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Determination of the Effect of Changing Ingredient Type and Concentration on Functional Properties of Banana-Vegetable Soup Powder

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ABSTRACT

Bananas continue to experience high post-harvest losses of up to 45% due to limited value addition. The limiting factor being lack of key nutrients in the fruit hence the need to supplement banana with different ingredients. The purpose of this study was to evaluate the effect of changing ingredient type and concentration on functional properties and analyze the potential of developing an acceptable soup for children between 6 to 59 months using banana flour. Using Nutri-survey, grain amaranth, pumpkins, tomatoes, mushrooms and carrots were the selected ingredients. Design Expert was used to perform Response surface methodology (RSM) using a mixture design to establish the optimal ingredient concentrations. The optimal formulation constituted banana, grain amaranth, pumpkins, carrots and mushrooms at 41%, 41%, 9%, 5% and 4% respectively. Tomatoes were eliminated for its insignificant effect (p<0.05) to functional properties of the soup flour. The product had an energy composition of 409.39 kCal/100 g, peak viscosity of 2631.41 Cp while the holding viscosity, breakdown viscosity, final viscosity, peak time, carbohydrates, proteins and zinc contents were 1430.11 Cp, 1209.57 Cp, 2495.29 Cp, 4.9 minutes, 65.38%, 14.86% and 13.50 g/100 g respectively. Mathematical models predicting variation of gross energy, protein content, fiber content and ash content were significant at p<0.05. The results suggest that a nutritious soup can be obtained from banana flour.

Keywords: Banana, mixture design, optimization, response surface methodology.

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I. Introduction

Globally 115.74 million tons of bananas are produced from 5.73 million hectares [1]. About 5.32×10^5 tons of these are produced in Uganda [2] [3]. In Uganda, production is done by 70% of farmers from western and central parts of the country [4]. Banana business contributes 42% to rural household income [5] and bananas serve as a staple food for 70% of Ugandans [4]. Banana is preferred for consumption due to its high energy content (399.63 kCal/100 g) [6] and additional health benefits [7]. They have high fiber content (10.52%) [8] making the fruit capable of lowering cholesterol to aid in the prevention of colon cancer [7]. Its high potassium content (982.28 mg/100 g) [7] is important in the prevention of raising blood pressure and muscle cramp. Despite the benefits, [9], reports that the banana value chain in Uganda continues to face challenges among which are delays in transportation due to poor road networks, transport means, storage systems and post-harvest handling technologies as well as fluctuating prices and market demands resulting into high post-harvest losses of between 22–45%. Development of value added products from bananas could potentially result into utilization of the fruit [10]. To achieve this, several food technologies have incorporated bananas into various staple food products among which are cookies [11], Pasta [12] and mayonnaises [13]. All these products are reported to have high nutrient compositions [7]. Bananas can be utilized into the development of soups for children between 6-59 months. However, banana flour is deficient in key micronutrients such iron (0.12 mg/100 g) [6] and zinc (0.74 mg/100 g) [7] and thus are not able to meet the nutrient demands of the target age group. To have a nutrient dense soup, bananas can be supplemented with highly nutritious grains and vegetables. In this study, a highly nutritious soup was developed from bananas supplemented by grain amaranths, pumpkins, tomatoes, mushrooms and carrots. Grain amaranths were selected for good protein (13.56%), Iron (7.61 mg/100 g), Vitamin C (4.2 mg/100 g) and Zinc (2.87 mg/100 g) [14]. Pumpkins, tomatoes, mushrooms, and carrots were preferred for Iron (4.5 mg/100 g) [15], Vitamin C (116.7 mg/100 g) [14], energy (328 kCal/100 g) [14] and Vitamin A (3423 µg RAE) [14] respectively.

II. Methods and Materials

A. *Raw Material Selection*

The plantain (Musa spp.) used in this study were the green type locally known as Nandigobe from the triploid acuminate genome group (AAA-EAHB). The banana species were chosen due to their superior nutritional properties compared to other banana species [5], [16]. To improve the protein content of banana flour, grain amaranth obtained from peak value industries Mukono, Uganda was used. The vegetables were chosen basing on their unique nutrient contributions: carrots for beta carotene [17], pumpkins for zinc [18] and mushrooms and tomatoes for useful micronutrients [19] for children between 6 to 59 months using Nutrisurvey software.

B. *Experimental Design*

The proportions of vegetables, banana, and amaranth powder used in this study were determined basing on the nutritional requirements of children aged 6-59 months. The ingredients were entered into the Nutri-Survey for windows (SEMEO-TROPMED RCCN, University of Indonesia) and adjustments in the proportions of the ingredients made to meet the target percentages of proteins (16 g), energy (1060 kCal). The resultant ratios were further used in Design expert (Stat Ease, Version 11.1.0.1 Minneapolis, USA) to obtain replications from which optimal product can be obtained. Thirteen formulations were generated in a mixture design, Table I. Each proportion had a banana to grain amaranths ratio of 1:1. The variations in pumpkins, tomatoes, mushrooms and carrots were simultaneously varied at 10%, 15%, and 20% in any of the formulations. The predicted output of nutrient compositions from Nutri-survey were presented in Table II.

