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Valorization of *Vigna radiata (l.) Wilczek*. and *Moringa oleifera* to improve food recipes of 6-23-month-old children in northern Benin

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A R T I C L E I N F O

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A B S T R A C T

Biodiversity valorization is one way to improve food choices and contribute to a diversified diet among households. This paper aimed to valorize *Vigna radiata (l.) Wilczek*. and *Moringa oleifera* to improve food recipes of 6-23-month-old children. Two local recipes (*Zankpiti* and *Abobo*) were formulated from these plant species. The formulation was done with Minitab software, version 18 using the mixing design. The optimized recipes were tested through a hedonic test by 62 children in three (03) communes. The nutritional densities of accepted recipes were then determined. The hedonic test showed that 83.33% and 82.69% of children respectively appreciated *Abobo* of mung bean with moringa leaves (*AMM*) and *Zankpiti* of mung bean (*ZM*). Regarding the nutritional densities, energy and vitamin A densities of the recipes were largely above the recommended standards (2.03 ± 0.02 kcal/g and 1085.18 ± 14.56 RE μg/100 kcal for *ZM*; 1.72 ± 0.08 kcal/g and 1028.8 ± 74.1 RE μg/100 kcal for *AMM*. The nutritional densities of iron, calcium and zinc did not meet the recommended standards. Regarding the cover rates of the daily children's needs, both recipes had very high cover rates in vitamin A and low levels in daily calcium requirements. *ZM* had covered interesting daily requirements rate up to 37.64 ± 25.56%, 15.82 ± 10.75%, 24.94 ± 16.94% and 919.43 ± 624.82% respectively for energy, zinc, iron and vitamin A while *AMM* recipe covered high rates up to 36.36 ± 30.73% for energy and 655.38 ± 537.07% for vitamin A. These two plant species in children's feeding can also contribute to a better coverage of children's daily requirements.

1. Introduction

Inadequate nutrition is the leading cause of mortality and morbidity worldwide especially among vulnerable groups, ahead of many other important global health issues [1]. In 2020, about 22% (149.2 million) of children under 5 years worldwide were stunted; 6.7% (45.4 million) were wasted, while 5.7% (38.9 million) were overweight [2]. Most of these undernourished children live in Africa and Asia where more than nine children in ten are stunted and wasted and more than seven out of ten are overweight. Of all children, more than nine out of ten stunted children, more than nine out of ten wasted children and more than seven out of ten overweight children in the world are living in Africa and Asia.

In Benin, a sub-Saharan African country, the nutritional status of children aged 6–59 months is of big concern. Approximately one-third (32%) of children under 5 years are stunted [3]. Within Benin, Atacora department records the highest percentage (85%) of anemic children [3].

Inadequate feeding practices are one of the main factors exposing children to chronic malnutrition and micronutrient deficiencies [4]. From 6 months, breast milk is no longer sufficient to cover the nutritional needs of children and complementary foods need to be introduced into the child's diet. Then, during this period, stunting and micronutrient deficiencies are very frequent, since children's nutrient requirements are high relative to their energy and micronutrient intakes [5]. Among micronutrient deficiencies, vitamin A, iron and zinc deficiencies are the most prominent [6]. However, some studies showed that most of the complementary foods consumed by the infants in many parts of world have low nutrient densities leading to malnutrition

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(Adeoti et osundahunsi, 2017; Wakil et Kazeem, 2012). An appropriate complementary diet should be balanced and varied to meet all the nutrient needs of children [7]. Elsewhere, local biodiversity represents a reserve of edible species that are sometimes under-exploited but often rich in micronutrients that can be used in the diet of populations [8]. Indeed, Benin's biodiversity contains fruits, legumes and vegetables and other resources that are very rich in nutrients and are used to supplement the staple foods of the population especially in order to have a balanced diet [9].

Legumes are the third largest family of angiosperms belonging to the family of Fabaceae (or Leguminosae). A pulse is the edible seed from a legume plant and is carried in pods [10]. Among the pulses, the peas, beans, lentils, soybeans, lupins, lotus, sprouts, mung beans, green beans and peanuts are commonly used for human consumption [11]. Legumes are a good source of vitamins and minerals while supplying adequate protein [12]. Mineral contents of legumes especially some dry bean cultivars range from 18.8 to 26.6 mg/kg db for zinc, 28–66.6 mg/kg db for iron, 823–2035 mg/kg db for calcium, 1525–2078 mg/kg db for magnesium, 16166–19464 mg/kg db for potassium, 5044–6564 mg/kg db for phosphorus [12]. Due to their richness in essential nutrients, legume crops are often used to prevent protein and micronutrient deficiencies specifically among women and children and thus have the potential to play a major role in strategies to attain nutritional security [13]. Moreover, the absorption of iron from these pulses may increase if their consumption is associated with vitamin C rich foods. In that case, the consumption of these foods can play a major role in the prevention of anemia, especially in women of reproductive age [14]. Mung bean (*Vigna radiata* (L.) Wilczek) is one of the legumes that grows well in temperate warm regions and under adverse arid and semiarid conditions [15]. In spite of being a minor grain legume in Sub-Saharan African, mung bean, a short-duration and drought-tolerant crop, has a good potential for improving soil fertility and enhancing food security of smallholder farmers [16]. It is a major source of dietary protein (24–28% db) and carbohydrate (59–65% db) and provides about 3400 kJ of energy/kg of grain [17]. Mung bean also induces less flatulence and is well tolerated by children as it has a lower phytic acid content (72% of total phosphorus content) compared to pigeon pea, soybean (Glycine max) and cereals [17]. Because of its high protein content and digestibility, combining mung bean with cereals for consumption can significantly increase the quality of protein in a meal [18]. Apart from having similar nutritional content to cowpea and dry beans, mung bean performs better than them under semi-arid conditions mostly in Benin, which are likely to increase in the coming years due to the climate change [19]. Its production is still being promoted in northern Benin. As an important source of minerals, mung beans are rich in calcium (72.89 mg), iron (5.04 mg), zinc (2.83 mg), sodium (32.92 mg), potassium (1145.88 mg), phosphorus (315.30 mg), and magnesium (132.69 mg) for 100 g of fresh edible product [20].

