out of the regression model [3]. The 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 does not affect the response. Using only the statistically significant regression coefficients, we then define the fitted (or predicted) model as;

$$y = [b_0 \pm ....] \quad 19$$

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 $\bar{Y}_1, \bar{Y}_2,...........\bar{Y}_N$ and the fitted or predicted values $\hat{Y}_1, \hat{Y}_2,...........\hat{Y}_N$ were the residuals which were given by

$$e_u = \bar{Y}_u - \hat{Y}_u; \quad u = 1,2,..........81 \quad 20$$

Thus, the model can be used to generate the predicted values in the range of the observation 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 the results. The residuals are the deviations of the measured values $\bar{y}_u$ from their predicted counterparts Y_u.

The sum of squares for the effects was 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 was computed with equation 21.

$$SS_R = \frac{r}{N}(contrast)^2 \qquad 21$$

and has a single degree of freedom. Consequently, the main effects and the interactions were computed using equations 22 to 25.

$$SS_{bi} = \frac{r}{N}\sum_{u=1}^{N}\left(x_i\,\bar{Y}_u\right)^2 \qquad 22$$

where x_i was the coded signs in the x_i column of the design matrix.

For the two-factor interactions

$$SS_{bij} = \frac{r}{N}\sum_{u=1}^{N}\left(x_{ij}\,\bar{Y}_u\right)^2 ; i = \qquad 23$$

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

For the three-factor interactions

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

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

For the four-factor interactions

$$SS_{bijkl} = \frac{r}{N}\sum_{u=1}^{N}\left(x_{ijkl}\,\bar{Y}_u\right)^2 ; i \;\; j \;\; k \;\; l \qquad 25$$

where x_{ijkl} 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

$$SS_T = \sum_{u=1}^{N.r} Y^2 uv - \sum_{u=1}^{N.r}(Yuv)^2 / N.r \qquad 26$$

The error sum of squares was given as;

$$SS_E = SS_T = -\sum SS_R \qquad 27$$

$$i.e\; SS_E = SS_T - SS_{bj.} + \ldots + SS_{bij} + \ldots\ldots + SS_{bijklm}$$ **[3]**

28

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

$$F_{cal} = \frac{MS_R}{MS_E} = \frac{SS_R / df_R}{SS_E / N(r-1)} \qquad 29$$

Where df_R = the degree of freedom regression

The null hypothesis will be rejected if

$$F_{cal} > F\{\alpha, df_R, N(r-1)\} \qquad 30$$

With the conclusion that the coefficient contributes significantly to the regression [3]. 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

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

31

where λ = number of inadequate coefficients.

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

$$F_{cal} = \frac{S_{(ad)}}{S^2_{(y)}} \qquad 32$$

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 is

$$F_{cal} \le F\{\alpha, N-\lambda, N(r-1)\} \qquad 33$$

The condition was satisfied, then we concluded that the fitted (or predicted) regression model was adequate.

III. 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 cashew fruits juice samples are presented in Table 4, The mean, dispersion, some of the dispersion and maximum dispersions were determined from the data generated on the samples. The dependent variable "y"'s were the values of an ascorbic acid level obtained at the random mixture of the samples.

Table 4: 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	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

The summary of mean experimental observations, fitted values, residuals, and squares of residuals for both samples of cashew fruit juice were presented in table 5.

Table 5: The Mean Experimental Observations, Fitted Values, Residuals, and Squares of Residuals for Red Cashew fruit Juice.

Run No	$\bar{y}_u$	$\hat{y}_{u1}$	$\ell_u = \left(\bar{y}_u - \hat{y}_u\right)$	$\ell_u^2 = \left(\bar{y}_u - \hat{y}_u\right)^2$
1	141.90	171.64	-29.74	884.47
2	158.36	157.63	0.73	0.53
3	163.70	166.12	-2.42	5.86
4	127.15	130.65	-3.50	12.25
5	138.62	138.78	-0.16	0.03
6	153.00	149.41	3.59	12.89
7	174.80	174.22	0.58	0.34
8	147.81	146.80	1.01	1.02
9	177.55	178.56	-1.01	1.02
10	190.09	191.17	-1.08	1.17
11	238.67	239.59	-0.92	0.85
12	185.85	184.43	1.42	2.02
13	259.89	258.07	1.82	3.31

