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Formulation and Evaluation of the Physicochemical Composition of Maize Based Complementary Flour

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Abstract
Childhood malnutrition is a current and perpetual public health concern in many African countries. Challenges remain the difficulty in formulating nutritionally adequate diets. This study was carried out to produce maize based complementary flour from maize, soybean, germinated maize, dried calyxes of *Hibiscus sabdariffa* and fresh cut leaves of *Gnetum africanum*, groundnut paste and table sugar. The nutritional quality of the flour blends was then assessed. Results indicate that the flour blendes satisfy the recommended energy and macronutrients requirements according to set standards. Thus, the flour blends can be used for managing protein-energy malnutrition. The zinc and iron contents also respect the standards. However, calcium fortification is needed to fulfill the standard. In all cases, the weaning flours need to be fortified with more micronutrients or supplemented with synthetic nutrients to meet the micronutrients codex standard and this represent a challenge for future study.

Keywords: Childhood Malnutrition, Complementary Flour, Formulation, Balanced Flour

Introduction

Child malnutrition is a public health problem in developing countries. Malnutrition affects more than 90% of people in developing countries [1]. Children are the most affected. It usually occurs during the weaning period when breast milk alone is no longer sufficient to provide energy and nutrients for a growing child. Additional foods must then be added to the diet to supplement the breast milk for a satisfactory growth and development of the child [2, 3]. Traditional weaning foods are cereals based complementary flour used to make bulky porridge rich in carbohydrates. The major disadvantage of cereal based foods remains in the low protein content, limitation in some essential amino acids like lysine and the presence of antinutrients such as phytates, tannin and phenolics [4]. In avoiding nutritional deficits, cereals are often blended with protein and fat-rich foods such as soybean and/or groundnuts to meet the accompanying nutritional goals. To overcome the bulkiness (high volume/unit weight) of traditional weaning foods, alpha amylase rich sources are often used to increase the energy density. Micronutrients are essential for growth, development and prevention of illness in young children. Proper weaning foods should be able to supply vitamins and minerals not present in breast milk while providing additional calories. Local foods rich in micronutrients like dried calyxes of *Hibiscus sabdariffa* and fresh cut leaves of *Gnetum africanum* [5, 6] may be used as micronutrients suppliers to meet the necessary requirement. Anemia is most often associated with protein-energy malnutrition [7], and scientific studies of shown the properties of those plant elements in raising iron status [5, 6, 8, 9]. Hence, production of complementary food from *maize, soy, groundnut paste,* dried calyxes of *Hibiscus sabdariffa* and fresh cut leaves of *Gnetum africanum* is innovative and the success in making a balanced diet requires taking into account parameters such as energy, carbohydrate, protein, lipid, vitamin and mineral content [10]. The objective of this study was to formulate complementary foods from maize using protein, fat, vitamin and mineral complementation to supply the requirements not met by milk. Soy bean flour, groundnuts paste, germinated maize flour, dried calyxes of *Hibiscus sabdariffa* and fresh cut leaves of *Gnetum africanum* were used to fortify the maize flour with adequate nutrient density and high mineral bioavailability to meet the recommended macro and micronutrients specification of standards and for easy replication at the household level. Specifically, it aims at determining the optimal blend formulas and comparing nutritional value of the maize based formulation regarding to their macro and micronutrients with the reference standards.

Sample collection

Maize (*Zea mays*), soybeans (G*lycine max*), groundnut (*Arachis hypogaea*), dried calyxes of *Hibiscus sabdariffa* and fresh cut leaves of *Gnetum africanum* were purchased from local market in Douala city, Cameroon and transported to the IUT of Douala quality control laboratory. All the samples were kept at room temperature before processing.

Processing technologies

Preliminary treatment of the raw material

Cleaning and washing

Samples were manually sorted to remove impurities. Groundnuts were toasted. Maize and Soybeans were completely de-hulled and roasted over heat (120^{0}C) during 20 min to reduce fiber and antinutrients. Seeds were subsequently crushed, varnished and stored in plastic bags before grinding.

Germination of maize:

Maize sample was used to produce germinated maize as sources of alpha amylase to increase the nutrient density of the food. Germination was carried out according to the technique described by Ariahu *et al.* [11].