Traditional leafy vegetables are also an important category in food-based approaches because they constitute a major source of micronutrients in the diet, and could contribute significantly to lessen the burden of 'hidden hunger' [21]. Along these lines, *Moringa oleifera* (Moringaceae) has good potential to contribute to solving malnutrition problems [22]. Moringa leaves are rich in minerals [847.1 mg/100 g for calcium, 151.3 mg/100 g for magnesium, 549 mg/100 g for potassium, 17.5 mg/100 g for iron, 1.3 mg/100 g for zinc, 11.5 mg/100 g for phosphorus for 100 g of fresh edible product [23]. It is also a good source of vitamins (16.3 mg/100 g for vitamin A-Beta carotene, 2.64 mg/100 g for vitamin B1, 20.5 mg/100 g for vitamin B2, 8.2 mg/100 g for vitamin B3, 17.3 mg/100 g for vitamin C and 113 mg/100 g for vitamin E for the dried leaves) [22]. These leaves are highly recommended for infants and nursing mothers especially those from developing countries or areas prone to cases of malnutrition. In addition, due to a lack of information, knowledge about food use, accessibility to these species, or the pressure of certain traditions, etc., the consumption of these species by the populations is low. There is therefore an under-utilization or negligence of some species very interesting considering their nutritional value. Thus, the valorization of mung bean and moringa oleifera through the formulation of improved recipes could boost child's nutritional status. In the same way, various studies have been conducted in Benin and have shown the benefits of using local plant species in infant porridges as well as in other recipes for children [24]. Then, even if plant-based foods were used to feed children, it is also interesting to include other mineral sources as animal products (small fish for instance Ref. [25]) in order to increase micronutrient content in complementary foods and avoid monotonous diet (Mitchodigni et al., 2017). Nevertheless, the application of some processing operations such as heating, soaking, germination or autoclaving reduce the effectiveness or the level of the anti-nutritive substances present in some foods [26]. Hence, the appropriate use of the species locally available and combinations of some processing could help to improve the nutritional densities of some recipes consumed by the children for a better dietary diversification and address micronutrient deficiencies in young children upon transition to complementary foods. The aim of this study was then to explore the use of *Vigna radiata (l.) Wilczek*. and *Moringa oleifera* to improve nutrient content of food recipes for 6-23-month-old children.

2. Methodology

The study took place in three (03) communes highly affected by food insecurity (FI) in the department of Atacora. The FI rates were 29.8% moderate FI and 0% severe FI in Toucountouna, 23.4% moderate FI and 4.4% severe FI in Natitingou, 25% moderate FI and 1.5% severe FI in Tanguiéta [27]. In each commune, one village was selected based on the availability of *Vigna radiata* and *Moringa oleifera*; a fourth village was selected for the pretest. The nutritional analysis was done at the Laboratory of Food Sciences (LSA) and Laboratory of Analytical Chemistry and Drug Analysis (LCAM) of the University of Abomey-Calavi (UAC). This study was carried out in four (04) main phases, which are: formulation and calculation of the nutritional values of the recipes, the acceptability test, analysis of nutritional values and determination of cover rates of daily nutritional requirements.

2.1. Selection of recipes for formulation

For the valorization of the targeted plant species, two recipes consumed by households were selected on the basis of food consumption survey (FCS) previously conducted (data not yet published) in the study area. Two of three criteria below were applied to select each recipe: (1) The main ingredients of the recipes are locally available from own production or the local markets (2) The recipe is not widely consumed in the area (not consumed regularly and by a large number of children and women of childbearing age) but probably has a high nutritional density or (3) The recipe is widely consumed in the community (consumed regularly and by a large number of children and women of childbearing age) but probably has a low nutritional density. Based on these criteria, the first recipe namely «*abobo*» was selected based on the criteria 1 and 3 and the second recipe namely «*zankpiti*» was selected based on criteria 1 and 2 for formulation. Both were two cowpea-based recipes. *Abobo* consists of boiled cowpea seeds with salt and chili pepper; it is consumed with shea butter and/or gari (dried fermented cassava). *Zankpiti* is also cooked from cowpea seeds; after boiling and seasoning with salt, chili pepper, shea butter and roasted maize flour is added.

2.2. Ingredients for the improved recipes

Mung bean (*Vigna radiata (l.) Wilczek)* was the specie used to substitute cowpea in the two selected recipes. Moringa leaves *(Moringa oleifera)* were also added to the *abobo* recipe for improving its nutritional value. In addition to chili pepper and salt used, others ingredients such as tomato, onion, black pepper, garlic and red palm oil were added to the recipes not only to improve the nutritional value but also the taste of the recipes. All ingredients used were purchased in local markets or directly harvested.

2.3. Recipe formulation

The Food Consumption Survey database served as a basis to fix the quantities of the ingredient used during the formulation of the new recipes based on *Vigna radiata* and *Moringa oleifera*. Theoretical recipe formulation was done using a mixing plan (Benlemmane et *al.,* 2018) to determine the quantities of ingredients needed to obtain nutritionally dense recipes in energy and micronutrients (rich in vitamin A, iron, calcium, zinc). These micronutrients were selected as a public health issue in developing countries [28]. The "extreme summit" constraints (where the lower and upper bounds of the components of the recipe are defined) without repetition were chosen for the mixing design set with MINITAB 18.0 software. For each recipe, two factors (two main ingredients of the recipe) were considered. The bounds of the factors per 100 g of the recipe were set according to the quantities used in the recipe. The quantities of other ingredients were kept fixed for each recipe and five (05) trials were generated by the mixing plan (Table 1).

The different trials were reconstituted to determine the final weights (Pf) of the recipes after preparation. The mixed method was used to calculate estimated nutritional values (NV) according to the following formulas (EuroFir, 2008):

(1) NV cooked ingredient = NV raw ingredient *FRT
with NV = nutritional value and FRT = retention factor;
(2) NV ingredients recipe = Quantity ingredient recipe *NV cooked ingredient)/100;
(3) NV recipe = ∑NV ingredient recipe *FRD recipe
with FRD = yield factor of recipe; ***FRD=Pf/Pi*** (with Pf = final weight of a recipe combination obtained after reconstitution and Pi = Initial weight of ingredients of recipe).

