

Evaluation of the nutritional quality of supplemental porridges enriched with vegetable corchoria (*Corchorus olitorius*) and cashew kernel (*Anacardium occidentale*) for moderately malnourished children aged 6 to 59 months.

ABSTRACT :

In developing countries and particularly in Côte d'Ivoire, the period of introduction of weaning foods is generally affected by a high prevalence of malnutrition with a high death rate. The aims of this study is to improve the nutritional quality of breastmilk substitute foods for young children with moderate malnutrition. The physicochemical, biochemical, nutritional characteristics, the antioxidant and anti-nutritional properties of three porridges supplemented with dried three porridges supplemented with dried leaves of *Corchorus olitorius* leaf (*Corchorus olitorius*) and cashew kernel (*Anacardium occidentale*) from a basic porridge made of millet, peanut, palm oil, sugar and water were determined according to standard methods. The results indicated that the enrichment significantly improves the proportion of dry materials, the intake of energy, fat, essential amino acids, particularly leucine, and micronutrients (vitamin, iron, zinc, copper). These proportions of essential nutrients in these porridges are in conformity with the Recommended Dietary Allowances (RDA) for Moderate Acute Malnutrition (MAM) with good bioavailability of iron, zinc and their antioxidant activities. These results also showed that the supplemented porridges are very rich in essential fatty acids linoleic acid (omega 6) and linolenic acid (omega 3) with contents higher than the range of values recommended for MAM. Eventually, these porridges could be recommended not only for the nutritional rehabilitation of MAM but also to prevent the complications linked to certain chronic diseases such as obesity and cardiovascular diseases.

Keywords: Essential amino acids, Children, Côte d'Ivoire, Micronutrients, Nutrition.

1. INTRODUCTION

In most of the developing countries, child malnutrition represents a major public health problem that these States seem powerless to tackle. The forms of malnutrition commonly experienced are chronic malnutrition or stunting, iron deficiency anemia, vitamin A deficiency and iodine deficiency [1]. In Côte

d'Ivoire, child nutritional problems are mainly due to chronic malnutrition, acute malnutrition and micronutrient deficiencies, particularly iron [2]. Indeed, chronic malnutrition affects more than 30% of children under five, including 18% in moderate form and 12% in severe form. Rural areas and particularly northern regions are more affected with prevalence rates approaching the critical threshold (40%) [2]. Regarding acute malnutrition, it affects 18% of children. As for iron deficiency, it is the cause of 80% of anemia in Côte d'Ivoire, which affects nearly 75% of children under five, including 46% in moderate form [2]. Unfortunately, these different forms of malnutrition lead to physical, physiological and cognitive development delays and high mortality in young children. If we do not take action, those who become adults will be vulnerable to chronic diseases such as obesity, diabetes, and cardiovascular diseases, which will therefore perpetuate poverty [3].

In response to these serious food and nutritional problems, the State of Côte d'Ivoire has made fortified infant flours more available on the market for the preparation of balanced complementary porridges. These porridges are enriched with micronutrients including vitamins and minerals [4]. Unfortunately, these industrial porridges are not accessible to the most vulnerable populations (56.8%) [5] because of their high cost. In this situation, poor families continue to feed children with traditional porridges made from cereals and local starchy foods that are poor in protein, energy and essential micronutrients, and are therefore not recommended for a diet of appropriate nutritional quality [6]. These traditional porridges can be improved however as there is a variety of local foods that are sources of energy, protein and healthy and inexpensive micronutrients [7]. This is the case with cashew kernels and leaves of *Corchorus olitorius*, which are very widely used in Côte d'Ivoire but are rarely added into infant porridge. Indeed, cashew kernels are good sources of energy (585 kcal per 100g of food), micronutrients (copper, zinc, iron, magnesium, manganese, vitamin B group) and complete proteins [8].

The availability of raw cashew kernels is high since the country is the world's largest producer with around 750,000 tonnes. Regarding the leaves of *Corchorus olitorius*, they are dark green in color with the local name kroala, they are more common and widely consumed in Côte d'Ivoire [9]. It is recognized for its richness in iron (87mg per 100g of food) and in provitamin A (β carotene 2360 μ g per 100g of food) [8], in trace elements such as zinc, iodine, copper, manganese and some minerals like calcium, magnesium and potassium. Also, the incorporation of cashew kernels and leaves of *Corchorus olitorius* boosts the nutritional values of these foods and also improves the nutritional status of young children. For this purpose, several scientific studies have focused on improving the nutritional quality of local

infant flours by adding legumes and leafy vegetables [10]. The current work aims to promote complementary food of appropriate nutritional quality in young children but also and above all accessible to rural communities and poor households in Côte d'Ivoire. Its objective is to assess the nutritional quality of basic supplement porridges enriched with two local ingredients, including cashew kernels and the powder of dried leaves of *Corchorus olitorius* leaf, for the rehabilitation of moderately malnourished children (MAM).

