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Development of a Predictive Model for Preparation of Banana Modified Drink

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Abstract. Fresh ripe banana drink was modified to produce non-carbonated, non-alcoholic food drink comparable to selected (four) commercial fruits juices mimic. The effects of a hydrocolloid (0.01-0.1 g), tart enhancer (0.005-1.000 g) and onion extract (0.02-0.2 mL) were concurrently studied using the central composite rotatable design on some product characteristics namely, titratable acidity, pH, relative viscosity and total soluble solids as responses. Preparations were compared with food commercial drink substitutes with respect to evaluated characteristics. Equations for predicting the responses were developed and their adequacy confirmed using analysis of variance and residual assessment. The empirical model could be useful as a base data for preparation and manipulation capable of yielding a peculiar banana base drink brand. This process provides an additional means for utilization of ripe banana fruits thereby lending enhanced economic value to producers consequently contributing to reduction in post harvest losses of banana fruits.

Keywords: banana drink, food grade additives, model for juice preparation

Introduction

The physiological benefits of both nutrients and phytochemicals of banana fruit are profoundly expressed in the literature (Englberger *et al*., 2003; Sharma and Caralli, 2002; Hills and Kirwood, 1989). In Nigeria, banana fruits are abundantly available and could be found all the year round. However, the comparative short post-harvest shelf life of banana coupled with lack of sufficient quality transportation system as well as storage facilities lead to spoilage of large proportion of this highly nutritious fruit before its reaching the consumers (Yomeni *et al*., 2004).

Although, products such as clarified juice, banana powder, jam, candy and fermented products like ethanol brandy, could be obtained from ripe banana fruit (Palmu *et al.*, 1999), they are scarcely produced at commercial scale, probably due to the low technological acquisition. Among the named products, banana juice shall be focused here for modification. The investigation appears economically worthwhile for the following reasons:

- World demand for fruit juices is increasing most probably due to their health benefits and highly appreciated flavour and aroma (Palmu *et al.*, 1999).
- Banana fruit has economic advantage in terms of availability and price, compared to other fruits available in developing countries e.g., Nigeria.
- The product (juice) yield is high comparative to the yield of other fruits like pawpaw (with too much water content) or orange (with too much food fibre).
- Such preparation can be used to boost import substitution of non-carbonated, non-alcoholic fruit juice mimic brands.

An indigenous challenge associated with production of banana juice, as with many other fruits and vegetables, is its susceptibility to discolouration caused by enzymatic browning (Arslan and Dogan, 2005). Other constraints are flat taste and variable viscosity (depending on the brand of drink to be prepared). Attempt to eliminate the limitations had singly been accomplished using various methods.

Therefore, the objective of this investigation is to study concurrently the effect of application of three food grade additives that can circumvent the shortcomings by developing a predictive model using three additives as process variables for modification of banana juice with a view to preparing a non-carbonated, non-alcoholic drink comparable to the commercial fruit drinks mimic.

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Materials and Methods

Material: Ripe fresh banana (*Musa* spp.) was obtained from commercial fruit pack shed in Ado-Ekiti, Nigeria. The banana fruits were ripe enough to be blended using domestic blending machine. Food plant gum (Khaya gum) and onion (*Allium cepa*) white variety were obtained from a local processor and seller, respectively. Food grade citric acid was sourced from departmental laboratory stock. Four commercial fruit juice mimic brands were used as reference.

Preparation of banana modified drink. Fresh ripe banana (*Musa* spp.) fruit was washed, peeled and blended with onion (*Allium cepa*) extract. This was followed by extraction and filtration to obtain juice. The juice was then treated with citric acid and plant food gum to obtain banana modified drink. The schematic diagram for the modification process is shown in Fig. 1. Details of combination of additives in the experimental design are presented in Table 1.

