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Phytochemical composition and nutritional properties of a weaning food produced from tigernut (*Cyperus esculentus*), white beans (*Phaseolus vulgaris*) and African locust bean pulp (*Parkia biglobosa*) flours, three foods consumed in Northen of Côte d'Ivoire

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Abstract

The aim of this study is to contribute to fight against child malnutrition in Côte d'Ivoire. For this purpose, a weaning food is formulated. Three local foods tigernut (*Cyperus esculentus*), white bean (*Phaseolus vulgaris*) and African locust bean (*Parkia biglobosa*) cultivated and consumed in northen of Côte d'Ivoire are used. The methodology used included a biochemical analysis of ingredients and the formulation using the matricielle method to generate proportions of ingredients to be mixed to obtain the required nutrient content. Phytochemical analysis of formulated weaning food showed that contents of total phenolics, flavonoïds, tannins, oxalates and phytates are 52.27 mg/100g, 16.25 mg/100g, 8.18 mg/100g, 22.6 mg/100g and 0.07 mg/100g respectively. Biochemical composition showed that contents of moisture, ash, lipids, proteins and total glucides are 5.27%, 3.03%, 15.63%, 12.67% and 63.41% respectively. The comparison with a standard weaning food shows that the contents in nutrients are satisfactory and corresponding to the standard fixed for complementary foods. The ratios Na/K and Ca/P are less than one (0.09) and above one (3.07) respectively. The formulated weaning food has low [oxalate] / [Calcium], [phytate] / [Zinc], [phytate] / [Iron], [phytate] / [Calcium], ratio values. Given its nutritional potential, this formulated weaning food shall be recommended for child's complementary feeding.

Keywords: weaning food, malnutrition, local foods, Côte d'Ivoire

Introduction

Malnutrition persists in many developing countries despite abundant global food supplies. The World Health Organization has been concerned about this trend, particularly PEM (Protein-Energy Malnutrition) and micronutrient deficiencies among infants and children [1]. Faced with malnutrition, several strategies are promoted internationally by many authorities to prevent and fight against this scourge. Complementary foods play a vital role on child growth and development since it complements for both nutritional and developmental needs of the infant when breast milk alone is no longer sufficient [2]. In developing countries, poor families and low income earners find it difficult to purchase highly nutritious commercially formulated brands of weaning food. Therefore, they resort to patronizing high starchy gruels which contain low protein and essential minerals as weaning diet in order to meet the nutritional requirements of a growing child considering the purchasing power of most families in developing countries.

The FAO/WHO (2008) [3] recommends that complementary foods be made from available and accessible local products and of sufficient nutritional quality to meet the nutritional needs of the child. The valorization of plant resources is a strategy to fight effectively against the nutritional deficit because of their exceptional nutritional qualities [4]. The use of cheap and highly proteinous weaning food formulated using underutilized readily available raw materials such as tigernut, white beans and African locust bean pulp flours becomes a good alternative.

Tiger nut has been cultivated over a long period of time in South Europe and West Africa for its small tuberous rhizomes, which can be eaten raw, roasted, dried, baked or processed into Tiger-nut milk [5]. It is a swe*et al*mond-like tuber that has long been recognized for their health benefits as they have a high content of soluble glucose and oleic acid, along with high energy content (starch, fats, sugars and proteins), they are rich in minerals such as phosphorous and potassium, calcium, magnesium and iron necessary for bones, tissue repair, muscles, the blood stream and for body growth and development and rich in vitamins E and C [6]. The tubers have a relatively high total antioxidant capacity, because they contain considerable amounts of water-soluble flavonoid glycosides. Consumption of antioxidants could protect the immune system of malnourished populations [6]. Also the use of tiger nut products (such as biscuits, flour, milk etc.) should be recommended in children because it helps to reduce protein-calorie malnutrition, since it is rich in nutritional content [7].

Complementary foods in most developing countries are based on staple cereals or root crops [2]. Tigernut can be used as a replacement for cereals to function as a weaning formula [8].