2. Materials and Methods

2.1. Material

2.1.1. Plant material

The ingredients used for the preparation of the supplement porridges are millet flour, red palm oil, groundnut paste, leaves of *Corchorus olitorius* leaf powder, cashew almond paste and sugar. The millet flour was provided by the dietetics department of Yopougon General Hospital. Red palm oil, peanut paste and cashew kernel and sugar were purchased at the local market in Yopougon. The fresh leaves of *Corchorus olitorius* leaf were supplied by wholesalers from the Gouro market in Yopougon.

2.2. Methods

2.2.1. Preparation of ingredients

Production of cashew almond paste: The dried and roasted cashew almonds are obtained from an approved local supplier of Abidjan supermarkets. These unsalted almonds have been ground into an orange-yellow paste which is carefully stored in a jar at 4°C.

Production of dried leaves from the *cochorus oliterius*: The fresh leaves of *Corchorus Olitorius*, freed from foreign bodies, were weighed to obtain the fresh weight (FP). They were first disinfected with a dilute sodium hypochlorite solution (1/1000) for 20 minutes and carefully washed with tap water. Then, they were dried away from the sun every day until a constant weight, the dry weight (DW), was obtained. After that, they were ground to a powder using a Moulinex type mixer (Normandy, France) then sieved (sieve with a diameter of 250 µm, AFNOR). This powder is packaged in a hermetically sealed glass jar and stored at room temperature.

2.2.2. Formulation of supplementary porridges:

Based on the table of composition of West African foods [11], the complementary porridges were nutritionally supplemented taking into account the recommended energy intake by age group for children

aged 6-59 months [12]. Thus, three types of nutritionally supplemented porridges accepted by children of supplementation age were formulated from a basic porridge made of millet, groundnut paste, palm oil, sugar and water, recommended in the dietary services of the Urban Health Training (FSU). Each porridge was obtained with a cooking time of 8 minutes over low heat .

BC1 (Control): Supplementary porridge made from millet flour (20g), groundnut paste (5g), palm oil (1.5g), sugar (5g), water (218.5mL), usually recommended in FSU Dietary Services;

BC2 (BC1+AC): BC1 porridge containing cashew almond paste (10g). Composition: millet flour (20g), groundnut (5g), cashew kernel (10g), palm oil (1.5g), sugar (5g) and water (208.5mL);

BC3 (BC1+ FCOP): BC1 porridge containing powder of *Corchorus olitorius* leaf (2.5g). Ingredients: millet flour (20g), groundnut (5g), palm oil (1.5g), powdered of leaves of *Corchorus olitorius* leaf (2.5g), sugar (5g) and water (216mL);

BC4 (BC1+AC+FCOP): BC1 porridge containing both cashew kernel (10g) and *Corchorus olitorius* leaf powder (2.5g). Composition: millet flour (20g), groundnuts (5g), palm oil (1.5g), cashew kernel (10g), powder of leaves of *Corchorus olitorius* leaf (2.5g), sugar (5g) and water (206 mL).

2.2.3. Physicochemical parameters

The main physicochemical parameters, which are the moisture content, dry matter, ash and pH, were determined according to the method described by AOAC [13].

2.2.4. Nutritional composition of the supplemental porridges

Macronutrient content : The nutritional content of the porridge was evaluated by analyzing their macronutrient (protein, lipid, carbohydrate) and fiber composition. The crude protein content ($N \times 6.25$) was determined by the Kjeldahl method in triplicate according to the Standard Association of Official Procedures for Analytical Chemists [13]. The total lipid content was determined by the cold extraction method in chloroform-methanol (v/v) [14]. The total sugar content was determined by the phenol-sulfuric method as described by Dubois et al. [15] after ethanosoluble extraction using the method described by Agbo et al [16]. The fiber content was determined using the method described by AOAC [17] which consists of digesting the fibers with sulfuric acid, then incinerating the dried residues at 550°C. The fiber content (F) is determined by the following relationship: $F (\%) = (m_1 - m_2) / m_e \times 100$; m_e : mass of the sample, m_1 dried residue, m_2 calcined residue. The total carbohydrate content of the

foods was calculated by difference according to the method recommended by FAO [18] and the energy density of the porridge samples was calculated according to the method proposed by Atwater and Rosa [19] and described by FAO [18]. with the following formula: Energy value (Kcal/100g) = [(4×P (%)) + (9×F (%)) +4×C (%)]; P: proteins, F: lipids, C: carbohydrates.

Mineral content: The contents of copper, iron, calcium, zinc, cobalt and phosphorus in the porridges were determined by atomic absorption spectrophotometry. The copper, iron and calcium content was determined according to the method described by AOAC [20], the zinc content according to the method described by AOAC [21] and the cobalt content according to AOAC [22].

Amino acid content: The amino acid content was determined by UHPLC-UV according to the method described by AOAC [23].

