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Physicochemical and Elemental Analyses of Banana Composite Flour for Infants

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Authors' contributions

All authors contributed equally to the writing of protocols, literature review, sample collection, laboratory and statistical analyses, and manuscript preparation. All authors have read and approved the manuscript.

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Original Research Article

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ABSTRACT

Aim: To develop a nutritious product from banana for infants and increase banana utilization.
Methodology: Banana samples obtained from the Volta River Estate Limited were solar dried and milled into flour. Soybean and maize were obtained from a local market in Madina, Accra, mechanically dried and made into flour. Banana, soy bean and maize flour were mixed into composite flour in seven different percentage ratios. Physicochemical and elemental analyses were performed on the seven different banana composite flours.
Results: Results showed a significant difference in all parameters analysed for all the seven different banana compositions. Composite flour made of local crops, banana, soybean and maize, had high levels of potassium and sodium (19350 mg/kg and 12850 mg/kg respectively) and appreciable levels of Iron, Zinc and manganese. Physicochemical analyses showed total carbohydrate was relatively high in all the composites flour with a substantial amount of crude

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protein ranging between 5.46±0.51 to 8.95±0.51%, moisture content with a range of 3.16±0.39 to 8.15±0.96% and pH values ranging from 6.13±0.04 to 6.23±0.01.
Conclusion: The proximate result and mineral content makes the banana composite flour an ideal product for weaning babies and infants. Formulation of banana composite flour requires minimal infrastructure and the technology involved is quite simple for the ordinary household.

Keywords: Banana; soy bean; maize; physicochemical; elemental composition.

1. INTRODUCTION

Ghana has made steady progress towards achieving the Millennium Development Goals. However, the nutrition, health and mortality situation of young children and women as well as persistent regional disparities needs to be addressed [1]. Many children under 5 years are malnourished, coupled with 30% stunted in growth, there is therefore the need to promote better complementary feeding when children are no longer fully breastfed [2]. Improving the nutritional quality of weaning foods from locally produced agricultural produce has received a lot of interest in many developing countries. The production of complementary food under local conditions and technology gives an opportunity for improving the quality of complementary food using local ingredients [3]. Ready-to-eat complementary foods product formulation from locally available commodities can meet the macro nutrients needs of infants and children. Proper reformulation and fortification of these diets can provide a cost effective nutritious food that is suitable not only for weaning but also as a rehabilitation diet to malnourished children [4].

Banana production makes a major contribution to food security, particularly in Africa where it is a major food crop for 100 million people [5]. Ripe banana is a prized fruit for all age groups and usually eaten raw because of its nutrients. Although banana has a lesser importance as a basic food item, it has however become an important export commodity [6]. There is a huge post harvest loss of ripped banana on the local market because banana is usually eaten raw and does not receive any major value addition in Ghana. If the quantity of unripe banana allowed to rip will be reduce then post harvest loss of ripped banana can be reduced. A statistics by the Ghana Ministry of Environmental, Science, Technology and Innovation shows that the country loses between 20-50% of all vegetables, fruits, cereals, roots and tuber produced each year while it struggles to achieve food security and eradicate hunger. Ghana loses GHC 700,000 in post harvest losses [7].

Banana can be processed into flour and used as a composite in some flour products to improve their nutritional quality. The addition of banana pulp which is rich in micronutrients to food products can improve their nutritional value, aroma and taste. The objective of the study was to develop a nutritious product from banana for infants' and increase banana utilisation to reduce post harvest losses.

2. METHODOLOGY

2.1 Sample Preparation

2.1.1 Banana flour

Unripe banana samples were obtained from the Volta River Estate Limited (VREL) farms at Akuse in the Eastern Region of Ghana. The samples were peeled, cut into suitable sizes and dried in a solar dryer, with an average temperature of 65ºC, for three days at the Food Research Institute of Ghana. The dried banana samples were subsequently milled into 25 µm particle size flour using a hammer mill. The samples were then stored at -4ºC till all analyses were done.