14	153.70	154.64	-0.94	0.88
15	180.25	179.09	1.17	1.37
16	189.10	188.52	0.58	0.34
17	178.45	178.12	0.33	0.11
18	91.75	88.86	2.89	8.35
19	236.30	235.39	0.91	0.83
20	177.30	176.05	1.25	1.56
21	188.88	186.12	2.76	7.62
22	183.20	183.64	-0.44	0.19
23	90.58	91.26	-0.68	0.46
24	79.95	77.13	2.82	7.95
25	157.80	156.83	0.97	0.94
26	147.85	149.61	-1.76	3.10
27	120.38	119.90	0.48	0.23
28	85.87	84.00	1.87	3.50
29	130.10	132.56	-2.46	6.06
30	90.25	92.51	-2.26	5.11
31	94.70	93.61	1.09	1.19
32	97.65	95.36	2.29	5.24
33	138.95	140.79	-1.84	3.39
34	186.00	185.24	0.76	0.58
35	112.58	111.06	1.52	2.31
36	165.33	163.04	2.29	5.24
37	160.78	160.48	0.30	0.09
38	84.68	83.12	1.56	2.43
39	88.73	88.82	-0.09	0.008
40	158.35	157.48	0.87	0.76
41	100.60	99.02	1.58	2.50
42	73.20	74.23	-1.03	1.06
43	158.35	159.80	-1.45	2.10
44	221.07	220.13	0.94	0.88
45	78.15	78.82	-0.67	0.45
46	136.00	135.98	0.02	0.0004
47	177.15	176.09	1.06	1.13
48	209.75	212.68	-2.93	8.58
49	230.40	229.39	1.01	1.02
50	112.58	114.58	-2.00	4.00
51	221.07	224.01	-2.94	8.64
52	251.05	256.14	-5.09	25.91
53	221.05	224.78	-3.73	13.91
54	165.50	165.70	-0.20	0.04
55	200.75	199.72	1.03	1.06
56	220.97	223.22	-2.25	5.06
57	251.05	254.82	-3.77	14.21
58	301.20	303.97	-2.77	7.67
59	215.07	223.71	-8.64	74.65
60	188.88	189.61	-0.73	0.53
61	126.27	125.01	1.26	1.59
62	151.93	153.05	-1.12	1.25
63	165.50	166.94	-1.44	2.07
64	188.88	190.81	-1.93	3.72
65	287.13	286.66	0.47	0.22
66	291.47	290.81	0.66	0.44

67	152.35	151.44	0.91	0.83
68	132.17	131.18	0.99	0.98
69	85.85	85.22	0.63	0.40
70	155.30	154.37	0.93	0.86
71	147.80	145.90	1.90	3.61
72	162.53	161.41	1.12	1.25
73	183.20	182.50	0.70	0.49
74	248.10	247.66	0.44	0.19
75	188.88	188.26	0.62	0.38
76	285.42	283.61	1.81	3.28
77	197.95	198.48	-0.53	0.28
78	335.97	329.33	6.64	44.09
79	264.77	264.12	0.65	0.42
80	298.25	301.19	-2.94	8.64
81	281.58	280.84	0.74	0.55
		TOTAL	**=**	**1244.54**

The fitted or predicted model for red (equation 34) sample becomes.

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

A. Discussion

It was seen from equation 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 a significant influence on the level of the ascorbic acid on the red cashew fruit juice sample. This implies that high levels of each of these factors with their interactions led to the drastic reduction in the ascorbic acid level of the juice. 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} = 329.33 mg/100 ml, maintained the ascorbic acid level of the juice at the highest level. 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 (Table 1). The optimum condition was an experiment that falls within 200 – 240 mg/100 ml of an ascorbic acid level. The experiments that fall within specifications 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). A model developed (equation 34) showed that 31 insignificant regression coefficients of red samples were recorded at 5 percent after checking the adequacy of the predicted model. The positive signs against the coefficients of the interactions in equation 34 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 interactions showed that the levels of ascorbic acids were reduced from low to intermediate and to high levels.

IV. CONCLUSIONS

The results of the experiment and the developed model of Red sampled cashew fruit juice showed that pH and duration of storage with other interactions were the major parameters that govern the shelf life and also important factors for characterizing the quality of the sample of the juice. These quality variables enabled the prediction of the shelf-life of the juice under non-refrigerated storage and distribution conditions. The coefficient of correlation (R^2) of the dependent variable (ascorbic acid) and independent variables (temperature, total soluble solids, pH, and duration of storage) in the model was 0.954. 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 a maximum of 16 days storage duration maintained the highest optimum level of ascorbic acid at 239.59 mg/100 ml. The optimum condition of the ascorbic acid in the experiment was used to determine the shelf-life of the red sample of cashew fruit juice. The sample of cashew juice recorded seventeen experiments that did not meet the minimum quality requirement of ascorbic acid level and also nine experiments that fall within the optimum level of ascorbic acid. Equation 34 expresses the fitted model for predicting the shelf life of a red sample of cashew fruit juice. The statistical analysis of the experimental data shows that sample of cashew fruit juice model was adequate for shelf-life prediction but a more elaborate factorial design, such as increasing the main effect to five or more by adding other deteriorative parameters to find out changes in ascorbic acid level and shelf-life of the juice, should be extended as further studies.

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