Production of freeze-dried decoction of *H. sabdariffa* calyxes and *G. africanum* leaves

The calyxes of *H. sabdariffa* (HS) and the leaves of *G. africanum* (GA) were ground separately in a HAUSBERG 150W Inox brand coffee grinder. The powders were then mixed in a proportion of 25:75 (*HS*/*GA*). The mixture (product/water ratio of 100:1250 (mg/mL)) was boiled for 15 minutes. The mixture was then filtrated using Whatman No. 4 paper and the filtrate evaporated at 92°C on a Heidolph brand rotavapor. The residue was lyophilized for 2 days. The powder obtained was bagged and stored at -18^{0}C until chemical analyzes were conducted.

Drying and milling

Samples (except dried yam) were dried at 70 ± 5 °C during 3h in a cross flow cabinet dryer (Binder, FDL 115) to a moisture content less than 10%. All dried samples were ground into fine flour using a (Cullati) hammer mill (germinated maize and soybeans) or a robot blender (Moulinex) (groundnut, carrot, egg shell). Dried yam slices were grounded in a milling machine (Retsch ZM 200) equipped with a 1 mm sieve. Flour was then sieved through a sieve of 500 μm, packaged in an air tight polyethylene bags and stored at -18 °C until chemical analyses were conducted.

Formulation of yam and soybean complementary foods

The methodology of mixture design as a mathematical approach was used to calculate the proportions of ingredients needed in order to have balanced composite flour [4]. Optimal mixtures of ingredients in formulating balanced flour are shown in Table 1.

Table 1: Optimal mixture of ingredients (%) in formulating balanced flour

Ingredients	Maize based complementary flour
Maize flour	40.00
Soy Flour	22.00
Groundnut paste	6
Germinated maize flour	12
Hibiscus sabdariffa/*Gnetum africana*	10
Table sugar	10
Total	100

Chemical analysis

Proximate composition

Moisture and ash were determined by AOAC method [12]. Crude protein has been analyzed according to Kjeldahl method [13]. Total fat content was quantified according to Weibull–Stoldt method [14]. Total dietary fiber was analyzed according to the AOAC 985.29 method [15]. Carotenoids profile, alpha tocopherol and the levels of simple carbohydrates/sugars: Maltose, sucrose, free glucose and fructose were determined by HPLC [4].

Minerals analysis

Determination of zinc and iron concentrations in the samples was performed using flame atomic absorption spectroscopy in acid digested ash according to the AOAC, 999.11 methods [16].

Results and discussion

Nutrient composition of the complementary flours

Macronutrients content and gross energy

Proximate composition of the formulated maize flours compared to standards is shown in Table 2. Only the protein content meets the requirement (68%) when comparing the value with the standard baby food formulation proposed by Sanogo *et al.,* [17]. The moisture content (4.84%) and ash content (1.93%) of the maize based flour were closer to the values in standard baby flour. Carbohydrate and lipids content were slightly higher than the values in standard baby food (73.92 and 15.20%, respectively). In all cases, the composite maize flour provide the standard set for, moisture (< 10%), ash (≤ 5%) and carbohydrates (60–75 g/100 g) stipulated in the codex Alimentarius standards [18] and by PAG [19] and SON [22]. The Gross energy (482.54 Kcal/100 g) was slightly higher than 400 Kcal/100g. The protein content (13) satisfy the codex requirement values (13–15%) and is closer to the minimum requirement proposed by PAG [19] and SON [20]. Proteins are essential constituents of all body tissues. They help the body in maintaining body tissue, including development, repair and aids in growth and health [21]. Carbohydrates provide heat and energy for all forms of body activity. Deficiency can cause the body to divert proteins and body fat to produce the consumed energy requirements, thus leading to a depletion of body tissues [22]. The fortified food formulation is a very good source of energy with values of 482.54 kcal/100 g. Carbohydrates can contribute to about 61.27% of the total energy.