Fatty acid content: Fatty acids have been converted to their methyl esters (FAME) as described by the European Communities. Approximately 0.1 g of oil sample was mixed with 2 ml of n-heptane and 0.2 ml of methanolic solution of potassium hydroxide (2N). This was stirred for 30 sec and allowed to stand for 5 min. The top layer containing the FAMES was used for analysis by gas chromatography (GC). The FAME solution (1 L) containing the internal standard (erucic acid) was injected into a gas chromatograph (Shimadzu, GC 14 A, Japan) equipped with a flame ionization detector (FID) and a TRD1 capillary column (60 m X 0.25 mm inner diameter X 0.25 µm film thickness). The carrier gas was nitrogen and the flow rate was adjusted to 23 mL/min. The detector and injector temperatures were 250°C. The initial column temperature was set at 100°C and programmed to increase 5°C per minute to 220°C and maintained for 10 minutes at this temperature. The peaks of the fatty acid methyl esters were identified by comparing their retention times with those of the standards. After adjusting the areas with the internal standard (erucic acid), the yield of each fatty acid was calculated as follows: area of fatty acid/area of total fatty acids in the oil sample × 100 (%). $T\% = (\text{Area E} \cdot \text{PT} \cdot 100) / (\text{Area T} \cdot \text{PE})$; Area T: control zone; Area E: test area; PE: mass of the test in g; PT: mass of the control in g.

Vitamin content : The vitamin content was determined using a SHIMADZU SPD 20A type HPLC chain with a PAD detector, a Cluzeau France C18 ODS 250 x 4.6 column, in isocratic mode (acetonitrile : 55 mL, tetrahydrofuran: 37 mL and water: 8 mL); mobile phase flow rate (1.5 mL/min); detection wavelength (325 nm). One (1g) of sample is weighed and transferred to a 100 mL beaker protected from light with aluminum foil. 20 mL of methanol are then added and the resulting solution is stirred with a magnetic bar for 2 h 30 at room temperature. The methanol was extracted by filtration and quantitatively

placed in a 25 ml flask to form the test solutions. A standard solution of the different types of vitamin was immediately prepared by simple dilution in methanol to form the control solution.

2.2.5. Evaluation of phenolic compounds in supplemental porridge

Total polyphenol content: The phenolic compounds were determined by spectrophotometry after their extraction with methanol according to the method described by Singleton et al [24] based on the oxidation of the phenolic compounds by the Folin-Ciocalteu reagent.

Flavonoid content: The flavonoid content was determined by spectrophotometry according to the method described by Meda et al., [25]. This method is based on the reaction of flavonoids with aluminum chloride in the presence of potassium acetate to give a yellow complex whose intensity is proportional to the quantity of flavonoids present in the medium. **Tannin content:** After extraction from phenolic compounds to methanol according to the method of Singleton et al. [24], the tannin content was carried out in a sulfuric acid medium with vanillin according to the method described by Bainbridge et al., [26]. The quantity of tannins in the samples was determined using a standard curve established from a stock solution of tannic acid (2 mg/mL) under the same conditions as the test.

2.2.6. Evaluation of antioxidant activity

The determination of the antioxidant activity is performed according to the method described by Choi et al., [27] using 2, 2-diphenyl-1-picrylhydrazyl (DPPH). The antioxidant activity (AA) is expressed as a percentage of inhibition of DPPH according to the following relationship: $AA (\%) = ([DOc - (DOe - DOb)] \times 100) / DOc$; With, DOc: absorbance of the control tube (1 mL of DPPH + 2.5 mL of methanol); DOe: absorbance of the test tube (1 mL of DPPH + 2.5 mL of extract); DOb: absorbance of the blank or control tube (1 mL of methanol + 2.5 mL of extract).

2.2.7. Determination of anti-nutritive factors in complementary porridges

Oxalate content: The content of oxalates was determined by the methods described by AOAC [13]. This method consists of extracting the total oxalates (insoluble and soluble) then dosing them with potassium permanganate to the point where a slight pink coloration appears and persists for at least 30 sec.

Phytate content: The determination of the phytate content was carried out by the method described by Mohammed et al [28]. This method consists of forming the phytate-iron complex and then determining the iron content by spectrophotometry. A standard range is established from a stock solution of Mohr's salt (10 µg iron/ml) under the same conditions as the test for determining the quantity of phytate-iron in the sample.

2.2.8. Statistical analysis

The results of measurements of the physico-chemical and biochemical parameters were processed from the analysis of variance (ANOVA1) using the StatPlus 2009 software. All the tests were carried out in triplicate and the results expressed as mean \pm standard deviation. Duncan's test at the 5% level is used to determine the significant differences between the means.