African locust bean (*Parkia biglobosa*) is a perennially grown leguminous plant with fruits containing sweet pulp and seeds [9]. The tree grows widely in many parts of the Sahel, particularly, the drier parts of West Africa [10]. *Parkia biglobosa* is also known as dawadawa in Hausa, African locust bean in English, Igba/Iyere in Yoruba and Nere in Bambara. The seed of African locust bean, which is a grain legume, is one of the most useful parts of the plant and serves as a source of useful ingredients for consumption. The seeds are known to be rich in protein, edible oil and contain easily digestible calcium, hence the locust bean is important especially for Third World countries where protein malnutrition is a problem and there is a growing need for protein supplementation among both adults and infants [11]. A mature pod contains yellow, dry and powdery pulp in which dark brown seeds are embedded. While the seed has been extensively studied [12]. African locust bean pulp, which constitutes about 60-70% of the pod [13], has not attracted much attention in terms of research and utilization [14]. In view of its availability, nutrition and health benefits, it is important that, the yellow powdery fruit pulp which is used sparingly be incorporated into most of our food products [15].

Worldwide, common beans (*Phaseolus vulgaris*) are the most important legumes in terms of production and consumption. Legumes have a great potential in the alleviation of protein energy malnutrition due to their relatively high levels of proteins and carbohydrates among other nutrients. The proteins from legumes are rich in lysine, the limiting amino acid in most staple cereal grains such as maize and rice, making it a good complement in providing a balanced amino acid ratio. Legumes are a relatively cheaper source of protein in the human diet, compared to the relatively more expensive animal protein sources [16].

Material and Methods

1. Source of Raw Materials

Tigernut tubers (*Cyperus esculentus*) varieties yellow, white beans seeds (*Phaseolus vulgaris*) and African locust bean pods (*Parkia biglobosa*) were purchased from local market in Korhogo, Côte d'Ivoire.

2. Methods

2.1 Processing of tigernut tubers Flour

Tigernut tubers were selected and cleared of all foreign matter (sand, pieces of wood, pebbles) and visible damaged tubers. After this step, sorting by flotation was used to allow better separation of the different compounds in the sample. Spoiled or necrotic tubers and lighter plant debris float while healthy tubers, generally heavier, settle to the bottom of the container. The healthy tubers are then collected, washed by stirring to remove impurities before rinsing them and then finally drying them. The dried tubers were roasted in an oven at a temperature of 130 ° C for 30 min. the tubers manually freed of their skins and by winnowing are milled into flour in an electric blender. Flour is sieved using 0.5 mm sieve, packaged in tightly polyethylene bags at -18 °C until used.

2.2 Processing of white beans seeds Flour

White beans seeds were selected, cleared of all foreign matter (sand, pieces of wood, pebbles) and visible damaged seeds. After this step, sorting by flotation was used to allow better separation of the different compounds in the sample. Spoiled or necrotic seeds and lighter plant debris float while healthy seeds, generally heavier, settle to the bottom of the container. The healthy seeds are then collected, and were soaked in tap water for 3 hours then drained. These seeds were then dried in an oven at 65°C for 48 hours, roasted at 120°C for 20 minutes. The seeds manually freed of their skins and by winnowing are milled into flour in an electric blender. Flour is sieved using 0.5 mm sieve, packaged in tightly polyethylene bags at -18 °C until used.

2.3 Processing of African locust bean Pulp Flour

The African locust bean (*Parkia biglobosa*) fruit pods were sorted, cleaned and manually split open to remove the pulp with the attached seeds. The pulp with the attached seeds was oven dried at 50 C for 6 hrs in order of facilitate easy removal of the pulp from the seed. The pulp was separated from the seed manually, milled into flour in an electric blender. Flour is sieved using 0.5 mm sieve, packaged in tightly polyethylene bags at -18 °C until used.

2.4 Biochemical Analysis of Ingredients

Tigernut, white beans and African locust bean pulp flours were evaluated for the biochemical properties. Proximate components were analyzed using standard AOAC (2012) [17] methods. Moisture was deduced after oven-drying (Memmert, Germany) at 105°C. The ash content has resulted from incineration of 5 g of each flour at 550°C in an oven (PYROLABO, France) to constant mass. The proteins contents were valued on the Kjeldahl total nitrogen method basis. The lipids contents were resulted from the extraction with solvent (hexane) and a Soxhlet device. The total glucides content and total caloric energy value were estimated using following formulas:

- Total glucides content (%) = 100 – (% moisture + % proteins + % lipids + % ash) (1)
- Total caloric energy (%) = (% proteins x 4) + (% total glucides x 4) + (% lipids x 9) (2)

The results of proteins, lipids, ashes, total glucides contents were expressed on the dry weight basis.