TABLE I: PROPORTIONS OF BANANAS AND SELECTED VEGETABLES OBTAINED USING DESIGN EXPERT

Formulation code	Amounts of ingredients g per 100 g of flour					
	Banana	Grain Amaranths	Pumpkins	Tomatoes	Mushrooms	Carrots
S0 (Control)	50	50	0	0	0	0
S1	42.5	42.5	15	0	0	0
S2	42.5	42.5	0	15	0	0
S3	42.5	42.5	0	0	15	0
S4	42.5	42.5	0	0	0	15
S5	40	40	20	0	0	0
S6	40	40	0	20	0	0
S7	40	40	0	0	20	0
S8	40	40	0	0	0	20
S9	45	45	10	0	0	0
S10	45	45	0	10	0	0
S11	45	45	0	0	10	0
S12	45	45	0	0	0	10

TABLE II: NUTRITIONAL PROPERTIES BASED ON 100 G SERVING OF THE SAMPLE FORMULATIONS OBTAINED USING NUTRI-SURVEY

Formulation	Energy (kCal/100g)	Protein (%)	Fat (%)	Carb (%)	Vit A (µg)	Vit C (mg)	Potassium (mg/100g)	Iron (mg/100g)	Zinc (mg/100g)
S0	189.7	8.5	3.8	65.3	53.5	16.8	600.5	0.8	0.3
S1	245.2	10.9	10.1	57.6	51.2	14.3	632.5	2.6	1.3
S2	164.1	7.4	3.3	55.9	59.6	16.5	544.3	0.8	0.3
S3	163.5	7.7	3.3	55.6	45.8	14.8	556.2	0.9	0.4
S4	165.1	7.4	3.2	56.2	281.6	15.3	553.9	1.0	0.4
S5	263.8	11.7	12.1	55.1	50.4	13.5	643.2	3.2	1.7
S6	155.6	7.0	3.1	52.8	61.6	16.5	525.6	0.8	0.3
S7	154.7	7.4	3.1	52.3	43.2	14.2	541.4	0.9	0.4
S8	156.9	7.0	3.1	53.2	357.6	14.8	538.4	1.1	0.4
S9	226.7	10.1	8.0	60.2	52.0	15.1	621.9	2.0	1.0
S10	172.6	7.8	3.4	59.1	57.6	16.6	563.0	0.8	0.3
S11	172.2	8.0	3.4	58.8	48.4	15.5	571.0	0.9	0.4
S12	173.3	7.9	3.4	59.2	205.6	15.8	569.5	1.0	0.4

C. *Sample Preparation*

(a) (b) (c) (d)

Fig. 1. (a) Peeling and slicing of bananas before drying; (b) Drying of the bananas in the saver tray drier; (c) Milling of bananas, and (d) Cooking the soup for testing.

Green bananas were prepared according to a method described by [20] with slight modifications. The samples were peeled under cold water treated with 1 percent sodium metasulphite to avoid browning and sliced to about 2 mm thickness. The slices were laid out on metallic trays for drying at 65 ºC for 6 h (Harvest saver drier, Model: R-5A, eugene, USA) in air oven driers at Jakana foods ltd (JFL), Kawempe, Kampala Uganda. Fresh Mushroom (*Agaricus bisporus*) (with intact pileus and stripe) were purchased from Capital shopper's supermarket (Garden city, Kampala, Uganda) and prepared according to a method described by [21] with slight modifications. These were dried for 4 h at 60 ºC using the air oven driers at JFL. Carrots were purchased from Kalerwe market in Kampala. They were chopped, sliced and laid on steel trays to dry for 12 hours at 50 ºC in air oven driers [22] at JFL. Pumpkins, and tomatoes were purchased from Kalerwe market, Kampala transported in nylon bags to JFL. They were chopped, sliced, and laid on steel trays to dry for 6 h at 60 ºC using same driers at JFL. The dried samples were milled using a wonder mill (Pocatello, Idaho, USA) fitted with a 1250 W motor. The flour was sieved using a laboratory test sieve of 300 µn (Wagtech international, Ltd., 300 MIC, BS 410), packed in polythene papers, and kept in plastic buckets at 4 ºC for further analysis.

D. Determination of Proximate, Carbohydrate and Energy Content

The moisture, crude protein, ash, total fat, minerals (iron, potassium and zinc), total carbohydrate, dietary fiber, total fat and gross energy contents of the banana-based flours were determined using standard methods. Moisture content was determined using oven drying method by drying at 105 ºC for overnight [23]. Crude protein was determined by the Kjeldhal method using a conversion factor of 6.25 [24]. Total fat content was determined using the Soxhlet method [23]. Ash content was determined using a method described by [23] at 550 ºC for 6h. Dietary fiber was determined using the FOSS Fibertec equipment 2010. Carbohydrate content of the flour samples was obtained from a method of difference on dry weight basis by deducting total percentage of fat, crude protein, ash, dietary fiber from 100% to give the amount of nitrogen-free extract otherwise known as carbohydrate. On dry weight basis:

% CHO = 100 % - (%MC+% Fat + % Ash + % dietary Fibre ¬ % Crude Protein)

Gross energy content was determined by oxygen bomb calorimeter (Gallenkamp Autobomb) [24].

E. Determination of Physio-chemical Properties of Flours

Bulk density was determined by a method described by [25]. The water absorption capacity (WAC) of flours was measured using centrifugation method reported by [26]. The foaming properties was determined by employing a method of [27].

F. Determination of Pasting Properties of Soups

Pasting properties of the banana-vegetables soups were obtained using a standard method described by [28]. 3.5 g of flour was weighed into a canister with 25mls of distilled water and was placed in a Rapid Visco Analyzer (Model: RVA-4, New Port scientific, Pty. Ltd., Australia). The test runs included 1 minute of mixing, stirring, and warming up to 50 ºC, 3 minutes and 42 seconds of heating at 12 ºC/min up to 95 ºC, 2.5 minutes of holding at 95 ºC, 3 minutes and 42 seconds for cooling back to 50 ºC at the same rate as heating and 2 minutes holding at 50 ºC. The process ends after 13 minutes.