2.1.2 Soybean flour

Soy bean was purchased from Madina market in Accra, sorted to remove all debris from the beans and washed under running water. The samples were blanched for 30 mins to remove the beany flavour and bitterness from the bean. After blanching, the soy bean samples were drained and put under running water to allow for easy dehulling. Dehulled samples were dried in a mechanical dryer at 60ºC overnight. Dried soybean samples were milled into 25 µm particle size flour using the hammer mill. Milled soy bean flour was stored at -4ºC till all analyses were done.

2.1.3 Maize flour

Maize was purchased from Madina market in Accra, and sorted to remove all debris. The maize samples were roasted in a hot air oven at 80ºC till it become golden brown and cooked. The roasted maize was milled into 25 µm particle size flour using a hammer mill. The milled maize flour was stored at -4ºC till all analysis were performed.

2.1.4 Composite flour formulation

The three main ingredients (banana, soy bean and maize flours) were mixed into composite flour in seven different percentage ratios based on a modified FAO/WHO recommendation [8] of soy bean usage in composite flour for children. In all, 700g of each formula was made and used for the various laboratory analyses. Percentage formulation of banana, maize and soy bean for the different compositions is represented in Table 1.

2.2 Physicochemical Analyses of the Banana Composite Flour

2.2.1 Determination of moisture in banana composite flour (air oven method)

Five grams of the flour samples was weighed into clean dried petri dish according to AOAC method for moisture analysis [9]. The weighed samples were put in an air oven (Gallenkamp 300 series, England) previously heated to 130±30ºC. The oven was provided with an opening for ventilation. The samples were dried to a constant weight at a maintained temperature of 130±30ºC for a period of 24 hours. The dish was covered while still in the oven and transferred to a desiccator with activated desiccants and weighed soon after reaching room temperature. The petri-dishes with the dried samples were reweighed immediately at the end of the cooling period of 30 minutes and the moisture content calculated from the relation:
%Moisture=

[(Weight of test samples-Weight of sample after drying)/ (Weight of test samples)] X 100

2.2.2 Determination of pH of banana composite flour

The pH of the composite flour was determined according to AOAC method [9]. Ten grams of test samples was weighed into clean, dry erlenmeyer flask.100ml of distilled water was added to the flasks and homogenized until particles were evenly suspended and mixture free of lumps. The homogenate was then filtered through a filter paper (Whatman No. 1). The pH of the filtrate was measured immediately using a standard pH meter (Hanna Instruments, Model pH 211, Romania).

2.2.3 Estimation of total carbohydrate in banana composite flour (anthrone method)

Exactly 0.1g of composite flour samples were weighed into boiling tubes. The samples were hydrolysed by keeping the tubes in boiling water bath for three (3) hours with 5 mL of 2.5N HCl and then cooled to room temperature. The samples were then neutralized with sodium carbonate until effervescence ceased. The volume was made up to 100 mL and centrifuged. Using a pipette, 0.3 mL and 0.5 mL aliquots of the supernatant were collected for analysis.The standards were prepared by taking aliquots of 0, 0.2, 0.4, 0.6, 0.8 and 1 m*L* of the working standard with 0 serving as the blank. The working standard was prepared by diluting 10mL of stock (0.1g of Standard glucose dissolved in 100 mL of distilled water) with 100 mL of distilled water. It was then stored in a refrigerator after adding few drops of toluene.

Table 1. Percentage (%) formulation of composite flours

Sample code	Maize	Banana	Soy bean
BMS 1	25	50	25
BMS 2	25	60	15
BMS 3	30	50	20
BMS 4	20	70	10
BMS 5	45	30	25
BMS 6	55	20	25
BMS 7	35	40	25

BMS- Banana Maize Soy bean

The sample tubes were made up to 1 mL by adding distilled water and 4 mL of anthrone reagent (0.2 mg of anthrone dissolved in 100 mL of ice-cold 95% H_2SO_4). The tubes were then heated for eight minutes in a waterbath and cooled. The absorbance of the green to dark coloured samples was read on a spectrophotometer (Model CT 06484, U.S.A) at a wavelength of 630 nm. A standard graph was obtained by plotting concentration of the standard on the X-axis and absorbance on the Y-axis.The amount of carbohydrate present in the sample tube was extrapolated from the calibration curve [10]:

Total carbohydrate present in the 100 mg of the sample =

[(mg of glucose)/ (vol of test sample)] X 100

2.2.4 Determination of crude protein content of the banana composite flour

The crude protein content of the composite flour was determined using the Kjeldahl apparatus using AOAC method [9]. 0.2 g of the flour samples were weighed into a digestion flask. Two drops of N- catalyst (K_2SO_4 + G Se) and 5ml of H_2SO_4 were added to the flask and the solution was boiled briskly for about an hour whilst adding about 10 drops of H_2O_2. 3-4 drops were added slowly at a time to avoid vigorous reaction of the content until the solution became clear. The solution was allowed to cool and the volume made up to 100 mL by adding distilled water in a volumetric flask. An aliquot solution of 5 mL was taken into a flat bottom flask and about 5 mL of 40% NaOH was added to make the content strongly alkaline. The content was distilled against 10 mL of 2% boric acid solution containing 2-3 drops of mixed indicator (methyl red and bromocresol green) in a flask. About 50 mL of the distillate was collected into the receiving solution after which 0.01N HCl was titrated against it. A blank determination (without the sample) was also carried out with the reagents. The percent nitrogen and the crude protein content were calculated as follows:

$$\%N = \frac{Vol.(Acid) - Vol.(Blank)}{0.2g} \times \frac{0.01}{100} \times 14 \times \frac{100}{5} \times 100$$

% Protein = % N x 6.25

2.2.5 Elemental analysis of banana composite flour using Atomic Absorption Spectrophotometry (AAS)

The powdered sample was weighed (0.5 g) into a labelled 100 mL polytetrafluoroethylene Teflon bombs. 6 mL of conc. HNO_3 (65%) and 1 mL of H_2O_2 (30%) was added to the samples in a fume chamber. The samples were then loaded on a microwave carousel. The vessel caps were secured tightly. The complete assembly was microwave-irradiated for 20 min in a milestone microwave laboratory station (ETHOS 900 D model) using the following parameters; 2 min for 250W, 2 min for 0W, 6 min for 250W, 5 min for 400W, 5 min for 600W with a pressure of 100 psi, and temperatures of 400ºC and 500ºC. Five minutes was allowed for venting [11]. After digestion, the Teflon bombs mounted on the microwave carousel were cooled in a water bath to reduce internal pressure and allow volatilized materials to resolubilize. The digest was made up to 20 mL with distilled water and assayed for the presence of iron, zinc, manganese, cadmium, magnesium, chromium, and lead in an acetylene-air flame. Quality control and quality assurance were incorporated in the analytical scheme. Quality control was measures were checked to avoid contamination during analysis. The blank value procedure was used to determine the quantitative and qualitative determination limits of all the elements of interest. Reference standards for the elements of interest, blanks and repeats of the samples were digested the same way as the actual samples. These served as internal positive controls. The digested samples were then aspirated using Varian AA240FS fast sequential Atomic Absorption Spectrophotometer. The instrument was initially calibrated using 4% acetone solution containing know amount of the elements of interest before the reading of any element with a standard solution of the element. A linearity of the calibration curve was always checked before the samples were aspirated. Calculation was obtained as stated below:

Final concentration (mg/kg)

$$= \frac{\text{Concentration} \times \text{Normal volume}}{\text{Weight of sample in grams}}$$

Concentration recorded = given on the monitor attached to the instrument
Nominal volume = final volume after reagent and water were added
Weight of sample = 0.5 g.

2.2.6 Determination of sodium and potassium using flame photometer

Sodium and Potassium were determine by weighing 5 g of the sample was weighed and leached in 100 ml of distilled water for 3 hours at 630 RPM. The solution was then filtered to get a clear solution. 5 mL of the supernatant was measured and 2 mL of Lithium standard solution (100 PPM) which acts as Ionization Suppressor was added to it and homogenized. It was then aspirated into the flame photometer (Sherwood, Model 420) and the concentrations of Na and K read directly.