3. RESULTS

3.1. hysicochemical characteristics of the various supplementary porridges

Analysis of the results showed that the moisture content of the control porridge BC1 ($86.76 \pm 0.41\%$) was significantly higher than that of the enriched porridges BC2 ($82 \pm 0.5\%$), BC3 ($85.36 \pm 0.56\%$) and BC4 ($82.66 \pm 0.83\%$) ($p < 0.05$). Among the enriched porridges, the humidity levels of the BC2 and BC4 groups are similar but lower than that of BC3 ($p < 0.05$) (Table I). The dry matter content of enriched porridges BC2 ($18.0 \pm 0.5\%$), BC3 ($14.63 \pm 0.56\%$), and BC4 ($17.33 \pm 0.83\%$) is significantly higher than that control porridge BC1 ($13.23 \pm 0.41\%$) ($p < 0.05$). There is no significant difference between porridge BC2 and BC4. The ash content of BC4 enriched mixture ($2.0 \pm 0.00\%$) is higher than that of BC2 enriched mixture ($1.55 \pm 0.19\%$), BC3 ($1.33 \pm 0.00\%$) and control porridge BC1 ($1.33 \pm 0.33\%$) without significant difference. (Table I).

The mean pH value of the control porridge BC1 (5.71 ± 0.01) was similar to that of the enriched porridge BC2 (5.67 ± 0.01) but higher than the pH values of the enriched porridge BC3 (4.81 ± 0.01) and BC4 (5.12 ± 0.01). A significant difference was only observed between the BC4 porridge and the other porridge groups ($p < 0.05$) (Table I).

Table I: physicochemical parameters of the different complementary porridges

Physicochemical parameters	Porridge BC1 (Control)	Porridge BC2 (BC1+AC)	Porridge BC3 (BC1+FCOP)	Porridge BC4 (BC1+AC+FCOP)
Moisture (%)	86.76±0.41^a	82±0.5 ^c	85.36±0.56 ^b	82.66±0.83 ^c
Dry Matter (%)	13.23±0.41 ^c	18.0±0.5^a	14.63±0.56 ^b	17.33±0.83^a
Ash (%)	1.33±0.33 ^b	1.55±0.19 ^b	1.33±0.00 ^b	2.0±0.00^a
pH	5.71±0.01^a	5.67±0.01 ^b	4.81±0.01 ^d	5.12±0.01 ^c

The values of the same row assigned different alphabetical letters are significantly different according to Duncan's test at the 5% threshold ($p < 0.05$); those assigned the same letter are not. AC: cashew kernel; FCOP: leaves of *Corchorus olitorius* leaf; AC+FCOP: cashew kernel + leaves of *Corchorus olitorius* leaf

3.2. Nutritional characteristics of complementary porridges enriched with cashew kernels and vegetable kernel leaves

3.2.1. Macronutrient content of porridges

Mean lipid values in enriched porridges BC2 (16.00 ± 0.00 g/100g), BC3 (13.75 ± 0.25 g/100g), and BC4 (19.25 ± 0.35 g/100g) and those of proteins BC2 (3.06 ± 0.04 g/100g), BC3 (2.66 ± 0.08 g/100g), and BC4 (3.08 ± 0.05 g/100g) are significantly more higher than that of the control porridge BC1 (Lipids: 12.75 ± 0.25 g/100g; Proteins: 2.15 ± 0.05 g/100g) ($p < 0.05$) (Table II). The energy value in enriched porridges BC2 (473.76 ± 0.77 Kcal/100g), BC3 (463.43 ± 1 Kcal/100g), and BC4 (488.21 ± 1 Kcal/100g) is significantly higher than that of the control porridge BC1 (458.39 ± 0.33 Kcal/100g) ($p < 0.05$) (Table II).

Table II: Macronutrient contents of supplementary porridges enriched with cashew kernels and leaves of *Corchorus olitorius* leaf

Settings	Porridge BC1 (control)	Porridge BC2 (BC1+AC)	Porridge BC3 (BC1+FCOP)	Porridge BC4 (BC1+AC+FCOP)	RDA
Lipid (g/100g)	12.75 ± 0.25^d	16.00 ± 0.00^b	13.75 ± 0.25^c	19.25 ± 0.35^a	25 - 65 g
Carbohydrate (g/100g)	83.76 ± 0.01^a	79.38 ± 0.2^c	82.26 ± 0.26^b	75.66 ± 0.30^d	20 - 43 g
Protein (g/100g)	2.15 ± 0.05^c	3.06 ± 0.04^a	2.66 ± 0.08^b	3.08 ± 0.05^a	9,42-13,2 g
Total fibers (g/100g)	08.75 ± 0.25^c	09.37 ± 0.02^b	11 ± 0.00^a	10.5 ± 0.50^a	5-10 g
Energy value (Kcal/100g)	458.39 ± 0.33^d	473.76 ± 0.77^b	463.43 ± 1^c	488.21 ± 1^a	599-1231kcal

The values of the same row assigned different alphabetical letters are significantly different according to Duncan's test at the 5% level ($p < 0.05$); those assigned the same letter are not. AC: cashew kernel; FCOP: leaves of *Corchorus olitorius* leaf; AC+FCOP: cashew kernel + leaves of *Corchorus olitorius* leaf; RDA: Recommended Daily Allowance.