G. Data Analysis

All measurable parameters on a sample were conducted in triplicate (n=3) for functional properties and pasting properties. Statistical analysis of the data was performed by analysis of variance (ANOVA), using SPSS software (IBM statistics, version 20). A probability value of $p \leq 0.05$ was considered to denote statistical significance. All data were presented as mean values ± standard deviation (SD). Regression analysis was performed to indicate the relationship between measured properties and formulations.

III. Results and Discussion

A. Effect of Varying Formulations on Nutritional Quality of Soups

The results indicated in Table III indicated that changing ingredient concentration significantly ($p<0.05$) affected nutritional quality of soup flours. The energy content (GE) varied from 369 kCal/100 g to 442 kCal/100 g with formulation S4 (banana: amaranth: carrot = 42.5:42.5:15) having the highest energy content. This energy content is greater than that of bananas (399.63 kCal/100 g) [8], amaranths (371 kCal/100 g) [14], Pumpkin (364 kCal/100 g) (USDA, 2018), Tomatoes (302 kCal/100 g) [14], Mushrooms (328 kCal/100 g) [14] and Carrots (341 kCal/100 g) [14]. This shows that the composite flour has more energy compared to individual flours. The variation of energy content followed according to the model described in (1).

$$GE = 41.5X_1 + 210.9X_2 + 121.8X_3 + 25.65X_4 - 93.1X_5 - 2.08X_1X_2 - 1.04X_1X_3 + 1.66X_1X_5 \; (R^2 = 0.57) \quad (1)$$

The R^2 of the second order polynomial model predicted up to 57% of variability. The interaction and single variations were all significant terms of the model ($p<0.05$). The variation shows that GE increases with increase in banana-amaranths fours, pumpkins and tomatoes but decreases with increase in mushrooms. The interaction factors between bananas: amaranths: pumpkins and banana: amaranth: mushrooms show a reduction in GE while the interaction factor with carrots show a positive coefficient indicating an increase in GE.

Fiber varied from 1.45% to 3.81% with formulation S11 (banana: amaranth: mushrooms=45:45:10) having the highest fat content. The control formulation S0 (banana: amaranths=50:50) had the smallest fiber value of 1.45% which is smaller than the fiber content of bananas (3.50-10.51%) [6], [8], [20]. Fiber content varied according to the model presented in (2):

$$FC = 0.015X_1 + 0.08X_2 + 0.10X_3 - 1.03X_4 + 0.08X_5 + 0.014X_1X_4 \; (R^2 = 0.90) \quad (2)$$

The R^2 predicted up to 90% variability of fiber content in the formulation. The interaction and single variations were all significant terms of the model ($p<0.05$). Pumpkins and mushrooms have a negative coefficient indicating a significant ($p<0.05$) reduction in the fiber content of the formulations.

TABLE III: PROXIMATE COMPOSITION OF DIFFERENT FLOUR FORMULATIONS FOR MAKING BANANA-VEGETABLE SOUP

FC*	GE (kCal/100 g)	MC (%)	Fat (%)	Fiber (%)	Protein (%)	% Ash	Carb (%)	Starch (g/100 g)
S0	4147.5 ±0.21^{cd}	9.69± 0.19^{a}	3.25± 0.12^{bc}	1.45± 0.14^{a}	12.00± 0.65^{a}	2.94± 0.02^{a}	70.67± 0.20^{bc}	68.52± 0.74^{g}
S1	4105.0 ±5.53^{bcd}	10.96± 0.29^{bc}	2.91± 0.13^{a}	2.59± 0.04^{bcd}	13.79± 0.18^{bc}	3.11± 0.03^{bc}	66.64± 0.22^{ab}	60.18± 2.10^{de}
S2	3869.3 ±4.48^{ab}	11.09± 0.64^{c}	3.26± 0.08^{ab}	3.34± 0.39^{f}	13.51± 0.67^{bc}	3.25± 0.07^{de}	65.55± 0.90^{ab}	55.83± 0.56^{a}
S3	3694.1 ±11.16^{a}	9.56± 0.27^{a}	3.27± 0.13^{ab}	2.90± 0.11^{bcde}	15.50± 0.70^{e}	3.06± 0.04^{b}	65.71± 0.14^{ab}	64.03± 1.10^{f}
S4	4419.8 ±5.17^{e}	10.02± 0.24^{ab}	2.64± 0.80^{a}	2.43± 0.36^{bc}	12.92± 0.64^{ab}	3.42± 0.04^{f}	68.57± 0.65^{b}	57.63± 1.30^{abc}
S5	4113.1 ±11.28^{bcd}	10.52± 0.19^{abc}	3.71± 0.06^{bc}	2.79± 0.10^{bcd}	15.29± 0.90^{de}	2.93± 0.02^{a}	64.76± 0.79^{ab}	60.33± 0.61^{de}
S6	4140.7 ±1.15^{cd}	11.24± 0.36^{c}	3.83± 0.05b^{c}	3.02± 0.17^{def}	15.27± 0.64^{de}	3.31± 0.02^{e}	63.33± 0.45^{a}	56.70± 0.41^{ab}
S7	3916.9 ±3.13^{abcd}	9.66± 0.47^{a}	4.01± 0.10^{c}	3.17± 0.18^{ef}	17.20± 0.53^{f}	2.94± 0.04^{a}	63.02± 0.41^{a}	61.31± 1.79^{e}
S8	4015.5 ±6.62^{bcd}	10.68± 0.42^{bc}	3.88± 0.19^{bc}	2.95± 0.05^{bc}	14.29± 0.64^{bc}	3.20± 0.09^{cd}	65.00± 0.94^{ab}	57.37± 1.30^{abc}
S9	3905.3 ±4.77^{abc}	10.67± 0.25^{bc}	2.72± 0.05^{a}	2.25± 0.18^{b}	12.85± 0.84^{ab}	3.05± 0.02^{b}	68.46± 0.25^{b}	63.38± 0.99^{f}
S10	4105.9 ±0.35^{bcd}	11.15± 0.43^{c}	2.90± 0.03^{a}	2.54± 0.23^{bcd}	12.99± 0.35^{ab}	3.63± 0.02^{g}	66.79± 0.61^{ab}	59.13± 0.74^{cd}
S11	4163.8 ±7.86^{d}	9.67± 0.26^{a}	3.03± 0.04^{a}	3.81± 0.04^{g}	14.56± 0.65^{cbd}	3.03± 0.05^{g}	68.93± 0.17^{b}	63.35± 1.10^{f}
S12	4141.9 ±7.48^{cd}	10.43± 0.23^{abc}	2.78± 0.10^{a}	2.61± 0.10^{bcd}	12.25± 0.62^{a}	3.17± 0.03^{cd}	68.76± 0.37^{b}	58.11± 2.11^{bc}