Extraction and purification of plant food gum. The Khaya gum was hydrated in double strength chloroform water for 5 days with intermittent stirring and extraneous materials were removed by straining through a cheese cloth. The gum was precipitated from the solution using absolute ethanol. The precipitated gum was filtered, washed with diethyl ether and then dried in hot air oven at 40 °C (Tyler *et al.,* 1981).

Preparation of onion extract. Onion (500 g) was homogenized with 500 mL of distilled water for 5 min. The homogenate was centrifuged at 12,000 rpm for 20 min at 4 °C. The supernatant was used as onion extract.

Experimental design. A central composite rotatable design for K = 3 was used (Cochran and Cox, 1957). The design generated 20 sample combinations comprising of eight points peculiar to 2^3 factorial six star points and six central points for replication. The effect of independent variables, amount of citric acid, gum and onion extract on preparation quality indices/

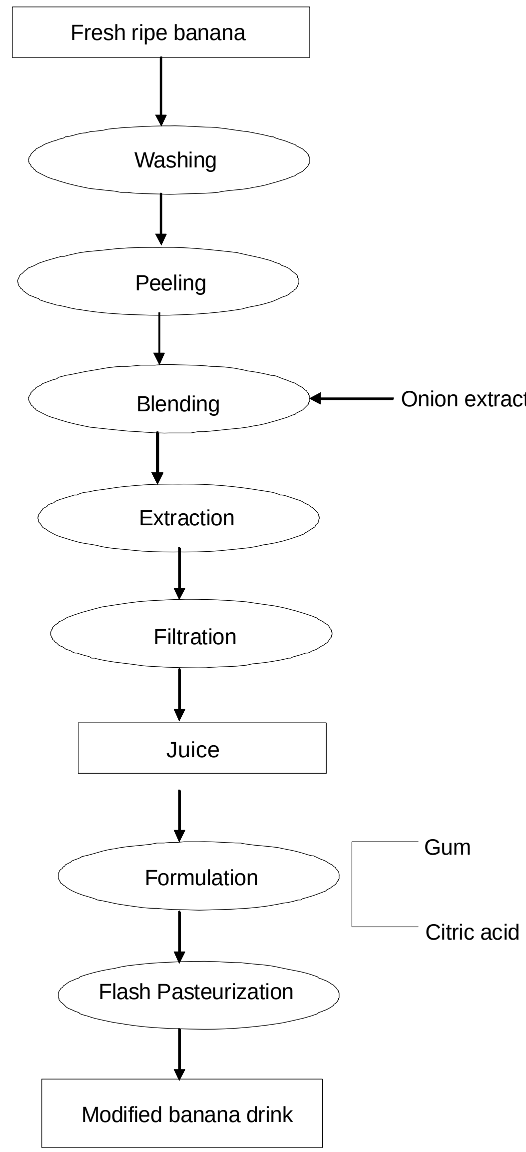

Fig. 1. Flow sheet for processing of banana modified drink.

markers, namely, titratable acidity, appearance, apparent viscosity and total soluble solids were evaluated. Step-wise regression analyses were performed on the data to yield equations for predicting selected physi-

Table 1. Process variables used in the central composite rotatable design (K = 3)

Independent variable*	Code	Levels				
		-1.682	-1	0	1	1.682
Onion extract (mL)	X_1	0.02	0.06	0.1	0.14	0.2
Citric acid (g)	X_2	0.005	0.025	0.125	0.5	1
Plant food gum (g)	X_3	0.01	0.03	0.05	0.07	0.1

* = 50 mL of banana juice was used for each treatment.

cochemical indices of the product that have quality consequences.

Analytical Methods. Total soluble solid determination. Refractive index of sample was measured using Abbe refractometer (ABBE 325 Zuzi). Corresponding soluble solid was determined using appropriate procedure and reference to appropriate designated table.

Determination of pH. This was accomplished by dispensing 50 mL of the sample into 100 mL beaker and reading the value directly on a pH meter (Omega H. HPx digital pH meter) which was previously standardized with buffer 4 and 9 solutions. Value was recorded when equilibrium pH was attained.