The nutritional values of the different formulations were related to 100 kcal of energy of the recipe in order to calculate the nutrient densities (ND) according to the formula:

(4) *ND= (VN recipe/Quantity energy recipe)* * 100 Kcal

The energy density (ED) is the energy content per unit weight. It was expressed per gram of recipe:

(5) ED = Quantity energy recipe/100

The different ingredients used, the step of their integration, the technological step of preparations, the couple of time/temperature applied for cooking both *ZM* and *AMM* were described below (Fig. 1):

2.4. Optimization

After validation of the model, each recipe was optimized based on the calculation of the estimated nutrient densities. The energy and nutrient densities (vitamin A, iron, calcium and zinc) of each optimized food recipe met the requirements (Table 2) for children aged 6–23 months consuming an average of three meals per day as recommended by Ref. [29]. The constraints were set to minimize estimated densities that exceeded the recommendations and to maximize estimated densities that did not reach the recommended standards.

2.5. Determination of the nutritional values of optimized recipes

In order to avoid problems related to the preservation of samples from the field to the analysis laboratory, the recipes were reconstituted at the Laboratory of Food Sciences (LSA). For that, ingredients of the recipes were collected in the study area and ingredients such as tomato, chili, onion, leaves were preserved in coolers at 4°C from the field to the laboratory (1 day of transportation) while the legume seeds were preserved in hermetically packed bottles during the transport [30,31]. Each formulated recipe was cooked in triplicates for their physico-chemical assessment.

Total energy was determined by the calorimetric method (ISO 1928–2009). Dry matter content and ash content were assessed by Ref. [32]. Mineral (iron, calcium and zinc) analysis were performed using the procedure described by Ref. [32] as follows: 2 g of samples were weighed into the porcelain crucibles and then introduced into the muffle furnace for incineration at 550 °C during 12 h. Five (5) ml of 20% hydrochloric acid were added to the ash and heated. The solution was filtered through a Whatman paper previously rinsed with acid and diluted with bidistilled water in 50 ml tubes. The mixture was submitted for Atomic Absorption Spectrometer (Perkin Elmer Element A200) analysis. Absorbance was measured against blank (HNO3.1%) at 248.3 nm and 213.9 nm wavelength for iron and zinc respectively and at 424.7 nm for calcium. For vitamin A determination, the extraction procedure for beta-carotene developed by the Laboratory of analytical chemistry and drug analysis (LCAM) was used. For the preparation of the 1 mg/mL reference solution, about 10 mg of beta-carotene were weighed in a 10 mL volumetric flask and then dissolved in acetonitrile (5min ultrasound) and homogenized. The dilution was made to 1/10 of this solution (1 mL of the latter solution was taken in a 10 mL volumetric flask and filled to the mark) to obtain a 100 μg/mL solution. Six (06) series of successive dilutions from this last solution were made, thus obtaining the following diluted solutions: 1.5 μg/mL (75 μL/5 mL), 1 μg/mL (50 μL/5 mL), 0.8 μg/mL (80 μL/10 mL), 0.4 μg/mL (40 μL/10 mL), 0.2 μg/mL (20 μL/10 mL), and 0.1 μg/mL (10 μL/10 mL). For extraction, 15 g of food matrix was taken into a mortar, triturate with a pestle until the solution becomes homogeneous. Then 10 g of crushed food matrix was weighed into a 50 mL falcon tube to which 20 mL of milli Q water was added. After thorough vortexing (for 2 min), 20 mL of

Table 1
Trials from mixture plan design.

Ingredients/100 g	Trials order	Mung bean	Maize flour	Garlic	Black pepper	Chili pepper	Onion	Small fish	Salt	Red palm oil	Water	
Zankpiti of mung bean	1	8.65	2.85	0.30	0.08	0.38	1.14	2.27	0.23	3.34	80.74	
	2	8.50	3.00	0.30	0.08	0.38	1.14	2.27	0.23	3.34	80.74	
	3	8.80	2.70	0.30	0.08	0.38	1.14	2.27	0.23	3.34	80.74	
	4	8.58	2.93	0.30	0.08	0.38	1.14	2.27	0.23	3.34	80.74	
	5	8.73	2.78	0.30	0.08	0.38	1.14	2.27	0.23	3.34	80.74	
Abobo of mung bean with moringa leaves		**Mung bean**	**Moringa leaves**	**Tomato**	**Garlic**	**Black pepper**	**Chilli pepper**	**Onion**	**Small fish**	**Salt**	**Red palm oil**	**Water**
	1	6.20	2.00	1.09	0.12	0.06	0.12	0.42	3.63	0.48	2.42	83.46
	2	6.40	1.80	1.09	0.12	0.06	0.12	0.42	3.63	0.48	2.42	83.46
	3	6.80	1.40	1.09	0.12	0.06	0.12	0.42	3.63	0.48	2.42	83.46
	4	7.00	1.20	1.09	0.12	0.06	0.12	0.42	3.63	0.48	2.42	83.46
	5	6.60	1.60	1.09	0.12	0.06	0.12	0.42	3.63	0.48	2.42	83.46

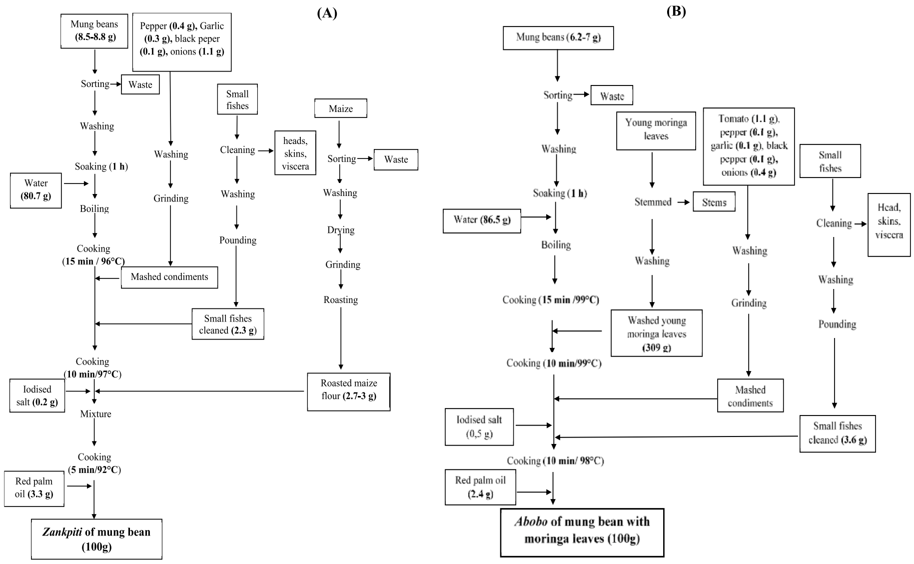

Fig. 1. Technological diagram of *Zankpiti* of mung bean (A) and *Abobo* of mung bean with moringa leaves (B) This figure presents the technological process of cooking *Zankpiti* of mung bean and *Abobo* of mung bean with moringa leaves formulated. For these two diagrams, each unit operation was recorded, the temperatures and the times as well.