2.5 Formulation of weaning food

Weaning food was prepared by blending tigernut, white beans and African locust bean pulp flours using the matrix method of formulation according to Olusayo and al (2013) [18], adapted method. This lead to generate proportions of ingredients to be mixed to obtain required nutrient content (Table 1). The system of equations used is as follows.

$$\begin{cases} a_{11}X_1 + a_{12}X_2 + \dots + a_{1n}X_n = b_1 \\ a_{21}X_1 + a_{22}X_2 + \dots + a_{2n}X_n = b_2 \\ a_{n1}X_1 + a_{n2}X_2 + \dots + a_{nn}X_n = b_n \end{cases} \quad (3)$$

Table 1: Composition of blend

Ingredients	Proportions (g/100g)
Tiger nut flour	50
White beans flour	40
African locust bean pulp flour	10

2.6 Phytochemical analysis of weaning food

The content of total phenolic compounds was determined using the Folin–Ciocalteu reagent method [19]. The absorbance of gallic acid as standard and the methanolic extract was measured at 765 nm using a spectrophotometer.

Flavonoid quantification was carried out using aluminium chloride colorimetric method [20]. The absorbance of standard (quercetin) and the methanolic extract was measured spectrophotometrically at 415 nm.

Tannins were quantified using vanillin reagent method [21]. The absorbance was measured at 500 nm using a tannic acid as standard.

Phytate (phytic acid) content was measured by the colorimetric method using Wade's reagent [22]. The absorbance at 490 nm was measured using sodium phytate as standard.

Oxalate was determined using the titrimetric method of Day and Underwood (1986) [23].

2.7 Biochemical analysis of weaning food

The proximate components of complementary food were determined by the same methods used to determined biochemical properties of ingredients.

2.8 Mineral analysis

Mineral elements, calcium, magnesium, potassium, sodium, zinc, iron and phosphorus were determined using a flame atomic absorption spectrophotometer (VARIAN AA20, Australie) according to the AOAC (1990) [24] digestion method using strong acids.

2.9 Data analysis

All analyses were performed in triplicate and data were treated in excel file. The results are expressed as the mean ± standard deviation (SD) and in percentage.

Results and Discussion

1. Phytochemical Composition

Results from the phytochemical analysis of formulated weaning food are compiled in Table 2. The phytate and oxalate contents are 0.07 mg//100g of dry matter and 22.6 mg/100g of dry matter respectively. These levels are acceptable and could be due to the steeping and roasting steps carried out during the processing of the ingredients. According to Hendek-Ertop and Bektas, (2018) [25], the methods used for the processing of the ingredients play an important role as they contribute to the reduction of the antinutrient content. The low phytate and oxalate content of the formulated food is an advantage, as this indicates that its consumption could help reduce the prevalence of micronutrient deficiencies in children. According to Mejborn and Tetens (2011) [26] and Gupta and al (2015) [27], phytates, when present in large quantities in infant formulas, chelate minerals such as calcium, zinc and iron, thus reducing their bioavailability. Oxalates, like phytates, limit the availability of calcium in the body by forming insoluble calcium oxalates, hence the decreased use of calcium by bones and tissues [28]. The oxalate content of the formulated food does not constitute a danger for children since according to Hassan and Umar (2004) [29], the toxic oxalate content for humans has been set at between 2 and 5 g.