3. RESULTS AND DISCUSSION

3.1 Physicochemical Analysis of Banana Composite Flour

The results of the physicochemical qualities of the banana composite flour are presented in Table 2. The highest moisture content of the seven different composite flours was 8.15% and the lowest 3.16%. There were significant differences ($P < 0.05$) in the moisture content of the composite flours. The pH of all the individual composite flour was within the neutral pH ranges with the highest being 6.23 and the lowest being 6.13. Significant differences ($P < 0.05$) were recorded amongst some of the pH values obtained. The highest carbohydrate content was 84.48% and the lowest being 52.47%. There were significant differences ($P < 0.05$) in the percentage carbohydrate in all the samples. The highest percentage protein mean was 8.95% and the lowest 5.46%. The mean values of protein for the various compositions did not show much difference as some samples were not significantly different ($P > 0.05$) from each other.

The different compositions showed significant differences in all the parameters analysed. However the differences did not follow any consistent pattern with respect to the percentages of the individual sample in each of the composite flour. The moisture content was very low as compared to the CODEX recommendation for flour 8% [12]. High moisture content during storage will promote microbial growth and survival especially that of mould and yeast, as well as proliferation of insects which may deteriorate the food. The sample with the lowest moisture content BMS 7 had a 40% banana composition whilst sample BMS 4 with 70% banana composition had the highest moisture content. This observation does not follow the trend reported in other studies [13,14], where the moisture content decreased with increasing banana content in composite flour. In this study, visual observation of the data values shows that moisture content did not vary with the different banana ratio in the composite flour.

Statistically, the *P*- value of the seven banana flour compositions did not show much difference in the pH values, however the mean values for the pH of the banana composite flour increased with decreasing banana content. A study [15] on two varieties of banana (cavendish and dream), showed a pH value of 4.77 and 4.63 respectively. This might be the reason for the trend in the pH values observed in this study. The pH values in this study showed that BMS 6 with 20% banana content had a lower pH then BMS 4 with a banana content of 70%.

In the case of carbohydrate, the results revealed significant difference in the different banana compositions. BMS 6 which had 10% banana content had the least carbohydrate of the entire seven different composites base on the observation of the analysed values. Green banana and plantain flour according to research has high carbohydrate content and rich in dietary fibre [16,17]. This possibly explains the low carbohydrate content of banana composite with the least content of banana (BMS 6) observed in this study. However, BMS 4 which had 70% banana in its composite did not have the highest carbohydrate content.

The banana composite flour with 25% soy bean and low percentages of banana recorded high protein content. Composite flours BMS 6, 5, 7 which had 25% soy bean and banana composition of 20, 30, and 40% respectively had the highest protein percentage contents. Composite flours (BMS 4, 3, and 2) had the lowest soy bean content of 10, 20, and 15% respectively. Protein content is reported to increase significantly in composite flours protein rich legume plants. Addition of soy bean increases the protein content of foods [18-20]. Unripe plantain is reported to have low crude protein content [17]. This explains why the composite flour with high levels of unripe banana flour has low protein content and vice versa.

3.2 Elemental Analyses of Banana Composite Flour

The banana composite flours were analysed for macro and micro elements as well as heavy metal composition. The result show a significant composition of some major macro elements and two micro elements. However major heavy metals that are toxic to human health were not detected in all the seven composite flours. Statistical analyses showed significant differences (*P* <0.05) in all the elements identified. Result of the elements of interest, detection limits and percentage recovery are represented in Tables 3 and 4. The highest iron content in the formulated banana flour was recorded in BMS 1 which had 5.9 mg/kg and the lowest being 0.7 mg in BMS 6. The composite flour BMS 4 with the highest banana composition (70%) had the highest potassium levels of 19,345 mg/kg and BMS 5 with 30% banana composition had 13,745 mg/kg potassium levels. A value of 12.6 mg/kg which was the highest magnesium content recorded for BMS 1 and 0.2 mg/kg as the lowest magnesium content recorded in BMS 4 and 7. The highest level of sodium 12850 mg/kg was recorded in BMS 4 which had 70% banana content. The least recorded sodium content, 590 mg/kg, was BMS 6 with 20% banana content. Zinc and manganese were the only two micronutrients that were detected in this study. The highest zinc level was 23.4 mg/kg in BMS 5, which had 30% banana content. However BMS 4 which had 70% banana recorded the lowest zinc content of 11.0 mg/kg. The highest manganese content (8.1mg/kg) was recorded in BMS 1 which had 50% banana and the least of 4.6 mg/kg was recorded in BMS 6. Copper, Chromium, Mercury, Lead, Cadmium were not detected in the banana composite flour.