Table 2
Recommended energy and nutrient densities.

Energy/Nutrients (units)	Recommended densities
Energy (kcal/g)	0.8–1
Iron (mg/100 kcal)	1.0–4.5
Calcium (mg/100 kcal)	63–105
Zinc (mg/100 kcal)	0.6–1.6
Vitamin A (μg RE/100 kcal)	23–31
Vitamin C (mg/100 kcal)	1.5–1.7
Folates (μg/100 kcal)	11–21

hexane was added, homogenized again by vortexing (for 2 min) and then centrifuged at 3500 rpm for 10 min. A quantity of 200 μL of the hexane phase was taken in a beaker and the solvent was evaporated under a fume hood. 5 mL (this volume also depends on the beta carotene content in the recipe; it varies from one recipe to another and allows to have a dilution rate that will allow to stay in the linearity of the calibration line) of the ethyl acetate/acetonitrile mixture (1:5) (V/V) were added. After homogenizing for 5 min in an ultrasonic bath, filtration in HPLC vials was done using 0.45 μm diameter filters and injected 10 μL. The three (03) tests were performed independently. The identification of vitamin A was done by comparing the retention times obtained from chemical chromatograms and UV spectra. The calculation of concentrations of vitamin A recipes (designated x) was carried out by means of the calibration line of type $y = ax+b$ (y being the area under the curve of the chromatogram and x the concentration) obtained from known concentrations of the reference.

2.6. Sensory analysis

Hedonic tests were conducted in order to evaluate the acceptability of the two formulated recipes. The tests were performed on the optimal formulations of the two recipes. The panelists, children aged 6–23 months were selected in the three communes according to the following criteria: already consuming foods, being healthy (no diarrhea/vomiting/fever in the three days before the survey) and their mothers agreeing to participate in the study. Sixty-two (62) volunteer mother-child pairs participated in the test according to sex. Then, an equal number of children were selected for each sex. All mothers signed a consent document before the test.

Children's facial expressions with five (05) levels of facial hedonic scales were used to assess the acceptability of recipes by children: don't like at all (1); don't like (2); don't care (3); like a little (4); like a lot (5) [33]. These nonverbal cues have been previously recommended (Guinard, 2000) and used by similar studies [34]. Additionally, the amount of recipe consumed by a child was also a criterion for that child's appreciation of the recipe [28,29]. A pretest was organized and consisted of simulating the different stages of the acceptability test in a control village different from the study villages but that had the same characteristics. This pretest also helped to define the quantities of recipes to be served to the children and to get an idea of the different problems that could occur during the real test.

2.7. Hedonic test procedure

Recipes were prepared on the day of the sensory test. Preparation took approximately 4 h and one recipe was tested per day in each village. The preparation of the recipes was done in collaboration with five (05) women volunteers who are used to preparing and serving meals to members of their households. The panelists (children) were installed with their mothers in a well-ventilated room where a member of the team explains the context of the study and the methodology to be followed during the test. The sensory sheet was also well explained so that the mothers could better understand what needed to be done.

Approximately two hundred grams (200 g) of each recipe was served to the children and clean water was provided for mouth rinsing. During the consumption of the recipes, each mother's role was to feed her child until satiety. Each recipe was served in a disposable dish and the quantity served was weighed before being given to the mother. Mothers were allowed to ask for more for their children if the child expressed a desire for more. The mother's role was to encourage the child to eat without consuming herself. If necessary, she was allowed to make a mime to stimulate the child to eat. Mothers were also asked not to give water or breast milk to the children during the meal to optimize ingestion capacity of children. Meal rejects were collected in a separate dish. Once the mother judged that the child was full, a member of the monitoring team measured the quantity of food remaining and the quantity of food discarded using an electronic kitchen scale (SF-400) (Range: 10 kg; Accuracy: 1 g).

The quantities of recipes consumed (QRC) by each child was calculated as follows:

QRC = Quantity of recipe served- (Remaining recipe quantity + rejects)

2.8. Focus group

A focus group was organized at the end of the acceptability test with the five (05) women who helped to prepare the recipe [35]. The purpose of the focus group was to get more information about possible ways of integrating the recipes into the family meals. As all ingredients used were available in their area and some of these ingredients were cultivated by the focus group participants, the discussion focused on estimating cost of the formulated recipes in a household of seven (07) people (average household size in the study) [31] if all the ingredients were purchased. Each focus group was conducted by a moderator and a village guide for translation. The recorded focus group data were transcribed and then analyzed.

2.9. Contribution to the coverage of energy and nutrients requirements

The quantities of recipes consumed were used to calculate the energy/nutrients intakes considering the nutritional values of each recipe.

$$Nutrients\ intake = (Nutritionnal\ value\ (per\ 100g)\ *\ Quantity\ consumed)/100 \quad (1)$$

Then, based on the micronutrients (iron, zinc, calcium, vitamin A) or energy intakes and the recommended daily intakes for each child according to age and sex [24,32], the contribution of *zankpiti* of mung bean and *abobo* of mung bean and moringa leaves to the coverage of the children's needs in iron, zinc, calcium, vitamin A and energy was determined:

$$Coverage\ rate = (Micronutrients\ intake\ or\ energy\ intake\ /\ Micronutrient\ or\ energy\ daily\ requirements)\ *\ 100 \quad (2)$$

2.10. Statistical analysis

Data were processed with Excel (Microsoft Office 2019) spreadsheet and Minitab 18 software. Excel was used to convert laboratory data to numerical scores. The ratings of responses for each sample of recipes were tabulated and a flat sort of individual variables was performed with Minitab to determine the percentages of children who liked or disliked the recipes. The comparison was also done function of sex. Minitab 18 software was used to generate the mixture design and validate the model through checking the coefficient of determination R^2 for each response obtained. SPSS software was used for on sample *t*-test to check if the nutritional densities met the recommendation standards. A comparison of means was made using independent sample *t*-test to verify the significance between the quantities ingested and the cover rates of the daily needs depending on the children's age groups. The normality and homogeneity of variances were respectively tested using Kolmogorov-Smirnov test and Levene test. The non-parametric Mann Whitner test was performed on data that did not meet the normality conditions. A significant difference was accepted at $p < 0.05$.