Values represent mean ± standard deviation (n=3). Means in the same column with different superscripts are significantly different ($p < 0.05$). *Formulation codes represent samples in the respective formulations indicated in Table I. FC=Formulation code, GE= Gross Energy Content.

Fat content varied from 2.64% to 4.01% with formulation S7 (banana: amaranth: mushrooms=40:40:20) having the highest fat content. The fat content is greater than for bananas (0.94%) [7] and pumpkins (0.70%) [29] indicating that the composite flour has improved fat content. Fat content in the formulations varied according to the model in (3):

$$\begin{aligned} \text{Fat} &= 0.03X_1 + 0.8X_2 + 0.58X_3 + 0.66X_4 + 0.68X_5 \\ &- 0.01(X_1X_2 + X_1X_3 + X_1X_4 + X_1X_5)\ (R^2 = 0.99) \end{aligned} \quad (3)$$

The coefficient of variation, R^2 of the second order polynomial model explained 99% of the variability. The interaction and single variations were all significant terms of the model ($p<0.05$). The model explains that variations in banana amaranths, pumpkins, tomatoes, mushrooms, and carrots caused a positive significant change ($p<0.05$). It can therefore be concluded that fat content of the soup increased with increase in the proportion of carrots, mushrooms, pumpkin and tomatoes in the formulation. The interaction between Banana-Amaranth with Pumpkin, Tomatoes, Mushrooms and Carrots had a significant negative effect on Fat content. The model had a non-significant lack of fit which suggests a good fit for the model. This means that this model is valid and can be used in subsequent prediction and optimization stages.

Protein content (PC) varied from 12 to 17.2% with S7 (banana: amaranth: tomatoes=40:40:20) having the highest protein content and the control S0 (banana: amaranth: tomatoes=50:50) having the lowest indicating that the added ingredients increased the protein content of banana flour. The protein content of individual ingredients is 13.56, 14.29, 12.91, 10.0, 8.10 % [14] for amaranths, pumpkins, tomatoes, mushroom and, carrots respectively. PC varied according to the model in (4):

$$\begin{aligned} \text{PC} &= 0.11X_1 + 0.21X_2 + 1.01X_3 + 0.44X_4 \\ &+ 0.27X_5 - 0.01X_1X_3\ (R^2 = 0.93) \end{aligned} \quad (4)$$

The R^2 of the second order polynomial model was good and explained 93% of the variability. The interaction and single variations presented were all significant terms of the model ($p<0.05$). It can therefore be concluded that PC of the soup increased with increase in proportions of carrots, pumpkin and tomatoes respectively in the formulation. This means that this model is valid and can be used in subsequent prediction and optimization stages.

The ash content varies between 2.93 and 3.63% with S10 (banana: amaranths: mushrooms= 40:40:20) having the highest starch value which was greater for bananas (2.36%) [17] but lower than for pumpkins (7.39) [29]. Ash varied according to (5):

$$\begin{aligned} \text{Ash} &= 0.029X_1 - 0.08X_2 - 0.27X_3 + 0.03X_4 - 0.03X_5 + \\ &0.001X_1X_2 + 0.004X_1X_3 + 0.001X_1X_5\ (R^2 = 0.91) \end{aligned} \quad (5)$$

The R^2 predicted up to 91% of variability in carbohydrates within the formulation. The interaction and single variations presented were all significant terms of the model ($p<0.05$). The model explains that changes in pumpkin, mushrooms, and carrots caused a negative significant effect in ash content while tomatoes had a positive linear effect indicating an increase in ash content in the formulation.

The carbohydrates of the formulations were determined by a method of difference. The carbohydrates content of the formulations varied between 63.02 and 70.67%. The control formulation S0 (Banana: Amaranths = 50:50) had the highest carbohydrate content while the sample formulation S7 (banana: amaranths: mushrooms= 40:40:20) had the lowest. The carbohydrates in the formulations are lower than the carbohydrates of pure banana flour (79.89%) [9], pumpkins (74.11) [29], tomatoes (74.68%) [14] and carrots (79.57%) [14] but lower than for mushrooms (64.66%) [14] and amaranths (65.25%) [14]. This shows that addition of ingredients significantly ($p<0.05$) carbohydrates content of the formulations. Carbohydrates varied according to the model in (6):

$$\text{Carb} = 0.71X_1 - 2.96X_2 + 2.3X_3 + 2.76X_4 + 0.41X_5 + 0.04X_1X_2 - 0.02X_1X_3 - 0.03X_1X_4 \ (R^2 = 0.82) \quad (6)$$

The model predicted up to 82% of variability in Carbohydrates within the formulation. The interaction and single variations presented were all significant terms of the model ($p<0.05$). The model explains that changes in tomatoes, mushrooms, and carrots caused a positive significant effect in carbohydrates content while pumpkins had a negative linear effect indicating a decrease in carbohydrates content.