3.2.2. Micronutrient content of the porridges

A significant increase in the mean values of zinc, calcium, iron, and phosphorus of the enriched porridges BC2, BC3, BC 4 was observed compared to that of the control porridge BC1 ($p < 0.05$). the

BC4 porridge contains the highest levels of zinc (5.05 mg/100g) and copper (1.63 mg/100g) while the BC3 porridge enriched with leaves of *Corchorus olitorius* leaf is the richest in iron (21.80 mg/100g), calcium (75.91mg/100g), and phosphorus (280.41 mg/100g). On the other hand, the average copper values are similar for the control porridge BC1 and the enriched porridge BC2, also for the enriched porridges BC3, BC4 (Table III).

Table III: Mineral content of additional porridges enriched with cashew kernels and leaves of *Corchorus olitorius* leaf in mg/100g of porridge

Parameters	Porridge BC1 (control)	Porridge BC2 (BC1+AC)	Porridge BC3 (BC1+FCOP)	Porridge BC4 (BC1+AC+FCOP)	RDA
Zinc	03.27±0,13 ^d	03.82±0,22 ^b	03.51±0,21 ^c	05.05±0,06^a	7.75-13,12
Calcium	12.51±0,24 ^d	48.01±0,17 ^b	60.91±0,07^a	49.51±0,21 ^c	375.75-525
Iron	12.62±0,20 ^d	14.95±0,04 ^c	21.80±0,20^a	19.57±0,30 ^b	6.75-11,25
Copper	00.97±0,04 ^b	01.07±0,04 ^b	01.57±0,04^a	01.63±0,20^a	0.37-1,31
Phosphorus	70.69±0,38 ^d	86.20±0,22 ^c	280.41±0,48^a	135.44±0,40 ^b	318.75-525

The values of the same line assigned different alphabetical letters are significantly different according to Duncan's test at the 5% level; those assigned the same letter are not. AC: cashew kernel; FCOP: leaves of *Corchorus olitorius* leaf; AC+FCOP: cashew kernel + leaves of *Corchorus olitorius* leaf; RDA: Recommended Dietary Allowance.

3.2.3. Content of essential amino acids in porridge

The average values of the essential amino acids (leucine, phenylalanine, threonine and tryptophan) of the enriched porridges BC2 BC3 BC4 are significantly higher than those of the control porridge BC1 ($p < 0.05$). Leucine content doubled in porridge BC2 (37.78±0.05 g/100g) and tripled in porridge BC3 (78.31±0.9 g/100g) and BC4 (73.77±0.09 g/ 100g) compared to the control (18.51±0.05 g/100g). In addition, the BC2 and BC4 enriched porridges contain 5 essential amino acids whose values are higher than the recommended dietary intakes (Table IV).

Table IV: Content of Essential Amino Acids (EAA) of the different supplement porridges in g/100g of porridge

Essential Amino Acids (EAA)	Porridge BC1 (control)	Porridge BC2 (BC1+AC)	Porridge BC3 (BC1+FCOP)	Porridge BC4 (BC1+AC+FCOP)	RDA
Isoleucine	1.30±0,01^a	1.04±0.09 ^b	0.00±0,00 ^d	0.08±0,00 ^c	0,25
Leucine	18.51±0,05 ^d	37.78±0.05 ^c	78.31±0,9^a	73.77±0,09 ^b	0,50
Lysine	24.15±0,39^a	19.57±0,12 ^b	0.07±0,01 ^c	6.53±0,02 ^c	0,38
Phenylalanine	0.00±0,00 ^d	2.00±0,00 ^c	3.07±0,03 ^b	3.28±0,06^a	0,21
Tyrosine	0.01±0,00^a	0.02±0,00^a	0.00±0,00 ^b	0.00±0,00 ^b	0,22
Threonine	0.00±0,00 ^c	0.19±0,00 ^b	0.17±0,01 ^b	0.24±0,03^a	0,22
Tryptophan	0.19±0,03 ^d	0.64±0,04^a	0.23±0,00 ^c	0.45±0,00 ^b	0,06
Valine	0.05±0,00^a	0.05±0,01^a	0.00±0,00 ^b	0.04±0,01^a	0,31

The values of the same line assigned different alphabetical letters are significantly different according to Duncan's test at the

5% level; those assigned the same letter are not. AC: cashew kernel; FCOP leaves of *Corchorus olitorius* leaf; AC+FCOP: cashew kernel + leaves of *Corchorus olitorius* leaf; RDA: Recommended Dietary Allowance.