3. Results

3.1. Participant characteristics

All mothers whose children were included in the study were between 18 and 45 years of age and their main and secondary activities were agriculture, processing, crafts work and small-scale trade. As for the children, 50% were girls and the other 50% were boys; most of them (80.65%) were between 12 and 23 months old. All children were already consuming complementary foods and were apparently healthy. The most dominant socio-cultural group was *Waama* (Table 3).

3.2. Calculation of estimated nutrient densities

The calculated energy densities (ED) for the five *ZM* mixtures (Table 4) ranged from 1.64 to 2.11 kcal/100 g and met the recommended standard (ED: 0.8–1 kcal) for children aged ranging from 12 to 23 months [29]. Highest energy density value was obtained from the mixture (1) composed of 8.65% mung bean and 2.85% maize flour. The calculated nutrient densities vary from 271.52 to 271.57 μg RE/100 kcal for vitamin A, 66.36–66.76 mg/100 kcal for calcium, 1.13–1.14 mg/100 kcal for iron and 0.60–0.61 mg/100 kcal for zinc. The calculated nutrient densities met the recommendations for vitamin A, calcium, iron and zinc for targeted children (Dewey & Brown, 2003). The combination (3) composed of 8.8% mung bean and 2.7% maize flour presented the highest nutrient densities of vitamin A (271.57 μg RE/100 kcal), calcium (66.76 mg/100 kcal), iron (1.14 mg/100 kcal), and zinc (0.61 mg/100 kcal).

As far as *AMM* is concerned, the energy densities calculated for the five mixtures ranged from 1.337 to 1.651 kcal/100 g and met the recommended standard for the targeted children (Table 4) [29]. The highest energy density was obtained from the combination (5) formulated with 6.6% of mung bean and 1.6% of moringa leaves. The

Table 3
Socio-demographic characteristics of children and their mothers.

Caracteristics	n (%)
Children	
Age of children (months)	
6–11	12 (19.35)
12–23	50 (80.65)
Sex	
Male	31 (50)
Female	31 (50)
Mothers	
Age of mothers (years)	
<18 years	0 (0)
18–49 years	62 (100)
Principal activities of mothers	
Agriculture	30 (52.62)
Food processing	14 (24.56)
Crafts (Couture, Hairdressing, weaving)	7 (12.26)
Student	1 (1.75)
Secondary activities of mothers	
Agriculture	22 (40.34)
Food processing	22 (42.31)
Small commerce	8 (15.38)
Handicraft	1 (1.92)
Ethnics groups of children and mothers	
Bariba	1 (1.79)
Ditamari	2 (3.57)
Natemba	2 (3.57)
Waama	50 (89.29)
Others	1 (1.79)

Table 4
Quantities of main ingredients and estimated nutrient density (ND) for ZM and AMM recipes mixtures.

Zankpiti of mung bean	Trials order (Wet basis)	Mung bean	Maize flour	Energy (kcal/g)	Vitamin A (μg RE/100 kcal)	Calcium (mg/100 kcal)	Iron (mg/100 kcal)	Zinc (mg/100 kcal)
	1	8.65	2.85	2.11	271.55	66.56	1.14	0.61
	2	8.50	3.00	1.64	271.52	66.36	1.13	0.60
	3	8.80	2.70	1.70	271.57	66.76	1.14	0.61
	4	8.58	2.93	2.10	271.53	66.46	1.13	0.60
	5	8.73	2.78	1.82	271.56	66.66	1.14	0.61
Abobo of mung bean with moringa leaves		**Mung bean**	**Moringa leaves**	**Energy (kcal/g)**	**Vitamin A (μg RE/100 kcal)**	**Calcium (mg/100 kcal)**	**Iron (mg/100 kcal)**	**Zinc (mg/100 kcal)**
	1	6.20	2.00	1.44	362.69	156.55	1.65	0.79
	2	6.40	1.80	1.34	353.27	153.22	1.62	0.79
	3	6.80	1.40	1.48	334.98	146.76	1.58	0.79
	4	7.00	1.20	1.61	326.11	143.63	1.56	0.79
	5	6.60	1.60	1.65	344.03	149.96	1.60	0.79
Recommended densities				**0.8–1**	**23–31**	**63–105**	**1.0–4.5**	**0.6–1.6**

calculated nutrient densities ranged from 326.11 to 362.69 μg RE/100 kcal for vitamin A, 143.625–156.554 mg/100 kcal for calcium and 1.562–1.646 mg/100 kcal for iron. Zinc density was similar for all combinations (0.79 mg/100 kcal). These values obtained also met the recommended nutrient densities for targeted children [29] and the combination (1) obtained from 6.2% mung bean and 2% moringa leaves had the highest nutrient densities in vitamin A, calcium and iron.

3.3. Validity of the recipe's models

Coefficient of determination R^2 sets the ratio of the variation in responses that is explained by the model. The nearer the R^2 value is closed to 1, the better the model's quality of fit. The analysis of variance of the two recipes showed that the mixture design developed for vitamin A, calcium, iron and zinc is adequate ($R^2 > 70\%$). However, the mixture design developed for energy density is only adequate for *ZM* recipe. Energy density of *AMM* has not been considered during the optimization of the recipes (Table 5).

3.4. Recipe optimized

In agreement with the model, the optimal combination for obtaining *ZM* with energy and nutrient densities close to the recommended standard is that obtained by combining 8.8% mung bean and 2.7% maize flour (Trial 3). Similar approach was used for optimization of *AMM* recipe. The optimal combination for obtaining *AMM* having energy and nutritional densities close to the recommended standard is that obtained by combining 6.2% mung bean and 2% moringa leaves (Trial 1) (Table 6).