The content of total phenolics (52.27 mg/100g dry matter) of the formulated food is acceptable. This low content would be due to the processes adopted for the production of the flours. Several studies have indicated that the technological treatments applied to plant material during the production of flour contribute to reducing the levels of phenolics compounds [30, 31, 32]. The content of total phenolics in the formulated food is much lower than the content of 492.86 mg/100g found by Songré-Ouattara and al (2016) [33] in infant flours formulated with cereals,

legumes and sugar in Burkina Faso. The formulated food, due to its moderate content of total phenolics, could have antioxidant properties to prevent rancidity by the oxidation of lipids. The low tannins content could improve the availability of nutrients in the food.
The tannins content of the formulated food is 8.18 mg/100g of dry matter. This content is acceptable. It is lower than the content of 26.77 mg/100g of dry matter found by Kouton and al (2017) [34] in flours formulated with sprouted sorghum, soybean, baobab pulp and sugar flours. According to Temesgen (2013) [2], tannins, ingested in excessive amounts, inhibit the absorption of minerals such as iron. Indeed, tannins are metal ion chelators and tanned metal ions are not bioavailable. This unavailability of iron, if prolonged, can lead to anemia [35]. Ghavidel and Prakash (2007) [36] also reported that tannins bind to both exogenous and endogenous proteins, including digestive tract enzymes, resulting in decreased protein utilization. Reducing tannins during production improves the nutritional value of foods by increasing protein digestibility. Therefore, food formulated with low tannin content would have good digestibility.
As regards flavonoids, the content is 16.25 mg/100g of dry matter. According to Van der Heide and al (2003) [37], the normal diet contains up to two grams of flavonoids/day. The consumption of this weaning food with a moderate content of flavonoids could reduce the risk of allergy in children and the risk of the appearance of goiter.
According to Singh and al (2011) [38], flavonoids have antiallergic properties. However, according to Dos Santos de Souza and al (2011) [39], at high levels, flavonoids could cause adverse effects on the biosynthesis and metabolism of thyroid hormones and thus promote the appearance of goiter in children.

Table 2: Phytochemical composition (mg/100g Dry matter) of formulated weaning food

Phytochemical composition (mg/100g Dry matter)	
Total phenolics	52.27 ± 0,02
Flavonoïds	16.25 ± 0,01
Tannins	8.18 ± 0,03
Oxalates	22.6 ± 0,00
Phytates	0.07 ± 0,01

Each value is an average of the results obtained by three tests ± standard deviation of this average

2. Biochemical composition of formulated weaning food

Results from the biochemical analysis of formulated food are compiled in Table 3. The moisture content of the formulated food is 5.27%. It is included in the standard indicating moisture content between 5% and 10% in infant flours [3]. This low moisture content is due to the fact that the raw materials used for its production have been dried before and could also be due to the efficiency of the drying method. According to Ejoh and al (2006) [40], the moisture content of a food sample is an index of product stability. This result is similar to that of Alabi and Anuonye (2007) [41] and Brou and al (2013) [42] who showed that flours with low moisture content could be stored safely without risk of microbial growth.
The ash content of the formulated food is 3.03%. This content indicates that the formulated food could provide sufficient minerals to meet the nutritional needs of the child. According to Dègnon and al (2015) [43], sufficient amounts of minerals in weaning foods are recommended for the formation of bones, teeth, nails, muscles and red blood cells in children.
The lipids content of the formulated food is 15.63%. This richness in lipids could be explained by the use of tiger nut flour in the formulation. The lipid content of the formulated food complies with the recommendations. Indeed, according to the standards defined by FAO/WHO (2008) [3], the lipid content of weaning foods must be between 10 and 25%. According to Delplanque and al (2015) [44], dietary lipids are essential for infants to not only meet their high energy requirements, but also perform many metabolic and physiological functions essential for growth, development and health. The lipid content in this formulated food could contribute to the neural, visual development and growth of the child.
The formulated food is an important source of proteins (12.67%). This high protein content could be justified by the use of a legume, the white bean in the formulation. According to Singh and al. (2004) [45], legumes are rich in protein with a content that varies from 20 to 50%. In the formulation carried out, the protein content complies with the standards recommended for weaning foods (11 to 21%). This food formulated could help reduce the risk of occurrence of protein-energy malnutrition in children.
The total glucides content in the formulated food is 63.41%. This content complies with nutritional recommendations. This content would be due to the use of tigernut in the formulation. According to Temesgen and al (2016) [46], roots, tubers and cereals are the main sources of carbohydrates in the diet. According to FAO/WHO (2008) [3], for weaning foods, a total glucides content of between 60 and 68% is recommended to meet the energy needs of children. The formulated food could be an important source of energy.
The energy intake of the formulated food is 444, 99 kcal/100g. It is the result of energy intake linked to macronutrients (total glucides, proteins and lipids).
According to Guesnet and al (2013) [47], rapid infant growth during the first year of life requires very high energy intake. Consumption of the formulated weaning food could help prevent protein-energy malnutrition in children.