3.2.4. Vitamin content of porridges

A significant increase in the mean values of vitamins A, B1, B2 and B9 was observed in the enriched porridges BC2, BC3, BC4 compared to those of the controls ($p < 0.05$) (Table IV). BC4 enriched porridge is richer in vitamin B group (vitamin B9: 35.16mg/100g), vitamin B2: 15.01mg/100g), vitamin B6: 0.55mg/100g).

Table V: Content of some vitamins in the various supplement porridges

Vitamin levels	Porridge BC1 (control)	Porridge BC2 (BC1+AC)	Porridge BC3 (BC1+FCOP)	Porridge BC4 (BC1+AC+FCOP)	RDA
Vitamin A (μg)	00.89±0.00 ^d	25.10±0.14 ^c	41.00±0.45^a	33.59±0.12 ^b	125
Vitamin E (mg/100g)	05.12±0.01^a	00.25±0.00 ^c	00,10	01.02±0.01 ^b	11,25
Vitamin C (mg/100g)	01.03±0.01 ^{ab}	01.10±0.00^a	01.25±0.00^a	00.42±0.00 ^b	56,25
Vitamin B ₁ (mg/100g)	48.23±0.39^a	12.54±0.03 ^b	12.50±0.16 ^b	11.12±0.11 ^c	> 0.375
Vitamin B ₂ (mg/100g)	08.33±0.01 ^d	12.39±0.01 ^b	10.81±0.01 ^c	15.01±0.01^a	> 1,5
Vitamin B ₃ (mg/100g)	00.65±0.00^a	00.30±0.01 ^{ab}	00,00±00,00	00,00±00,00	> 9,37
Vitamin B ₆ (mg/100g)	00.31±0.00 ^{ab}	00.24±0.00 ^{ab}	00,00±00,00	00.55±0.00^a	> 0,37
Vitamin B ₉ (mg/100g)	22.24±0.29 ^d	23.05±0.25 ^c	27.13±0.29 ^b	35.16±0.36^a	0.15
Vitamin B ₁₂ (mg/100g)	00.93±0.00^a	00.67±0.00 ^{ab}	00,00±00,00	00.30±0.00 ^{ab}	> 0.87

The values of the same line assigned different alphabetical letters are significantly different according to Duncan's test at the 5% level; those assigned the same letter are not. AC: cashew kernel; FCOP: leaves of *Corchorus olitorius* leaf; AC+FCOP: cashew kernel + leaves of *Corchorus olitorius* leaf; RDA: Recommended Dietary Allowance.

3.2.5. Essential fatty acid content of the porridges

All the porridges outlined average linoleic acid (omega 6) and linolenic acid (omega 3) values above the recommended dietary intakes (Table VI). In addition, the mean values of saturated fatty acid SFA (palmitic acid and stearic acid) of the enriched porridges BC2 BC3 BC4 were significantly higher than those of the control porridge BC1 ($p < 0.05$) (Table VI).

Table VI: Essential fatty acid content of different complementary porridges

Fatty acid (g/100g)	Porridge BC1 (control)	Porridge BC2 (BC1+AC)	Porridge BC3 (BC1+FCOP)	Porridge BC4 (BC1+AC+FCOP)	RDA
Palmitic acid	18.67±0.01 ^c	26.95±0.01^a	26.11±0.01 ^a	24.00±0.45 ^b	-
Stearic acid	14.45±0.01 ^d	34.74±0.02^a	30.78±0.03^b	28.55±0.21^c	-
Oleic acid	09.30±0.00 ^d	12.48±0.00 ^b	11.57±0.00 ^c	17.35±0.01^a	-
Linoleic acid	30.07±0.32^a	19.73±0.01 ^d	22.59±0.01 ^b	20.45±0.01 ^c	1.68-3.75
Linolenic acid	21.15±0.21^a	01.20±0.00 ^d	05.70±0.00 ^c	07.95±0.00 ^b	0.18-0.12

The values of the same line assigned different alphabetical letters are significantly different according to Duncan's test at the 5% level; those assigned the same letter are not. AC: cashew kernel; FCOP: leaves of *Corchorus olitorius* leaf; AC+FCOP: cashew kernel + leaves of *Corchorus olitorius* leaf; RDA: Recommended Dietary Allowance.