B. Effect of Varying Formulations on Micronutrients Content

The formulations were tested for micronutrients content and results are presented in Table IV. Iron content varied between 16 and 45.8 mg/100g with formulation S7 (Banana: Amaranths: Mushrooms =40:40:20) having the highest iron content and formulation S12 having the lowest iron content. This indicates that mushrooms contributed greatly to iron content of the flour. The Iron content in the formulations is greater than individual iron content for bananas (1.73 mg/100 g) [9], pumpkins (4.5 mg/100 g) [13], tomatoes (4.56 mg/100 g) [14], mushrooms (1.00 mg/100 g) [14], carrots (3.93 mg/100 g) [14], amaranths (7.61 mg/10 0g) [14]. This indicates that the composite ingredients contributed highly to the iron composition in the sample. The composition of iron in the formulations varied according to (7).

$$\text{Iron} = 0.27X_1 + 9.24X_2 + 8.78X_3 + 6.3X_4 + 10.01X_5 - 0.1X_1X_2 - 0.1X_1X_3 - 0.06X_1X_4 - 0.11X_1X_5 \ (R^2 = 0.751) \quad (7)$$

The R^2 predicted 75% of Variability in iron content within the formulations. The interaction and single variations presented were all significant terms of the model ($p<0.05$). The model explains that changes in pumpkins, tomatoes, mushrooms, and carrots caused a positive significant effect in iron content while interaction factors had negative effects on iron content thus a reduction in iron content.

Zinc varied between 8.13 and 19.64 mg/100 g. The formulation S3 (banana: amaranths: mushrooms =42.5:42.5:15) had the highest zinc content while S9 (banana: amaranths: pumpkins=45:45:10) had the lowest zinc content. The zinc varied according to (8):

$$\text{Zinc} = 0.1X_1 + 1.52X_2 + 1.33X_3 - 2.14X_4 + 2.1X_5 - 0.02X_1X_2 - 0.01X_1X_3 + 0.03X_1X_4 - 0.02X_1X_5 \ (R^2 = 0.90) \quad (8)$$

The R^2 of the model predicted 90% of the variability in zinc content. The interaction and single variations were all significant terms of the model ($p<0.05$). The model explains that changes in pumpkins, tomatoes and carrots in the composition effected significant changes in zinc content with carrots causing the most change. The coefficients for the model terms shows high positive changes in the model. It can therefore be concluded that Zinc content of the soup increased with increase in the proportion of carrots, pumpkin and tomatoes respectively in the formulation. The interaction factor for mushrooms was negative implying that Zn reduces with increase in the proportion of mushrooms.

Potassium varied between 923.4 mg/100 g to 1660.4 mg/100 g with sample formulation S6 (Banana: amaranths: tomatoes=40:40:20) having the highest potassium value. Potassium varied according to the mathematical model in (9):

$$\text{Potassium} = 11.23X_1 - 118.68X_2 + 142.8X_3 + 14.96X_4 + 11.75X_5 + 1.49X_1X_2 - 1.37X_1X_3 \ (R^2 = 0.71) \quad (9)$$

The R^2 of the model predicted up to 71% of variability of potassium in the formulations. The interaction and single variations presented were all significant terms of the model ($p<0.05$). The model explains that changes in tomatoes, mushrooms, and carrots caused a positive significant effect in potassium content in the formulations while pumpkin cause a significant negative effect in potassium.

Vitamin C content varied between 10.61 and 28.47 mg/100g with the control S0 having the lowest vitamin C content while S9 (Banana: amaranths: pumpkins=45:45:10) having the highest vitamin C content. Vitamin C varied according to (10).

$$\text{Vit C} = 0.09X_1 + 1.79X_2 + 1.47X_3 + 1.55X_4 + 1.48X_5 - 0.02(X_1X_2 + X_1X_3 + X_1X_4 + X_1X_5) \ (R^2 = 0.751) \quad (10)$$

The R^2 of the second order polynomial predicted up to 75% of variability of vitamin C in the formulations. The interaction and single variations were all significant terms of the model ($p<0.05$). The model explains that changes in pumpkins, tomatoes, mushrooms, and carrots caused a positive significant effect in vitamin C in the formulations while interaction effects caused a significant negative effect in vitamin C content.

TABLE IV: MICRONUTRIENTS COMPOSITIONS OF DIFFERENT FLOUR FORMULATIONS FOR MAKING BANANA-VEGETABLE SOUP

7,5	Iron (mg/100g)	Zinc (mg/100g)	K (mg/100g)	Vit C (mg/100g)	Vit A RAE (mg/100g)
S0	27.3	9.93	1115.2	10.61±2.34[a]	0.017±0.00[a]
S1	29.4	12.74	1017.2	14.25±1.04[a]	0.064±0.00[a]
S2	27.1	9.80	1098.4	24.52±2.67[a]	0.437±0.02[d]
S3	26.96	19.64	1134.4	16.19±1.25[a]	0.020±0.00[a]
S4	39.3	12.52	1188.8	16.64±1.14[a]	0.157±0.00[b]
S5	38.4	12.26	923.4	15.84±2.35[a]	0.062±0.00[a]
S6	42.0	13.28	1660.4	27.69±2.18[a]	0.449±0.02[d]
S7	45.8	16.81	1233.2	18.41±2.80[a]	0.014±0.00[a]
S8	38.1	13.92	1092.0	11.95±1.37[a]	0.205±0.02[b]
S9	21.4	8.13	1211.6	28.47±39.61[a]	0.063±0.00[a]
S10	26.2	10.76	1366.0	23.71±6.76[a]	0.321±0.14[c]
S11	32.7	15.98	1146.4	14.14±1.20[a]	0.019±0.00[a]
S12	16.0	9.09	1123.6	12.27±1.13[a]	0.167±0.01[b]

Values represent mean ± standard deviation (n=3). *Formulation codes represent samples in the respective formulations as indicated in Table I.