3.5. Acceptability of recipes optimized

The results showed that there is no significant difference between overall acceptability of children for both recipes ($p > 0.05$) with 83.33% and 82.69% of children who liked a lot while 13.33% and 13.46% who liked slightly *AMM* and *ZM* recipes respectively (Fig. 2). No significant difference was also observed according to gender for any of the recipes ($p > 0.05$). The average quantities of recipes consumed also showed that all children consumed more than half of the quantity of each recipe served (158.23 g for *ZM* and 140.37 g for *AMM*). This implied, according to the mothers, that the different recipes offered were very much appreciated by the children (Table 8).

Table 5
Coefficients of determination R^2 of the recipes responses models.

Parameters	Energy	Vitamin A	Calcium	Iron	Zinc
R^2 (%) *ZM*	79.25	100	100	100	100
R^2 (%) *AMM*	35.17	100	100	100	100

Table 6
Responses optimization.

	Abobo of mung bean with moringa leaves		Zankpiti of mung bean	
	Objective	Predicted	Objective	Predicted
Factors				
Mungo bean		6.2%		8.8%
Moringa leaves		2%		
Maize flour				2.7%
Responses				
Energy_kcal	Minimum	1.40	Minimum	1.63
Vitamin A_μg RE	Minimum	362.68	Minimum	271.57
Calcium_mg	Minimum	156.55	Maximum	66.75
Iron_mg	Maximum	1.64	Maximum	1.14
Zinc_mg	Maximum	0.79	Maximum	0.61

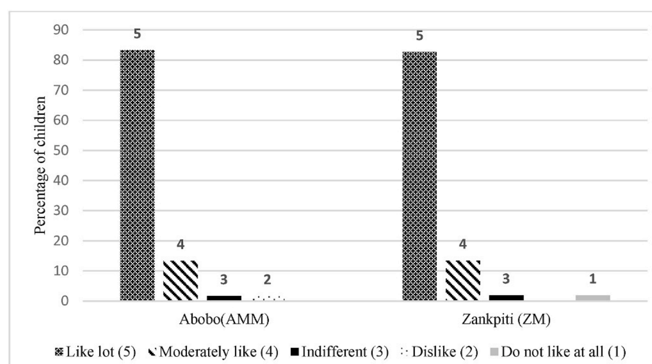

Fig. 2. Overall acceptability of children for *Abobo* of mung bean with moringa leaves and *Zankpiti* of mung bean This figure presents the percentage of children function of their overall acceptability for *Zankpiti* of mung bean and *Abobo* of mung bean with moringa leaves. Five levels of acceptability were used: like a lot, moderately like, Indifferent, dislike and do not like at all.

3.6. Nutritional values and nutrient densities of the recipes optimized

The results of nutritional analysis showed that *zankpiti* and *abobo* of mung bean formulated contained respectively 203.86 ± 0.23 and 172.33 ± 8.97 kcal/100 g of total energy, 0.61 ± 0.01 and 0.70 ± 0.03 mg/100 g of total minerals, 5.91 ± 0.20 and 9.83 ± 0.52 mg/100 g of calcium, 1.74 ± 0.26 and 0.52 ± 0.00 mg/100 g of iron, 0.79 ± 0.02 and 0.18 ± 0.00 of zinc and 2211.95 ± 6.41 and 1768.5 ± 41.3 μg RE/100 g of vitamin A (Table 7).

Regarding the nutritional densities, *ZM* and *AMM* recipes had respectively 2.03 ± 0.02 and 1.72 ± 0.08 kcal/g for energy, 2.90 ± 0.09 and 5.71 ± 0.44 mg/100 kcal for calcium, 0.85 ± 0.12 and 0.30 ± 0.01 mg/100 kcal for iron, 0.38 ± 0.00 and 0.11 ± 0.00 for zinc and 1085.18

Table 7
Nutritional composition of *ZM* and *AMM*.

Parameters (wb)	Zankpiti of mung bean	Abobo of mung bean with moringa leaves
Dry matter (%)	35.84 ± 0.23	31.86 ± 0.70
Total energy (kcal/100g)	203.86 ± 2.58	172.33 ± 8.97
Crude proteins (g/100g)	8.93 ± 0.52	10.14 ± 0.16
Lipids (g/100g)	7.44 ± 0.26	6.56 ± 0.42
Crude fibers (g/100g)	1.75 ± 0.32	1.99 ± 0.33
Total polyphenols (g/100g)	0.16 ± 0.01	0.20 ± 0.01
Total minerals (g/100g)	0.61 ± 0.01	0.70 ± 0.03
Calcium (mg/100g)	5.91 ± 0.20	9.83 ± 0.52
Iron (mg/100g)	1.74 ± 0.26	0.52 ± 0.00
Zinc (mg/100g)	0.79 ± 0.02	0.18 ± 0.00
Vitamin A (ug RE/100g)	2211.95 ± 6.41	1768.5 ± 41.3

Values presented are Mean±Std Deviation; **wb**: Wet base

Table 8
Nutritional densities of recipes of recipes optimized.

Recipes (Wet base)	Energy (Kcal/g)	Calcium (mg/100 Kcal)	Iron (mg/100 Kcal)	Zinc (mg/100 Kcal)	Vitamin A (ug RE/100 kcal)
Zankpiti of mung bean	2.03 ± 0.02	2.90 ± 0.09	0.85 ± 0.12	0.38 ± 0.00	1085.18 ± 14.56
Abobo of mung bean with moringa leaves	1.72 ± 0.08	5.71 ± 0.44	0.30 ± 0.01	0.11 ± 0.00	1028.8 ± 74.1
Recommended densities	**0.8–1**	**63–105**	**1–4.5**	**0.6–1.6**	**23–31**

Values presented are Mean±Std Deviation

± 14.56 and 1028.8 ± 74.1 μg RE/100 kcal for vitamin A. Comparison of the nutritional densities with the recommendations showed that only the energy density and nutritional density in vitamin A of both optimized recipes met the recommended standards ($P < 0.05$) (Table 8).