Table 2: Nutritional composition of the optimized maize based formulation

Maize		Standard baby flour [19][a]	FAO/WHO [20][b]	PAG [21]	SON [22]
Proximate analysis					
Moisture (%)	4.84	5	5	5.00–10.00 max	5.00–10.00 max
Ash (%)	1.93	2	< 5.00	5.00 max	5.00 max
Protein (%)	13	13	13 à 15%	15.00–20.00 min	14.00–17.00 min
Lipids (%)	15.20	7	2	10max	10max
Carbohydrates (%)	73.92	68	60 to 75		
Fibers (%)	1.585	5	< 5.00	5 max	5 max
Gross energy (Kcal/100g)	482.54	400	400	400	350-400
Contribution to total energy					
Protein (%)	10.38		6-15%		
Lipids (%)	28.34		20-40%		
Carbohydrates (%)	61.27				
Minerals[c]					
[dI]ron (mg/100g)	4.83		11.6, 5.8, 3.9		
eZinc (mg/100g)	192.54		8.3, 4.1, 2.4		
Calcium	15.62		400-500		

[a] Standard baby flour proposed by Sanogo *et al.* [19]. [b] FAO/WHO Codex Alimentarius Commission [20].

[c] Reference nutrient intake or INL98 from FAO/WHO Vitamins and Mineral requirements in Human Nutrition.2nd Edition. FAO/WHO, 2004 (for all nutrients except copper, manganese and phosphorus).

[d] Iron values are given for 5%, 10% and 15% dietary iron bioavailability.

[e] Zinc values are given for low, medium and high dietary zinc bioavailability.

The protein contribution in blended maize based flour is about 10.38% of the total energy intake while lipids contribution is 28.34%. Those values meet the requirement percent in total energy of the codex alimentarius for protein (6–15%) and lipids (20–40%). This high contribution in energy by carbohydrate make the complementary maize flour suitable to be applied in managing protein energy malnutrition since enough quantity of energy will be derived from carbohydrates sparing protein and fat. Yam-based formulation has fiber values of 1.585%. Though crude fibers does not have nutritional value, they can help in the prevention of heart disease and many gastrointestinal diseases in man by adding bulk to food thus facilitating bowel movements (peristalsis) [23].

Zinc and iron composition of the formulated composite flours

Zinc and iron composition of the formulated yam based complementary meals are shown in Table 2. The zinc content (192.54%) and iron content (4.83%) of the maize based flour meets the requirement when comparing the value with the codex Alimentarius standards [18]. Only the calcium content did not meet the codex Alimentarius standards requirement.

Nutritional quality of weaning foods

Complementary foods are expected to have sufficient energy and nutrient density and consumed in small amounts to provide a breastfed growing child with adequate daily energy requirement (0.8 kcal/g) to complete the 0.7 kcal/ml of breast milk for normal, term infants (Table 3). The energy expected from complementary foods (Table 3) for infants varies with the age. In a developing country, 6–8 months old infant consumes 200 kcal/day; 300 kcal/day is necessary for 9–11 months old infant and 550 kcal/day will be needed at 12–23 months old child in addition to daily energy coming from breast milk. The 200 kcal/day energy requirements can be covered by feeding (Table 4) a 6- to 8-month infant with 41.45 g of yam based flour. A daily portion intake of 62.17g is needed to cover the 300 Kcal/day of daily energy requirement from complementary food for 9–11 months old child. Feeding 12–23 months old child with 113.98g of maize based flour would satisfy the daily energy requirement.

Table 3: Daily requirement values and daily portion intake of energy, protein and lipids as a function of quantity of flour needed

Age (months)	Daily requirement values				Maize-based formulation			
	Energy (Kcal)	Energy density	Proteins (g/day)	Lipids (g/day)	Quantity of flour needed (g)	Energy density (g/100Kcal)	Proteins (g/day)	Lipids (g/day)
6–8	200	≥ 0.8	2	0	41.45	4.82	5.19	6.299
9–11	300	≥ 0.8	5-6	3	62.17	4.82	7.787	9.45
12–23	550	≥ 0.8	5-6	9–13	113.98	4.82	14.28	17,32