3.2.6. Antioxidant and anti-nutritional characteristics of porridge enriched with cashew kernels and vegetable claw leaves

A significant increase in the mean values of phenolic compounds, flavonoids, tannins, their antioxidant properties and antinutritional compounds, was observed in the BC2 BC3 BC4 enriched porridges compared to those of the controls ($p < 0.05$) (Table VII). Porridges enriched BC3 ($56.91 \pm 1.55\%$) and BC4 ($52.91 \pm 5.71\%$) had the highest antioxidant activities. Regarding antinutritional compounds, the enrichment of porridge led to a significant increase in oxalate and phytate contents. The highest level of oxalate was observed in the BC3 porridge (80.66 ± 2.59 mg/100g), and in phytates in the BC4 porridges (14.79 ± 0.24 mg/100g) (Table VII)

Table VII: Composition of porridge in antioxidant and anti-nutritive substances

Bioactive parameters	Porridge BC1 (control)	Porridge BC2 (BC1+AC)	Porridge BC3 (BC1+FCOP)	Porridge BC4 (BC1+AC+FCOP)
Antioxidant compounds				
Total polyphenol (mg/100g)	102.18 \pm 16.83 ^b	139.55\pm8.66^a	158.73\pm9.54^a	145.83\pm7.72^a
Flavonoid (mg/100g)	13.39 \pm 0.20 ^d	15.45 \pm 0.00 ^b	17.66\pm0.00^a	14.71 \pm 0.20 ^c
Tannin (mg/100g)	14.56 \pm 0.56 ^d	20.79 \pm 0.29 ^c	59.38\pm0.86^a	49.37 \pm 0.97 ^b
Anti OX (DPPH) %	41.58 \pm 4.34 ^b	47.52 \pm 3.47 ^{ab}	56.91\pm1.55^a	52.91\pm5.71^a
Anti-nutritive compounds				
Oxalate (mg/100g)	42.6 \pm 2.52 ^c	60.5 \pm 4.49 ^b	80.66\pm2.59^a	55.00 \pm 4.49 ^b
Phytate (mg/100g)	7.08 \pm 0.10 ^d	12.62 \pm 0.82 ^b	11.03 \pm 0.38 ^c	14.79\pm0.24^a

The values of the same line assigned different alphabetical letters are significantly different according to Duncan's test at the 5% level; those assigned the same letter are not. AC: cashew kernel; FCOP: leaves of Corchorus olitorius leaf; AC+FCOP: cashew kernel + leaves of Corchorus olitorius leaf

3.2.7. Evaluation of the bioavailability of minerals in porridges

The evaluation of the bioavailability of the minerals was carried out using different molar ratios. Only the mean values of the molar ratios [Phytates]/[iron], [Phytates]/[Calcium] and [Phytates]*[Calcium]/[zinc] observed were included in the range of the respective threshold values (Table VIII).

Table VIII: Molar ratios of mineral elements

Molar ratios	Threshold value	Porridge BC1 (control)	Porridge BC2 (BC1+AC)	Porridge BC3 (BC1+FCOP)	Porridge BC4 (BC1+AC+FCOP)
[Phytates]/[iron]	< 0,15	0.048	0.072	0.043	0.064
[Phytates]/[Calcium]	≤ 1	0.034	0.016	0.011	0.005
[Phytate] *[Calcium]/[zinc]	≤ 200	0.000	0.000	0.000	0.000
[Oxalate]/[Calcium]	≤ 0,4	1.052	0.394	0.413	0.350
[Zinc]/[copper]	5 - 20	2.085	3.715	3.782	3.546
[Vitamin C]/[iron]	3 - 16	0.025	0.007	0.018	0.007
[Calcium] /[phosphorus]	1 - 1,5	0.137	0.432	0.168	0.281

4. DISCUSSION

In this survey, the physicochemical analysis of porridges enriched with cashew kernels and dried leaves of *Corchorus olitorius* leaf (BC2, BC3 and BC4) showed a higher proportion of dry matter compared to that of the control porridge. fortification therefore improved the nutritional value of formulated porridges. Their minerals proportions remained the same except for the BC4 porridge which outlined a higher proportion. The BC4 porridge enriched with both cashew kernels and powder of dried leaves of *Corchorus olitorius* leaf would be the richest porridge in mineral salts. In addition, the porridges are acidic, which would reduce the risk of microbial growth [29]. These values are similar to the results of studies by Treche [6] in Congo and Azagoh [30] in Côte d'Ivoire on infant porridge. Regarding macronutrients, supplementation increased their lipid, protein and energy content. This increase comes from the contribution of the cashew kernel rich in lipids and proteins. This was also observed by similar work by Fofana [31] in Côte d'Ivoire. The lipid contents of enriched porridge are consistent with those of fats recommended for moderately acutely malnourished (MAM) children [32]. These porridges may contribute to the strengthening of the defense system, the brain development and allow better bioavailability of fat-soluble vitamins in young children [33]. As for proteins, the levels increased after supplementation, but these values are still below the minimum required for MAM children [32]. To meet the protein needs of children, it will therefore be necessary to take at least two meals. Therefore, the high carbohydrate content of the porridge corresponds to an energy intake estimated between 302.64 Kcal and 335.04 Kcal per 100g of porridge. This high carbohydrate content is due to the use of millet flour at more than 66.6% in the composition of the ingredients.