C. Effect of Varying Formulations on Physico-chemical Properties

The formulations were tested for bulk density, Foaming Capacity and Foaming stability as indicated in Table V.

TABLE V: PHYSICO-CHEMICAL PROPERTIES OF DIFFERENT FLOUR FORMULATIONS FOR MAKING BANANA-VEGETABLE SOUP

Formulation code*	Bulk density (kgm^{-3})	Foaming Capacity (%)	Foaming Stability (%)
S0	$774.03±9.81^{ef}$	3.55±0.33	0.00±00
S1	$813.57±19.99^{f}$	4.98±0.09	1.25±0.02
S2	$705.00±16.55^{cd}$	1.27±0.02	0.84±0.73
S3	$754.73±1.55^{de}$	1.22±0.03	0.00±00
S4	$645.40±0.87^{ab}$	5.07±0.19	0.00±00
S5	$753.93±15.44^{de}$	2.45±0.06	0.00±00
S6	$710.63±5.35^{cd}$	0.00±00	0.00±00
S7	$681.67±0.61^{bc}$	3.74±1.39	0.00±00
S8	$682.30±5.20^{bc}$	6.08±0.26	3.65±0.15
S9	$810.33±2.49^{f}$	1.25±0.05	0.00±00
S10	$769.70±1.39^{ef}$	0.00±00	0.00±00
S11	$725.10±2.95^{cde}$	5.54±0.84	0.00±00
S12	$631.37±59.93^{a}$	2.51±0.14	0.00±00

Values represent mean ± standard deviation (n=3). Means in the same column with different superscripts are significantly different ($p < 0.05$). *Formulation codes represent samples in the respective formulations indicated in Table I.

Bulk density content varied between 630 and 814 kgm^{-3}. The formulation S1 (banana: amaranths: pumpkins = 42.5:42.5:15) having the highest bulk density while S12 (banana: amaranths: carrots = 45:45:10) having the lowest. Foaming capacity varied between 1.22 to 6.08 % with S8 (banana: amaranth: carrots=40:40:20) having the highest foaming capacity. Most formulations were not stable after foaming.

D. Effect of Varying Formulations on Pasting Properties

General pasting properties differed throughout the sample formulations as indicated in Table VI. Peak Viscosity indicates the swelling of starch granules during cooking. The higher the PV values, the higher the swelling of starch granules and the higher the absorption of water. This increase is mainly due to starch content. The peak viscosity varied in the range of 2338.5 to 3413.5 cp. This peak viscosity was higher than the viscosity reported for pure green bananas flour of 1292.5 cp [30]. Breakdown Viscosity (BV) refers to the measure of resistance of gel to disintegrate at high temperature. Lower BV values indicate higher resistance to shear thinning and higher stability of flour paste. Breakdown Viscosity lied between 842.0 to 1681 Cp. The minimum range is slightly above 543 Cp recorded for pure bananas [30]. This indicated that the addition of vegetables and grain amaranth improved breakdown viscosity of green bananas. Final Viscosity (FV) refers to the ability of starch to form a viscous paste on cooling. The increase in final viscosity may be due to aggregation of amylose molecules. This is indicative of quick retro-gradation. The final Viscosity varied between 2010.5 to 2925.5 cp. The control formulation had the highest FV, thus the addition of vegetables reduced the FV of the sample formulations. Set back viscosity is the phase of pasting curve after cooling of starch. This phase involves re-association, retro-gradation or re-ordering of starch molecules. Setback viscosity is a measure of syneresis upon cooling of cooked paste. The higher the setback values, the lower the retro-gradation during cooling of products made from flour [31]. Setback viscosity varied between 658 to 1276.5 Cp. The control formulation had a setback viscosity of 1029Cp. High temperature indicate resistance towards swelling. Pasting temperature lied between 76.28 to 79.53 ºC. The time at which the peak viscosity occurs in minutes is termed as Peak time (PT). The pasting properties of bananas-amaranth mixture indicated the highest Viscosities due to starch content in Bananas being higher at 81.8% [2]. Viscosities tend to go down as the starch content goes down and this is due to the association of starch with other components such as proteins, fats among others [28], [32]. The peak Viscosity (219.28RVU), holding viscosity (119.18 RVU), and breakdown viscosity (100.80 RVU) were lower than the pasting properties exhibited by 100% banana flour according to [9] of 375.92 RVU, 201.29 RVU and 174.63 RVU for peak, holding and breakdown viscosities respectively which were good properties for use in baking industries [33]. This is explained by the reduction in the starch content of flours when the starch rich banana flour is replaced with the vegetable flours [28], [34]. The reduction in viscosities brings this to the viscosity range for children below five years of between 2000–3000 Cp (1Cp=12RVU). This indicates that the soup is palatable to the target group.

E. Optimal Solutions for Selection of Nutrient Enriched Soup Flour

The Optimal formulation (Table VII) was obtained basing on the behavior of starch (pasting properties) and nutritional composition of the formulation. The selection of the best combination was based on the value with the greatest desirability using Desirability Function approach (DFA). The best formulation had a composition of 81.67% bananas-amaranths mix in the ratio of 1:1, 9.24% pumpkins, 3.76% Mushrooms and 5.34% Carrots at a desirability index of 0.51. The formulation had an energy value of 4093.9 kCal/100 g), with peak, holding (hot paste), and breakdown, final and setback viscosities of 2631.41, 1430.11, 1209.57, 2495.29 and 1056.92 Cp respectively. The peak time, Pasting Temperature, Carbohydrates, Protein content and Zinc content were 4.9 minutes, 78.41 ºC, 65.38%, 14.86%, and 13.5 respectively.