Minerals are essential nutrients that are needed in the body to facilitate proper functioning of certain organs in the body. Some minerals are needed in smaller quantity (micro) while others are needed in larger quantity (macro). This study analysed for Iron, Magnesium, Potassium and Sodium which are macro nutrients needed in large quantities. The iron content of the different banana composite flours was low. Foods of vegetable origin generally have low iron content compared to food from animal origin. Varieties of foods can also affect iron content, therefore combination of varieties of food can help meet the recommended iron intake. Bukoba banana variety is reported to have a higher iron content compared to Mshal variety [21]. A study [22] reported that a diet made of yellow maize, soy bean and groundnut had 1.65± 0.64 mg/kg iron in the final product as compared to the individual ingredients.

Banana generally has a very high level of potassium. BMS 4 with 70% banana composition therefore recorded the highest potassium levels, with BMS 5 and 6 which had the least percentages of the banana composition recording lower potassium values. Potassium is reported to be the major element found in both fresh banana pulp and peel [23]. Potassium is a building block of body tissue and hence essential for infant growth [24]. There was no clear explanation for the levels of magnesium recorded as it did not correspond to the different percentages of the different ingredients used for the banana composite flour. Observation of the data did not show any corresponding increase in any of the ingredients and magnesium content. However soybean is reported to have high magnesium content [25]. Magnesium is a cofactor in more than 300 enzyme systems that regulate diverse biochemical reactions in the body, including protein synthesis, muscle and nerve function, blood glucose control and blood pressure regulation [26]. Magnesium keeps bones strong and heart rhythm steady. The levels of sodium present increased with increasing banana content. BMS 4 with the highest percentage banana had the highest sodium content and BMS 6 with the lowest banana content recorded the lowest sodium content. Sodium is essential to stimulate cell proliferation and protein synthesis and increase cell mass [27]. Sodium also forms an essential component of the blood. This study clearly shows an increase in the zinc content correlates with decreasing banana content. A related study [28] recorded lower zinc content in wheat bakery flour as compared to medium strength wheat flour. The manganese levels recorded in this study did not follow any pattern with respect to the banana content. Copper and chromium were not detected in this present study however a study on banana grown in North Tenerife, Spain [29] detected high copper levels. The absence of Lead, Mercury and Cadmium (heavy metals) makes it safe to use this banana composite flour as infant food. Lead, Mercury and cadmium are toxins that affect normal functioning of human organs. The presence of heavy metals such as mercury and lead can create serious health problems in humans. In infants, most organs and systems including the brain are in a stage of rapid development. Exposure to such heavy metals can therefore impair brain development and impact negatively on the future intellectual potential of the child. Other organs such as kidneys and the reproductive systems are also affected by intoxication of heavy metals [30-33].

Table 2. Physicochemical properties of the banana composite flour

Sample ID	Physicochemical properties			
	Moisture (%)	**pH**	**Carbohydrate (%)**	**Protein (%)**
BMS 1	6.55±0.69^{bc}	6.18±0.04^{abc}	82.23±0.87^{f}	7.20±1.33^{bc}
BMS 2	5.34±1.07^{b}	6.16±0.02^{ab}	87.48±0.60^{g}	5.46±0.51^{a}
BMS 3	6.84±0.10^{cd}	6.13±0.04^{a}	66.71±0.18^{b}	6.33±0.50^{ab}
BMS 4	8.15±0.96^{d}	6.13±0.04^{a}	74.04±0.10^{d}	6.62±0.50^{abc}
BMS 5	5.94±0.23^{bc}	6.19±0.05^{bc}	77.44±0.17^{e}	7.79±0.88^{cd}
BMS 6	5.73±1.30^{bc}	6.23±0.01^{c}	52.47±0.37^{a}	8.95±0.51^{d}
BMS 7	3.16±0.39^{a}	6.18±0.01abc	71.04±0.01^{c}	7.78±0.01^{cd}
	LSD = 1.3965	LSD=0.0585	LSD=0.7637	LSD=1.2512

Means ± standard deviations in the same column with different superscripts are significantly different (P= 0.05).