These carbohydrate contents are similar to those found in the work of Kayodé et al [35]. High amounts of fiber were observed in the supplemented porridges in this study. The small size of the stomach of young children and the low frequency of meals would not allow the ingestion of porridge rich in fiber. However, their excess could be significantly reduced by cooking time and food ingredient processing techniques [36]. Indeed, fibers are recognized for their water retention capacity, their positive effects on intestinal transit, the digestion of fats and carbohydrates [40]. The consumption of these porridges supplemented with an appropriate fiber content could therefore contribute to the maintenance of the intestinal flora of young MAM children.

In terms of energy density, supplementation led to a strong increase in the energy content of the porridges. These porridges are therefore a good source of energy. The Coverage of daily energy needs with few meals would be a considerable and very interesting asset for malnourished children given the small size of their stomach (30 to 40 g/kg of body weight or 150 to 200 ml) [36]. Similarly, the EFA contents of porridge are well above those required by the WHO for MAM children [32]. These supplemented porridges are therefore a potential source of EFAs. By consuming them, the intake of linoleic acid (omega 6) and linolenic acid (omega 3) could contribute to the development of the brain, the immune system, cardiovascular balance and allergic and inflammatory reactions in young children [33].

The increase in the content of essential amino acids (leucine, phenylalanine, threonine and tryptophan) of the supplemented porridge has shown their richness in EFA, particularly in leucine. The amino acid leucine is very important for muscle development in growing children [34]. Regarding micronutrients, the trace element iron, zinc and copper contents of the supplemented porridge are above the minimum required for MAM [32]. As for calcium and phosphorus, supplementation has allowed a significant increase in their levels without reaching the levels recommended for the management of MAM. This sufficient intake of these trace elements could correct anemia in malnourished children and also contribute to the development of their growth, immune and nervous systems [37]. For vitamins, the consumption of these porridges rich in vitamins B1, B2 and B9, above the proportions of food intake recommended for MAM, would be interesting to correct anemia. Indeed, vitamins B2 and B9 play an important role in iron absorption and hemoglobin biosynthesis [32]. As for antioxidant substances, supplementation resulted in a significant increase in total polyphenol, flavonoids, tannins and antioxidant activities. The porridge enriched with vegetable claw leaves (BC3), richer in phenolic compounds, has the highest antioxidant activity. These results are similar to those of NJOUMI [38] with meals made

from *Corchorus Olitorius* leaves. Thus, enriched porridges containing kallowweed BC3 and BC4 could be beneficial in the fight against both malnutrition and nutritional diseases (cancer, obesity, type I diabetes) [39]. Concerning the antinutritional compounds, the nutritional supplementation of porridges also led to an increase in oxalate and phytate contents with maximum values in porridges containing leaves of *Corchorus olitorius* leaf. This significant increase in antinutritional compounds was also observed in leaf-based meals in the work of NJOUMI [38] and Fofana [32]. This high intake of oxalates, phytates and fibers (>10g/d) could reduce the bio-absorption of certain essential minerals such as iron, zinc and calcium [40]

The [Phytate]/[iron] molar ratios of the different supplemented porridges, less than 0.15, indicate that the non-heme iron contained in the enriched porridges would be bioavailable [41]. On the other hand, the [vitamin C]/[iron] molar ratios with indices lower than the required minimum [32] reveal that the low content of vitamin C contained in the enriched porridge would be insufficient to optimize the absorption of non-heme iron. Under these conditions, a fruit intake could improve the ascorbic acid intake in the diet of young children. Concerning the bioavailability of calcium, porridge supplemented with [Phytate]/[Calcium] indices less than 1 would constitute a very bioavailable source of calcium compared to the control. As for the bioavailability of zinc, it was estimated using the [Phytate]*[Calcium]/[zinc] molar ratio [41]. The various enriched porridges indicate values well below the required threshold of 200. The supplemented porridges therefore constitute a better source of bioavailable zinc. These results have been observed in the work of FOFANA [32]. As for copper, its bioavailability was estimated using the [Zinc]/[copper] molar ratio. The various porridges all indicate indices below the minimum required, which is five [32]. This clearly shows a low bioavailability at the level of copper.

5. CONCLUSION

In this survey, the results showed that the basic porridges recommended by the dietetic services of health facilities contain antinutritive substances despite their richness in energy, fat content, minerals such as iron, zinc and essential fatty acids. However, supplementation with cashew kernels and leaves of *Corchorus olitorius* leaf significantly improves their energy and protein densities, their EFA content, particularly leucine, their levels of vitamins B1, B2, B9 and their levels of trace elements such as zinc, iron in accordance with the recommended dietary intakes for MAMs. The reduction of anti-nutritional factors through cooking and flour manufacturing techniques could optimize the improvement of the

nutritional quality of these supplemented porridges and allow the nutritional rehabilitation of young MAM children. The development of complementary porridges from locally available foodstuffs and accessible to all social strata is an alternative that is encouraged by the National Council for Nutrition, Food and Early Childhood Development (CONNAPE) in Côte d'Ivoire. Ivoire as part of efforts to reduce child malnutrition.

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