Titratable acidity determination. Titratable acidity was determined by titrating 100 mL of the sample against 0.1 M NaOH using phenophthalein as indicator of end point and the results were expressed in g citric acid equivalent /100 mL of the sample.

Measurement of apparent viscosity. Each sample was placed in a Baroid division rheometer cup and the instrument head was lowered until the sleeve was immersed exactly to the scribed line. The lock screw on the left leg of the instrument was tightened. The gear shift was then set to 600 rpm before rotation of the crank for 15 sec. The dial reading was allowed to come to a steady value before the value was measured. The gear shift was then set to 300 rpm and the reading was taken like wise. The apparent viscosity in centipoise is given as 600 rpm reading-300 rpm reading (Osunsami, 1987).

Assessment of discolouration. Discolouration of treated and untreated samples was determined subjectively following the procedure of Demooy and Demooy (1990).

Statistical analysis. The central composite orthogonal design was analysed as repored by Cochran and Cox (1957). Each of the X-matrix was multiplied by the Y-column (response) to obtain corresponding sum of products that is 0 y to 13 y for X_o to X_1 X_3. Consequently, the coefficients b_o to b_{13} were calculated as:

$$b_o = 0.166338\,(0y) - 0.056791\,\Sigma(iiy) \quad (1)$$

$$b_i = 0.073224\,(iy) \quad (2)$$

$$b_{ii} = 0.062500\,(iiy) + 0.006889\,\Sigma(iiy) - 0.056791\,(0y) \quad (3)$$

$$bij = 0.125000\,(ijy) \quad (4)$$

The quadratic model was fitted using the regression coefficients and the predicted response was calculated for each of the observed values. The model was assessed for adequacy by subjecting to analysis of variance and residual analysis.

Results and Discussion

Four technological parameters namely, titratable acid, pH, total soluble solids and apparent viscosity were assessed in the modified drink. Also, the parameters were examined (Table 2) on unmodified drink (when necessary) as well as the four commercial fruit drink mimic brands for the purpose of reference and analytical discussion.

The central composite orthogonal design to fit the polynomial model for the modification was accomplished as elicited by Cochran and Cox (1957). The computed sums of products and regression coefficients to fit the model are shown in Table 3.

Titratable acidity (TA). A cursory look at Table 2 revealed that TA (0.1485 g citric acid equivalent/100 mL) of banana unmodified juice is less than TA (0.482-1.018 g citric acid equivalent/100 mL) of any of the commercial fruit juice mimic brands. The result obtained in this study did not compare with the acidity reported earlier by Palmu *et al* (1999), because the acid equivalent used was not stated. But the fact that the determined pH is the same suggests that the acidity could be similar if

Table 2. Physicochemical parameters of the unmodified juice and commercial drinks

Parameter	Control	Berry blast	Chivita	5-alive	Dansa
TA (citric acid equivalent/100 mL)	0.1485	0.482	0.749	1.018	0.4922
pH	4.65	3.36	3.00	2.90	3.21
App visc (Cp)	1.400	1.022	1.022	1.043	1.059
TSS (^{0}Brix)	5.00	15.30	13.40	14.70	13.40

TA = titratable acidity; TSS = total soluble solids; App visc = apparent viscosity.

Table 3. Regression coefficients for the quadratic model equation for the banana modified drink