Table 3. Elemental analysis of the banana composite flour

Sample ID	Macro elements				Micro elements			
	Fe	**Mg**	**K**	**Na**	**Zn**	**Mn**	**Cu**	**Cr**
BMS 1	5.9±0.92^{d}	12.6±0.04^{e}	17850±14.1^{e}	610±14.1^{a}	17.4±0.28^{e}	8.1±0.08^{e}	ND	ND
BMS 2	3.9±0.20^{c}	10.8±0.53^{d}	17510±14.1^{c}	770±14.1^{c}	13.6±0.02^{b}	6.3±0.06^{c}	ND	ND
BMS 3	3.2±0.14^{bc}	0.3±0.01^{a}	17530±14.1^{c}	710±14.1^{b}	14.6±0.85^{c}	5.7±0.11^{b}	ND	ND
BMS 4	2.6±0.42^{b}	0.2±0.01^{a}	19345±7.1^{f}	12850±14.1^{d}	11.0±0.28^{a}	5.7±0.01^{b}	ND	ND
BMS 5	2.5±0.54^{b}	1.9±0.01^{c}	13745±7.1^{a}	690±14.1^{b}	23.4±0.28^{a}	6.7±0.08^{d}	ND	ND
BMS 6	0.7±0.03^{a}	1.1±0.01^{b}	14515±7.1^{b}	590±14.1^{a}	19.0±0.28^{f}	4.6±0.06^{a}	ND	ND
BMS 7	1.3±0.03^{a}	0.2±0.01^{a}	17725±7.1^{d}	750±14.1^{c}	16.5±0.07^{d}	6.1±0.08^{c}	ND	ND
	LSD =1.048	LSD =0.4752	LSD = 197.4	LSD = 33.44	LSD =0.914	LSD =0.1806		

Means ± standard deviations in the same column with different superscripts are significantly different (P = 0.05). ND means Not Detected

Table 4. Detection limits of all elemental analysis of the banana composite flour

Elements	Detection limits mg/L	Percentage recovery (%)
Fe	0.0060	98.96
Mg	0.003	100.40%
K	0.01 standard= 100mg/L	-
Na	0.01 standard= 100mg/L	-
Zn	0.0010	84.00
Mn	0.0020	100.05
Cu	0.0030	99.94
Cr	0.0010	100.05
Pb	0.0010	99.94
Hg	0.0010	80.00
Cd	0.0020	80.80

The standard percentage recovery ranges from 77-120%

Combination of different percentages of banana, soy bean and maize gave different elemental concentrations. A study on noodles incorporated with 30% banana flour and added oat β glucan [34] showed a high concentration of essential minerals (magnesium, calcium, potassium, phosphorus) and proximate components.

4. CONCLUSION

The combinations of different local food crops in foods help the body meet its nutritional needs. Composite flour made of local foods such as banana, soybean and maize has appreciable levels of minerals, crude protein and carbohydrate as well as low moisture content. The proximate and mineral composition makes banana composite flour an ideal product for weaning babies and infants. The introduction of banana in locally (Ghanaian) prepared weaning food is relatively new and this study has demonstrated its potential to meet nutritional needs of infants. Utilization of banana in product development will cater for banana overproduction reducing post-harvest losses of banana. Formulation of banana composite flour requires minimal infrastructure and the technology involved is quite simple for the ordinary household. Even though the banana composite flour has high levels of certain essential nutrients and will be cooked before consumption, it is recommended that the bio-availability of these nutrients and activities of certain anti nutrients in the three ingredients should be ascertained.

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COMPETING INTERESTS

The authors have declared that there is no competing interests exist.

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