F. Model Validation

Randomly selected samples, the optimal product S1 (Table VII) (Banana-amaranths: pumpkin: tomatoes: mushrooms: carrots = 81.67:9.24:0:3.76:5.34), the next optimal product (Table VII) S2 (Banana-amaranths: pumpkin: tomatoes: mushrooms: carrots = 80:10.41:0:3.62:5.97), the control formulation from Table I S3 (Banana-amaranths: pumpkin: tomatoes: mushrooms: carrots =100:0:0:0:0), S4 (Banana-amaranths: pumpkin: tomatoes: mushrooms: carrots =85:0:0:0:15) and S5(Banana-amaranths: pumpkin: tomatoes: mushrooms: carrots =80:20:0:0:0) all selected from Table I were tested with the model equations for selected parameters and the results presented in Table VIII.

TABLE VI: PASTING PROPERTIES OF DIFFERENT FLOUR FORMULATIONS FOR MAKING SOUPS

Formulation code*	Peak Viscosity (Cp)	Holding viscosity (Cp)	Breakdown Viscosity (Cp)[1]	Final Viscosity (Cp)	Setback Viscosity (Cp)[2]	Peak Time (Minutes)	Pasting Temp. (ºC)
S0	3413.50 ±45.96^{g}	1896.50 ±51.62^{h}	1517.00 ±97.58^{cde}	2925.50 ±12.02^{e}	1029.00 ±63.64^{cd}	4.73± 0.09^{abc}	78.70± 0.57^{cde}
S1	2952.00 ±26.87^{cdef}	1605.50 ±17.68^{ef}	1346.50 ±44.55^{bcde}	2771.00 ±9.90^{de}	1165.50 ±7.78^{cde}	4.83± 0.05^{abcd}	78.75± 0.49^{de}
S2	3336.00 ±288.5^{fg}	1654.50 ±23.33^{fg}	1681.50 ±265.17^{e}	2858.50 ±200.11^{e}	1204.00 ±176.78^{de}	4.77± 0.14^{abcd}	76.33± 0.53^{a}
S3	2865.50 ±10.61^{cde}	1473.00 ±38.18^{cd}	1392.50 ±27.58^{cde}	2239.50 ±2.12a^{b}	766.50 ±36.06^{ab}	4.67± 0.00^{ab}	77.43± 0.04^{abcd}
S4	2338.50 ±12.02^{ab}	1313.50 ±10.61^{ab}	1025.00 ±1.41^{ab}	2530.50 ±17.68^{cd}	1217.00 ±7.07^{cde}	5.00± 0.00^{de}	78.70± 0.57^{cde}
S5	2817.00 ±14.14^{cde}	1528.00 ±12.73^{de}	1289.00 ±1.41^{bcd}	2670.50 ±3.54^{de}	1142.50 ±9.19^{cde}	4.90± 0.05^{bcd}	78.33± 0.04^{bcde}
S6	2749.00 ±132.94^{cd}	1492.50 ±4.95^{cde}	1256.50 ±127.99^{bc}	2520.00 ±91.92^{cd}	1027.50 ±86.97^{cd}	4.93± 0.00^{cde}	76.28± 0.53^{a}
S7	2646.00 ±28.28^{bc}	1352.50 ±6.36^{b}	1293.50 ±21.92^{bcd}	2010.50 ±17.68^{a}	658.00 ±11.31^{a}	4.67± 0.00^{ab}	77.10± 0.64^{abc}
S8	2054.00 ±22.63^{a}	1212.00 ±46.67^{a}	842.00 ±24.04^{a}	2288.50 ±19.09^{bc}	1076.50 ±27.58^{cde}	5.17± 0.05^{e}	79.53± 0.53^{e}
S9	3206.00 ±8.49^{efg}	1746.00 ±15.56^{g}	1460.00 ±7.07^{cde}	2842.50 ±0.71^{e}	1096.50 ±14.85^{cde}	4.77± 0.05^{abcd}	78.30± 0.14^{bcde}
S10	3271.50 ±140.71^{fg}	1643.50 ±54.45^{fg}	1628.00 ±86.27^{de}	2764.00 ±66.47^{de}	1120.50 ±12.02^{cde}	4.73± 0.09^{abcd}	76.70± 0.00^{ab}
S11	3075.00 ±0.00de^{fg}	1576.50 ±2.12d^{ef}	1498.50 ±2.12^{cde}	2530.50 ±10.61^{cd}	954.00 ±8.49^{bc}	4.63± 0.05^{a}	77.50± 0.14^{abcd}
S12	2641.00 ±9.90^{bc}	1404.00 ±0.00^{bc}	1237.00 ±9.90^{bc}	2680.50 ±53.03^{de}	1276.50 ±53.03^{e}	4.93± 0.00^{cde}	79.15± 0.00^{e}

Values represent mean ± standard deviation (n=3). Means in the same column with different superscripts are significantly different ($p < 0.05$). *Formulation codes represent samples in the respective formulations indicated in Table I. [1]Break down Viscosity= Peak – Holding Viscosity, [2]Setback Viscosity=Final-Holding Viscosity.