Sum of products	Parameter TA	pH	TSS	App visc	Regression coefficient	Parameter TA	pH	TSS	App visc
Oy	21.0894	68.4200	135.5000	27.3350	b_o	0.8254	3.5112	6.1549	1.3615
Y	0.545	- 2.1092	2.5387	-0.5022	b_1	0.0399	- 0.1544	0.1859	- 0.0368
2y	10.0092	- 10.8050	11.7801	- 0.1362	b_2	0.7329	- 0.7912	0.8626	- 0.0010
3y	0.0332	- 0.8569	0.7341	- 0.4761	b_3	0.0024	- 0.0627	0.0538	- 0.0349
11y	14.7245	45.1063	96.1646	18.9215	b_{11}	0.0480	- 0.1119	0.3025	0.0166
22y	18.0699	48.2183	97.0134	18.8592	b_{22}	0.2571	0.0826	0.3556	0.0127
33y	14.4416	45.2477	95.3159	18.3076	b_{33}	0.0303	- 0.1030	0.2495	- 0.0218
12y	- 0.0397	0.3000	0.75	- 0.0480	b_{12}	- 0.0050	0.0370	0.0938	- 0.0060
13y	- 0.1031	0.0000	1.35	- 0.0220	b_{13}	- 0.0129	0.0000	0.1688	- 0.0028
23y	- 0.3091	0.5000	- 2.15	- 0.010	b_{23}	- 0.0386	0.0625	- 0.2688	- 0.0013
Σ(ii) y	47.2360	138.5723	288.4939	56.0883		R^2 = 0.998	0.9858	0.9618	0.9122

TA = titratable acidity; TSS = total soluble solids; App visc = apparent viscosity.

same unit is used. Taking cognizance of the fact that one of the major necessary modifications is suppression of flat taste inherent to banana ordinary juice in order to impart tartness characteristic of all the selected commercial fruit juice mimic brands, the quadratic model takes the form,

$$\hat{A}_{tt} = 0.8254 + 0.0399X_1 + 0.7329\,X_2 + 0.00024\,X_3 + 0.048X_1^2 + 0.2571X_2^2 + 0.0303\,X_3^2 - 0.0050X_1\,X_2 - 0.0129X_1\,X_3 - 0.0386\,X_2\,X_3 \text{ \_\_\_\_\_\_\_\_ } (5)$$

The predicted total titratable acidity, $\hat{A}_{tt}$, for each of the experimental run and their respective residual are shown in Table 4. Examination of the residuals suggests that the fitted model was reasonably adequate. The claim was confirmed on model testing. In addition, the analysis of variance to test the fitness of the model is shown in Table 5. The first and the second order terms were significant as shown by the higher calculated F-ratio compared with the tabulated values. However, since the calculated F- ratio for the lack of fit was lower than the tabulated value, adequacy of the fitted model is affirmed. The coefficient of multiple determinations (R^2) also showed the fitness of the residuals. Since there are differences in TA of various commercial fruit juice mimic brands used in this study, the model can be used to simulate a particular brand with respect to TA with consequent sensorial tartness.

pH. The pH value of the banana unmodified juice was 4.65, similar to the earlier report by Palmu *et al.* (1999). pH values of the commercial juice brands ranged between 2.71 to 3.36 which revealed that all of them were acidic comparative to the banana unmodified juice.

The pH quadratic model takes the form:

$$\hat{}pH = 3.5112 - 0.1544\,X_1 - 0.7912\,X_2 - 0.0627\,X_3 - 0.1119\,X_1^2 + 0.0826\,X_2^2 - 0.103\,X_3^2 + 0.037X_1\,X_2 + 0X_1X_3 + 0.0625\,X_2\,X_3 \text{ \_\_\_\_\_\_\_\_ } (6)$$

The predicted pH (ˆpH) for each of the experimental run and their residuals are presented in Table 4. The residuals suggest that the fitted model is adequate. The view on adequacy of model fitness was verified by conducting analysis of variance test. As the first and the second order terms were significant (Table 5) due to the higher calculated F-ratio in comparison with the tabulated values, and the calculated F-ratio for lack of fit was lower than the tabulated value, attesting adequacy of the model. The pH model may even be advantageous to predict acidity because it is a rapid objective test in comparison to titratable acidity measurements.

Apparent viscosity. The apparent viscosity (Cp) of the banana unmodified juice as determined in this study shows higher value (1.400) compared to the low values (1.022-1.059) of the tested commercial fruit mimic brands. This is not surprising since the constituents (flavourant, colourant and sweetener) of the reference drinks are monomers (citric acid, tetrazine yellow, glucose for each of the constituents, respectively) of high solubility index.