Because of the high-energy-density (> 4 kcal/g) of yam composite flours, children from 6 to 23 months old would be able to satisfy their daily energy needs from maize based complementary foods if they received one meal per day which would be a possible task considering the size of an infant's stomach (30 g/kg reference body weight). Their protein and lipids daily quantity requirement would also be satisfied when eating the formulated flours, since the value of the estimated daily proteins and fat intake from maize based complementary food are higher than the suggested intake at the age range of 6–24 months (Table 4). WHO/FAO [24] has established levels of Reference Nutrient Intakes ($RINL_{98}$) (Table 4) as a guide for amounts of vitamins and minerals that should be supplied when a formulated complementary food is eaten. This nutritional guideline suggests that a daily ration of a formulated complementary food should supply at least 50% and up to 100% of the WHO $RINL_{98}$ daily total quantity of each of these vitamins and/or minerals. The WHO $RINL_{98}$ daily total quantity of zinc and iron requirement from a formulated complementary food depends on the percentage of nutrients bioavailability in food matrix (medium). By considering the lower levels (50% of the WHO $RINL_{98}$), feeding 6–23 months old child could satisfy 100% of the average daily intake ($RINL_{98}$) of zinc and iron daily requirements at all serving portions while considering the high zinc dietary bioavailability and 15% dietary iron bioavailability. Children of 6–8 months old receiving, 41.45 g could meet the 100% of daily average intake ($RINL_{98}$) of zinc in a medium bioavailability matrix and 70% of iron in 10% dietary iron bioavailability matrix. Feeding 9–23 months old child could satisfy 100% of the average daily intake ($RINL_{98}$) of zinc and iron daily requirements at all serving portions while considering the medium zinc dietary bioavailability and 10% dietary iron bioavailability. Children of 6–8 months old receiving, 41.45 g could meet the 100% of daily average intake ($RINL_{98}$) of zinc in dietary low bioavailability medium and only 36% of iron in 5% dietary iron bioavailability. Feeding 9–23 months old child could satisfy 100% of the average daily intake ($RINL_{98}$) of zinc and 55 (9-11) and 100% (12-23) iron daily requirements at all serving portions while considering the low zinc dietary bioavailability and 5% dietary iron bioavailability. The calcium content did not meet the standards at all age and serving portions.

An attempt was made to produce maize based complementary food with high-energy-density from maize based complementary food. From the above results, maize based formulation has a great potential as weaning flour since it satisfies the recommended energy and macronutrients requirement according to the standards. They can be used in managing protein energy malnutrition by preparing adequate weaning food with flour blended according to the percentage of ingredients stipulated in the optimal formula. Proper weaning foods should be able to supply vitamins and minerals not present in breast milk. Taking micronutrients in consideration, we focused on iron, zinc and calcium because these are considered key ‘problem’ nutrients in many developing countries [25]. The average daily quantity intake of these micronutrients increases with the increase of the serving portion which is related to the age of the child. Taking into consideration their contribution in meeting the micronutrients daily intake suggested reference value, a highest daily serving portion of 113.98 g intended for 12–23 months old child is the most suitable. People should be encouraged to produce weaning food from maize since food-based approaches to combat micronutrient malnutrition are more likely to be sustainable in the long-term and children will be receiving other foods in addition to formulated complementary foods.

Table 4: Average daily intake of micronutrients from maize-based formulation as a function of quantity of flour needed

	Reference Nutrient Intake (INL98)17	Daily ration of the formulated complementary Food (at least 50% of INL98)	Maize-based formulation		
Age			6–8 months	9–11 months	12–23 months
Energy requirement (Kcal)			200	300	550
Quantity of flour			41.45	62.17	113.98
Zinc (mg)4	8.3; 4.1; 2.4	4.15; 2.05; 1.2	79.80	119.71	219.46
Iron (mg)5	11.6; 5.8; 3.9	5.5; 2.9; 1.95	2.00	3.00	5.51
Ca	400-500	200-250	6.48	9.71	17.81

Conclusion

The formulated maize flour blend is balanced flour capable of meeting the energy and nutritional needs of weaning age children in accordance with the standards. It can be used in managing protein energetic malnutrition. The zinc and iron contents also respect the standards. However, calcium fortification is needed to fulfill the standard.

Declaration of Competing Interest

No potential conflict of interest relevant to this article was reported.

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