TABLE VII: OPTIMAL FORMULATIONS FOR BANANA-VEGETABLES SOUP FORMULATIONS BASED ON 100 G OF SOUP FLOUR MIX

Number	*1*	2	3	4	5
Banana + Amaranths	*81.67*	80.00	81.58	80.00	80.00
Pumpkins (%)	*9.24*	10.41	12.53	12.89	13.74
Tomatoes (%)	*0.00*	0.00	0.19	0.85	0.00
Mushrooms (%)	*3.76*	3.62	0.00	0.00	0.00
Carrots (%)	*5.34*	5.97	5.71	6.26	6.26
Peak Viscosity (cP)	*2631.41*	2557.80	2645.15	2574.98	2575.85
Holding viscosity (cP)	*1430.11*	1403.42	1459.55	1433.72	1434.81
Breakdown Viscosity (cP)	*1209.57*	1176.56	1195.13	1164.21	1164.36
Final Viscosity (cP)	*2495.29*	2468.71	2612.53	2579.33	2584.79
Setback Viscosity (cP)	*1056.92*	1043.98	1148.06	1132.38	1137.29
Peak Time (Minutes)	*4.90*	4.94	4.95	4.98	4.98
Pasting Temp. (ºC)	*78.41*	78.45	78.66	78.60	78.69
Carbohydrates (%)	*65.38*	64.56	65.62	64.86	64.91
Protein content (%)	*14.86*	15.31	14.48	14.95	14.96
GE (kCal/100g)	*4093.9*	4134.5	4159.3	4200.3	4201.5
Zinc (mg/100g)	*13.50*	13.80	12.38	12.96	13.00
MC (%)	*9.821*	9.792	9.647	9.477	10.259
Fat (%)	*3.411*	3.429	3.555	3.603	3.288
FC (%)	*3.189*	3.206	3.330	3.350	3.173
PC (%)	*15.687*	15.781	16.457	16.747	15.037
Ash (%)	*3.094*	3.086	3.040	3.001	3.221
Vit C (mg/100g)	*7.299*	7.323	7.527	7.551	7.309
Vit A RAE (mg/100g)	*0.071*	0.070	0.063	0.061	0.082
Starch Content (%)	*64.686*	64.772	65.227	65.447	63.424
Iron (mg/100g)	*34.626*	34.895	36.623	37.317	32.454
Potassium (mg/100g)	*1167.269*	1168.848	1207.499	1185.682	1266.911
Desirability	*0.51 Selected*				

TABLE VIII: TESTING VALIDITY OF MODELS

Codes	GE (kCal/100g)	MC (%)	Fiber (%)	Fat (%)	Protein (%)	Ash (%)	Carb (%)	Starch (%)
S1	4076.5(4093.9)	10.6(9.8)	2.8(3.2)	3.1(3.4)	14.0(14.9)	2.8(3.1)	60.3(65.4)	69.1(64.7)
S2	4094.8(4134.5)	10.5(9.8)	2.8(3.2)	4.3(3.4)	14.2(15.3)	2.7(3.1)	63.1(64.6)	72.1(64.7)
S3	4150.0(4147.5)	9.5(9.7)	1.5(1.5)	3.0(3.3)	11.0(12.0)	2.9(2.9)	74.0(70.7)	68.0(68.5)
S4	4247.5(4419.8)	9.9(10.0)	2.5(2.4)	3.8(2.6)	13.4(12.9)	3.3(3.4)	77.9(68.6)	66.1(57.6)
S5	4178.0(4113.1)	11.2(10.5)	2.8(2.8)	4.0(3.7)	13.0(15.3)	2.3(2.9)	61.6(64.8)	72.8(60.3)

(X1:X2:X3:X4:X5) S1(81.67:9.24:0:3.76:5.34), S2(80:10.41:0:3.62:5.97), S3(100:0:0:0:0), S4(85:0:0:0:15), S5(80:20:0:0:0).

The results indicate that there are slight differences between model values and tested values (in parentheses). The observed differences are due to errors produced from rounding off of coefficient terms in the models. The models can be used to make predictions about the response for given levels of each factor. The levels should be specified in the original units for each factor to be fed into the design expert program. These models should not be used to determine the relative impact of each factor since the coefficients are scaled to accommodate the units of each factor and the intercept is not at the center of the design space. A comparison of the laboratory value with model value for some selected parameters are as shown in Table IX. The observed differences could be attributed to slight differences in change in conditions during sample preparation as well as differences in maturity of the raw materials.

TABLE IX: COMPARISON OF LABORATORY RESULTS AND MODEL RESULTS FOR THE OPTIMAL PRODUCT

Response	Laboratory Value	Model value
Moisture %	10.32±0.13	9.82
Carbohydrates (g/100g)	60.30±2.30	62.21
Vitamin A RAE (mg/100g)	0.067±0.01	0.07
Fiber %	3.02±0.27	3.19
Fat %	3.39±0.35	3.41
Ash %	3.12±0.01	3.09

The optimal product (Table VII) (Banana-amaranths: pumpkin: tomatoes: mushrooms: carrots = 81.67:9.24:0:3.76:5.34).

IV. CONCLUSION AND RECOMMENDATIONS

The purpose of this study was to evaluate the effect of ingredient type and concentration on functional properties of a mixed banana-vegetable soup. The study has demonstrated that varying ingredients in a soup flour formulation significantly affects the nutritional value, physical chemical properties and pasting properties. Inclusion of tomatoes and pumpkins lowers carbohydrates, starch content and fat content but improves protein content, Iron, vitamin A and vitamin C. Addition of mushrooms. Addition of mushroom increase fiber content, Vitamin A content while Inclusion of carrots increases energy content, fiber, Iron, and vitamin A. Therefore careful proportioning of ingredients was necessary to achieve an optimal soup flour mixture. In this case a formulation of bananas, amaranths and/or pumpkins, tomatoes, mushrooms, and carrots was required to produce a soup flour mixture with 20.1 g, 25 g, 1350 kCal, 600 mg and 13 g of protein, fat, energy, calcium and Iron respectively. The 100 g serving of this formulation can meet 65.38% of carbohydrate, 14.86% of protein, and 409.39 kCal/100 g of GE for children aged 6-59 months. Future studies will be required to optimize the extrusion conditions that can be used to produce an instant flour mix with improved flour properties.

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