The apparent viscosity quadratic model ($_A\hat{}v_C$) for the modified drink takes the form:

$$_A\hat{}v_C = 1.3615 - 0.0368X_1 - 0.010X_2 - 0.035X_3 + 0.0166\,X_1^2 + 0.0127\,X_2^2 - 0.0218\,X_3^2 - 0.006X_1X_2 - 0.0028\,X_1X_3 - 0.0013\,X_2\,X_3 \text{ \_\_\_\_\_\_\_\_ } (7)$$

Fitteness of the model (Table 4) was assessed and found adequate. Comparative study of the viscosity of each

Table 4. Residual analysis of assessed parameters

Run	TA			pH			TSS			App visc		
	Observed	Predicted	Residuals	Observed	Predicted	Residuals	Observed	Predicted	Residuals	Observed	Predicted	Residual
1	0.2571	0.3291	-0.072	4.45	4.4867	- 0.0367	5.65	5.9541	-0.3041	1.413	1.4407	-0.0277
2	0.5000	0.447	0.0553	4.10	4.1039	-0.0039	5.95	5.8007	0.1493	1.375	1.3847	-0.0277
3	1.9000	1.8821	0.0179	2.60	2.7053	-0.1053	8.00	8.0293	-0.0293	1.445	1.4353	0.0097
4	1.9600	1.9777	-0.0177	2.40	2.4705	-0.0705	8.00	8.2511	-0.2511	1.343	1.3553	-0.0123
5	0.4200	0.4369	-0.0169	4.30	4.2363	0.0637	6.35	6.2617	0.0883	1.374	1.3789	-0.0049
6	0.4483	0.5009	-0.0526	3.95	3.8535	0.0965	6.65	6.7835	-0.1335	1.285	1.3117	-0.0267
7	1.7483	1.8355	-0.0872	2.70	2.7049	-0.0049	6.95	7.2617	-0.3117	1.361	1.3683	-0.0073
8	1.9138	1.8795	0.0343	2.50	2.4701	0.0299	8.30	8.1587	0.1413	1.288	1.2771	0.0109
9	0.9713	0.8941	0.0772	3.50	3.4543	0.0457	6.95	6.981	0.2519	1.480	1.4704	0.0096
10	1.0000	1.0283	-0.0283	2.90	2.9349	-0.0349	7.30	7.3235	-0.0235	1.361	1.3466	0.0144
11	0.3550	0.3201	0.0349	5.00	5.0757	-0.0757	5.75	5.7101	0.0399	1.447	1.4142	0.0328
12	2.8000	2.7855	0.0145	2.50	2.4141	0.0859	8.80	8.6119	0.1881	1.372	1.3806	-0.0086
13	0.9000	0.9071	-0.0071	3.45	3.3253	0.1247	6.95	6.7704	0.1796	1.374	1.3588	0.0152
14	0.9713	0.9151	0.0562	3.00	3,1143	-0.1143	7.00	6.9514	0.0486	1.250	1.241	0.0090
15	0.8741	0.8254	0.0487	3.50	3.5112	-0.2112	6.00	6.1550	-0.155	1.360	1.3615	-0.0015
16	0.8322	0.8254	0.0068	3.55	3.5112	0.0388	6.30	6.1550	0.145	1.370	1.3615	-0.0085
17	0.7601	0.8254	-0.0653	3.55	3.5112	0.0388	6.30	6.1550	0.145	1.340	1.3615	-0.0215
18	0.8322	0.8254	0.0068	3.57	3.5112	0.0588	6.00	6.1550	-0.155	1.350	1.3615	-0.0115
19	0.8322	0.8254	0.0068	3.60	3.5112	0.0888	6.30	6.1550	0.145	1.377	1.3615	0.0155
20	0.8135	0.8254	-0.0119	3.50	3.5112	-0.0112	6.00	6.1550	-0.155	1.370	1.3615	0.0085

TA = titratable acidity (g citric acid equivalent /100 mL), TSS = total soluble solids (^{0}Brix), App visc = apparent viscosity (Cp); residual = observed value – predicted value.