3.7. Contribution of the recipes to the daily needs of the children and recipe cost

The average quantities of *ZM* recipe ingested were 85.81 ± 61.16 g and 174.00 ± 109.53 g respectively for children aged 6–11 and 12–23 months while the average quantities of *AMM* recipe ingested were 146.75 ± 119.70 g and 142.43 ± 78.89 g respectively for children aged 6–11 and 12–23 months. No significant difference was founded between the average quantities ingested for *AMM* recipe depending on age ($P > 0.05$) contrary to *ZM* recipe ($p < 0.05$) (Table 9). The highest cover rates of daily micronutrient needs achieved after consumption of *ZM* recipe were 37.64 ± 25.56% for energy, 15.82 ± 10.75% for zinc, 24.94 ± 16.94% for iron and 919.43 ± 624.82% for vitamin A. These cover rates were achieved for children aged 12–23 months. A significant difference was observed between the cover rates of daily requirements of children aged 6–11 and those aged 12–23 for iron, zinc and vitamin A ($p < 0.05$). As for the *AMM* recipe, the highest cover rates of daily micronutrients needs achieved after consumption were respectively 36.36 ± 30.73 for energy and 655.38 ± 537.07% for vitamin A. These cover rates were achieved for children aged 6–11 months. No significant difference was found between the cover rates of daily micronutrients need by children aged 6–11 and those aged 12–23 ($p > 0.05$). Furthermore, no significant difference was also observed according to gender for any of the recipes.

4. Discussion

The gap between the nutritional needs of children and the intake of breast milk must be filled by the supply of good quality complementary foods to ensure growth and development. From 6 months, infants can eat pureed, mashed and semi-solid foods prepared from cereal, vegetables, fruits, meat, and other protein-rich foods [36]. From 8 months, most infants are able to eat "finger foods". Two recipes based on mung bean and moringa leaves have been formulated and evaluated in the present study. Both recipes were generally well accepted by mothers and children. Since the amount eaten is also a criterion of acceptability, Lutter and Dewey [37]. found that the average recommended amount of complementary food per serving for a child aged 6–24 months is 50 g. In this study, the average amounts of 140.37 g and 158.23 g for *AMM* and *ZM*, respectively were consumed by the children. Then, it can be stated that these recipes were well accepted by the children, which was also supported by the acceptability test carried out. Then, Bugizzi et al. [38] equally evaluated the acceptability of two recipes formulated from the common bean by the quantities consumed by the children and found that the average quantities consumed of both food supplements were more than 50 g, indicating that both recipes were well acceptable. The discussion with mothers during the acceptability test revealed that the presence of maize flour, moringa leaves, spices, fish and especially red palm oil provides a good taste, odor and color to the recipes. A study conducted in Tanzania showed a high appreciation for similar parameters by the children for improved recipes based on dried beans, amaranth leaves and red palm oil [39]. Glover- Amengor et al. [40] enhanced meals such as *wakee* (cowpea and rice), groundnut soup and jollof rice using local ingredients and moringa leaves and achieved high

Table 9
Average quantity ingested and contribution of recipes to the coverage of daily recommendations of zinc, calcium, iron and vitamin A of children aged 6–23 months.

Categories Parameters		Age groups			Sex		
		6–11 months	12–23 months	P value	Male	Female	P value
Zankpiti of mung bean							
Average quantity ingested (g)		85.81 ± 61.16	174.00 ± 109.53	**0.02***	*161.38 ± 21.41*	*156.10* ± 21.24	**0.24**
Coverage rate of daily recommendations (%)	Energy	22.07 ± 17.79	37.64 ± 25.56	**0.07**	34.09 ± 23.58	34.95 ± 26.99	**0.90**
	Zinc	7.60 ± 6.39	15.82 ± 10.75	**0.02***	13.89 ± 10.66	14.25 ± 10.78	**0.89**
	Calcium	1.20 ± 1.02	1.96 ± 1.33	**0.09**	1.87 ± 1.30	1.77 ± 1.33	**0.78**
	Iron	7.22 ± 5.96	24.94 ± 16.94	**0.00***	21.10 ± 17.09	22.31 ± 17.11	**0.79**
	Vitamin A	431.91 ± 357.35	919.43 ± 624.82	**0.02***	833.04 ± 610.09	825.22 ± 114.27	**0.96**
***Abobo* of mung bean with moringa leaves**							
Average quantity ingested (g)		146.75 ± 119.70	142.43 ± 78.89	**0.67**	*140.66* ± 16.64	*129.31* ± 15.78	**0.23**
Coverage rate of daily recommendations (%)	Energy	36.36 ± 30.73	26.05 ± 15.87	**0.67**	29.89 ± 19.29	26.34 ± 20.57	**0.49**
	Zinc	3.27 ± 2.74	2.96 ± 1.78	**0.85**	3.27 ± 1.90	2.68 ± 2.09	**0.25**
	Calcium	3.79 ± 3.20	2.68 ± 1.61	**0.65**	3.22 ± 2.09	2.58 ± 1.98	**0.22**
	Iron	4.10 ± 3.34	6.11 ± 3.69	**0.09**	5.92 ± 3.28	5.50 ± 4.09	**0.66**
	Vitamin A	655.38 ± 537.07	603.43 ± 364.18	**0.86**	661.97 ± 375.67	565.67 ± 423.47	**0.35**

Values presented are Mean±Std Deviation; * significant at the 5% level acceptability by children. On the other hand, all those ingredients were the local ingredients that they are accustomed to use in their communities. This affirmation was supported by Abamecha [41] by the fact that foods formulated from locally available ingredients are accepted and thus, do not present challenges to consumers. However, there was a minority of children who moderately liked the recipes since some children preferred porridge to family foods [41]. It can be due to the fact that at this stage, infants prefer soft and smooth textured food which requires minimal oral manipulation before it is swallowed and as their oral feeding skill develops, infants can begin to orally handle semi-solid foods [42].

For ensuring optimal health, growth, and development of infants and young children, adequate intakes of micronutrients, such as iron, zinc, and calcium, are essential [43]. Both of the recipes formulated had excellent estimated nutritional densities. Laboratory analysis showed that the energy densities of the recipes were adequate for both recipes. These results were similar to those obtained by Madodé et al. [44] who formulated *zankpiti* based on cowpea (*Vigna unguiculata*), a legume of the same genus as mung bean (*Vigna radiata*). This result would have been due to the high proportion of the main ingredients in the recipes (mung bean, maize flour and red palm oil).