Table 3: Biochemical composition of formulated weaning food

Characteristics	Weaning food formulated	Standard weaning food (FAO/WHO, 2008)
Moisture (%)	5.27± 0,02	5
Ash (%)	3.03 ± 0,00	2.9
Lipids (%)	15.63 ± 0,01	10-25
Proteins (%)	12.67 ± 0,01	11-21
Total glucides* (%)	63.41 ± 0,03	64± 4
Energy value* (Kcal/100 g)	444.99	400-425

* Values obtained by calculation
Each value is an average of the results obtained by three tests ± standard deviation of this average.

3. Minerals composition of the formulated weaning food

Mineral content, calcium, magnesium, potassium, sodium, zinc, iron and phosphorus were determined as shown in Table 4. Contents of calcium, magnesium, potassium, sodium, zinc, iron and phosphorus are 13 mg/100g, 509 mg/100g, 309.7 mg/100 g, 26.8 mg/100 g, 0.6 mg/100 g, 0.3 mg/100g and 4.23 mg/100g respectively. The ratios of potassium to sodium (Na/K) and phosphorus to calcium (Ca/P) are indices of body electrolyte balance and bone formation respectively. Na/k less than one is recommended in the diet of infant. Therefore the weaning food formulated in this study is comparable to recommended ratio. The high Ca/P ratio observed in this study is of great nutritional benefits particulary for children that needs higher intake of calcium and phosphorus for bone formation. Study has shown that food is considered good if the Ca/P ratio is above one and poor if the ratio is less than 0.5 [48].

Table 4: Minerals composition of the formulated weaning food

Minerals composition (mg/ 100g)	
Calcium (Ca)	13± 0,00
Magnesium (Mg)	509 ± 0,00
Potassium (K)	309.7 ± 0,00
Sodium (Na)	26.8 ± 0,00
Zinc (Zn)	0.6 ± 0,00
Iron (Fe)	0.3 ± 0,00
Phosphorus (P)	4.23 ± 0,00
Na/K	0.09
Ca/P	3.07

Each value is an average of the results obtained by three tests ± standard deviation of this average

4. Phytochemical compound/mineral ratios

Calculated phytochemical to mineral ratios that indicate the bioavailability of minerals in the formulated weaning food are presented in Table 5.

The results show that the ratios [oxalate] / [Calcium], [phytate] / [Zinc], [phytate] / [Iron], [phytate] / [Calcium] are respectively 1.74, 0.11, 0.23, and 0.005. The formulated weaning food has low [oxalate] / [Calcium], [phytate] / [Zinc], [phytate] / [Iron], [phytate] / [Calcium], ratio values. These values are lower than the reference values defined by Hassan *et al*. (2007) [49] which are 2.5, 1.5, 0.4, and 0.5 respectively. This implies that the oxalate and phytate content of the formulated food would not have deleterious effects on the bioavailability of calcium, zinc and iron in child nutrition.

Table 5: Phytochemical compound/mineral ratios

Parameters	Ratios	Critical value
[oxalate] / [Calcium]	1.74	2.5
[phytate] / [Zinc]	0.11	1.5
[phytate] / [Iron]	0.23	0.4
[phytate] / [Calcium]	0.005	0.5

Conclusion

The work carried out with a view to making our contribution to the fight against child malnutrition by improving the diet during weaning has made it possible to formulate a complementary food. This food was made from tigernut, white bean and African locust bean pulp flours, three foods grown and consumed in northern Côte d'Ivoire. The study of the phytochemical and biochemical composition reveals that the nutritional value of this weaning food complies with the recommendations relating to weaning foods. It would therefore be important to offer households in this region of Côte d'Ivoire this food of good nutritional quality for feeding children from the age of 6 months.

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