Table 5. Analysis of variance (ANOVA) for the Predictive model equations

*Dependent	Statistical term variable	DF	SS	MS	F-ratio calculated	Tabulated	
						5%	1%
TA	First order	3	7.3577	2.4526	1751.86	5.41	12.06
	Second order	6	0.9725	0.1621	115.79	4.95	10.67
	Lack of fit	5	0.0330	0.0066	4.71	5.05	10.97
	Error	5	0.0069	0.0014			
	Total	19	8.3701				
pH	First order	3	8.9283	2.9761	252.21	5.41	12.06
	Second order	6	0.4857	0.0810	6.86	4.95	10.67
	Lack of fit	5	0.0333	0.0067	0.57	5.05	10.97
	Error	5	0.0591	0.0118			
	Total	19	9.5064				
TSS	First order	3	10.6727	3.5576	131.76	5.41	12.06
	Second order	6	4.2301	0.7050	26.11	4.95	10.67
	Lack of fit	5	0.4797	0.0959	3.55	5.05	10.97
	Error	5	0.1350	0.027			
	Total	19	15.5175				
App visc	First order	3	0.0365	0.0122	61.00	5.41	12.06
	Second order	6	0.0131	0.0022	11.00	4.95	10.67
	Lack of fit	5	0.0054	0.0011	5.5	5.05	10.97
	Error	5	0.0010	0.0002			
	Total	19	0.0560				

* = see interpretation in Table 4; DF = degree of freedom; SS = sum of square; MS = mean square.

run resulted in no acute increase in viscosity. This observation is presumably due to the span of quantity of plant food gum used or/and solvation effect of tart enhancer (food grade acid) added to each run. However, preparations are characterized by higher apparent viscosity relative to that of the commercial fruit juice mimic brands used in this study.

Total soluble solids. The total soluble solids (°Brix) of the banana unmodified juice was less (5.00) compared to high (13.40–15.30) total soluble solids of the commercial fruit juice mimic brands used in this study. Much difference in the values is believed to be due to the method adopted in preparation of the banana juice (unmodified) in this study. For example, no enzyme or heat was used to facilitate dissolution of pulp. Besides, the TSS, figure could have been inflated by the synthetic colourant used in the commercial fruit juice mimic brands. However, modification resulted in increase in TSS and the quadratic model takes the form:

$$\hat{TSS} = 6.1549 + 0.1859X_1 + 0.8626X_2 + 0.0538X_3 + 0.3025X_1^2 + 0.3556\,X_2^2 + 0.2495\,X_3^2 + 0.0938X_1X_2 + 0.1688X_1X_3 - 0.2688X_2X_3 \quad (8)$$

One of the benefits of the model is that it can give insight to response if one or combinations of the independent variables are manipulated. Therefore, inspection should inform on direction to manipulate to affect the desired changes. Also, the fact that the assessed physicochemical parameters of the commercial fruit juice mimic brands vary suggests that it may not be mandatory to determine optimum values by canonical means (RSM) and consequently, were not attempted in this study.

Visual assessment showed that the banana unmodified juice was discoloured (brown) due to enzymatic browning but all the samples treated with onion extract were not characterized with discolouration. The mode of anti-browning action of extract of onion is believed to be complexing of the bioactive components of onion with polyphenolases, thereby, making the phenolases not available for oxidation of phenolic compounds to quinone and other substrates that are responsible for brown pigments.

Conclusion

Modification of banana drink using three classes of additives concurrently yielded food preparations comparable to non- carbonated, non-alcoholic commercial fruit drink mimics. The model developed was found adequate to provide a means of predicting tested preparation (drink) characteristics. The model can be useful for product development with respect to diversification of banana fruit utility with the view to enhancing agro-economic rewards.

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