However, despite favorably estimated nutrient densities, both recipes, when prepared and subsequently analyzed for nutrient content in the lab, showed low nutrient densities and hence did not meet the standard recommendations for iron, calcium and zinc. The same results were noticed for the nutritional densities of calcium obtained by Madodé et al. [44]. Furthermore, Ogboyonna et al. [45] also formulated several complementary foods with a lot of ingredients including beans and noticed that only one of the meals met the recommendations only for zinc. This could be due to some technological operations that might lead to a loss of micronutrients. Then, Mubarak [46] showed that processes such as dehulling, soaking and cooking on *Vigna radiata* seeds could lead to mineral losses even though soaking and dehulling promotes the bioavailability of minerals in the seed. A study conducted by Mubarak [47] found that heating treatments, such as cooking of legumes causes the loss of minerals such as calcium, iron and zinc. Additionally, it is also important to notice that, legumes contain components such as polyphenols or phytates that reduce the bioavailability of minerals [48]. Regarding the cover rate of daily needs of children, contrary to the *AMM* recipe, *ZM* recipe covered levels of 15–24% for iron and zinc. Amoussa-Hounkpatin [4] and Mitchodigni [49] in their studies obtained higher cover rates while improving traditional recipes, including cowpea-based "Zankpiti", also known as "Aïtoutou". Estimated cover rates for iron, zinc and calcium needs of children aged 6–23 months, ranged from 37 to 92%, 18–68% and 85–212% respectively. *Zankpiti* was a recipe that appeared to be the ideal dish that could ensure intakes of these micronutrients in the complementary diet of children [49]. Vitamin A content was very high compared to the recommended daily intake of vitamin A for children aged 6–23 months. This could be explained by the use of red palm oil that contains 11 400 μg RE/100 g (vitamin A) [50] and is the richest natural source of β-carotene, a carotenoid that the human body can convert into retinol. Palm oil has a high efficacy in improving vitamin A status in populations at risk of vitamin deficiency [51]. Furthermore, the red palm oil is added towards the end of cooking to better maintain the vitamin A content in each recipe. This is in line with the results of [52]who found that the addition of palm oil at the end of cooking contributed to carotenoid preservation. It should also be noted that other recipes such as *fufu* of ripe and unripe plantain with red palm oil, cassava leaf sauce with fish, vegetables and red palm oil prepared in Burkina Faso, a west African country, contained a very high vitamin A content respectively of 2630 μg RE/100 g and 1510 μg/100 g. In addition, moringa leaves contain a significant amount of β-carotene [53] that could improve vitamin A content of recipes.

It important to highlight that whether children have eaten *ZM* or *AMM,* one recipe alone cannot necessarily cover a child's entire daily micronutrients needs. For foods containing recommended minimum energy density (0.8 kcal/g), assuming gastric capacity of 30 g/kg body weight, the meal frequency expected to provide adequate daily energy requirement is about two to three times for 6–8, and three to four times for 9–11 and 12- to 24-month-old children, with one to two nutritious [29]. It is therefore necessary to add other micronutrient-rich recipes in order to allow children to cover all of their recommended daily requirements.

Regarding the cost of diet, all ingredients purchased were about 2500 FCFA (3.88 $) for each recipe with quantities about 9 kg and 5.8 kg respectively for *AMM* and *ZM* to eat once by a household of seven (07) people. However, most ingredients such as tomatoes, peppers, onions, moringa and even mung bean which are increasingly promoted in the study area, are grown by households. Only theothers ingredients such as garlic, pepper, salt, small dried fish and red oil will be purchased on the market for the preparation of the recipes. Hence, it is a good poiin the introduction of these recipes in family meals within the households Agriculture is the main activity of one-third of rural households, and provides a monthly income of 6652 FCFA (9.79 €) for each person in a household of an average of seven people [27]. Based on focus group discussions, households in the study area could replicate these recipes considering the fact that almost all the ingredients come from their own production.

5. Study limitation and recommendations

A limitation of the study was the use of the West African composition table in recipe formulation and estimation of nutritional values. It would have been more interesting to use a Beninese composition table or foods nutritional composition data-based for more precision in the estimated values. Unfortunately, Benin currently does not have a food composition table and this obliged researchers to use the West African composition table or other tables for precise nutritional values assessment. Schakel et al. [54] also stated that the most desirable validation of nutrient estimation methods is the direct comparison of the estimated values with the values obtained and analyzed in laboratory for the same food.

As for recommendations, the formulated recipes need to be promoted through community-based nutrition education sessions. In addition to being an excellent source of energy and vitamin A, they can also cover significant levels of daily iron and zinc requirements when consumed in adequate quantities by children. Then, cooking sessions could be organized with mothers to help them to learn the preparation technology [55]. Education materials such as posters and videos can also be developed based on the improved recipes as suggested and tested in a nutrition program in Southern Benin [56]. It is also necessary to include fruits and vegetables in the children diet, to supplement the intake of minerals and vitamins [57]. In addition, it is strongly recommended for people to follow WHO recommendations stating to continue breastfeeding until the age of 2 years, because the contribution of breast milk is still valuable even at this age when children have access to family meals [7]. Breastfeeding practices were almost medium in Benin and, thus, still need to be improved through nutrition intervention program including nutrition education [58].

6. Conclusion

The present study evaluated the use of *Vigna radiata* and *Moringa oleifera,* both nutritionally dense local plant species, for formulation and development of recipes for children aged 6–23 months in Atacora Department, Northern Benin. The two recipes formulated have good estimated energy and nutritional densities as well as good energy and nutritional densities in vitamin A. Both recipes were well accepted by the children aged 6–23 months. However, their nutritional densities, as per the laboratory analyses, in terms of calcium, iron and zinc should be improved to allow a better cover rate of daily nutritional requirements. These findings suggest the needs for setting alternative interventions which can help households increase access to nutrient-dense foods that can fill the nutrient gaps noticed.

Ethics approval and consent to participate

This study was conducted according to the guidelines laid down in the Declaration of Helsinki. All procedures involving research study participants were approved by the Benin National Health Research Ethics Committee (CNERS-www.ethique-sante.org) with ethical approval number No.46 of November 07th' 2019 and reference number No_093/MS/DC/SGM/DRFMT/CNERS/SA. A permission letter was obtained from each selected children's mothers. Written informed consent was obtained from all mothers for the acceptability test after receiving complete information about the study in the local language.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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