Original Research Article

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

ABSTRACT:

This study aims to improve the nutritional quality of traditional porridge intended for young children with moderate malnutrition. The biochemical and nutritional characteristics of three supplement porridges enriched with dried leaves *Corchorus olitorius* and *Anacardium occidental* were determined according to standard methods. The results revealed that enrichment with these two ingredients significantly improved the proportion of dry matter of porridges enriched with high contents in those containing only Western *Anacardium* BC$_2$ (17.33 ± 0.83%) and that enriched with both *Corchorus olitorius* and *Anacardium occidental* BC$_4$ (18.0 ± 0.5%) compared to the traditional non-enriched porridge BC$_1$ (13.23 ± 0.41%) and that enriched with *Corchorus olitorius* only BC$_3$ (14.63±0.56%). With regard to fat, the three enriched porridges showed significantly high levels: 16.00±0.00% (BC$_2$); 13.75±0.25% (BC$_3$); 19.25±0.35% (BC$_4$) compared to porridge BC$_1$ (12.75±0.25%). As for carbohydrates, enrichment did not lead to a significant increase in levels. On the other hand, the levels of proteins experienced a significant increase between 2.66 ± 0.08% (BC$_3$) and 3.08 ± 0.05% (BC$_4$). All the porridges showed high energy densities with values ranging between 463.43±1 Kcal/100g (BC$_1$) and 488.21±1 Kcal/100g (BC$_4$). Regarding micronutrients, the results indicated a significant increase in trace elements with higher mineral values in the porridge BC$_4$ (Zinc: 05.05±0.06) and BC$_3$ (Calcium: 60.91±0.07 mg /100g; Iron: 21.80±0.20 mg/100g; Copper: 01.57±0.04 mg/100g; Phosphorus: 280.41±0.48 mg/100g). The contents of fat-soluble vitamins, in particular vitamin A (BC$_2$: 25.10±0.14µg/100g; BC$_3$: 41.00±0.45µg/100g; BC$_4$: 33.59±0.12µg/100g) and water-soluble vitamins B2 (BC$_2$: 12.39±0.01 mg/ 100g; BC$_3$: 10.81±0.01mg/100g; BC$_4$: 15.01±0.01mg/100g) and B9 (BC$_2$: 23.05±0.25mg/100g; BC$_3$: 27.13±0.29mg/100g; BC$_4$: 35.16±0.36mg/100g) experienced a significant increase in the enriched porridge compared to the control. There is also a significantly high content of essential amino acid (leucine) with values between (37.78±0.05 and 78.31±0.9 g/100g) in the enriched porridge compared to the control (18.51±0. 05g/100g). All the porridges are very rich in essential fatty acids, linoleic acid (Ω6) with contents between 19.73±0.01 and 22.59±0.01g/100g and linolenic acid (Ω3) with contents between 01.20±0.00 and 07.95±0.00g/100g, and this in accordance with the recommended values for moderate acute malnutrition (MAM). This nutritional supplementation also significantly improved their antioxidant properties with DPPH values varying between 47.52±3 and 56.91±1.55% compared to the control (41.58±4.34%). Enriching these porridges with *Corchorus olitorius* and *Anacardium occidental* improved their nutritional quality in accordance with the recommended dietary intakes for my moderately malnourished for most essential nutrients. These enriched porridges could then be recommended not only for the nutritional rehabilitation of MAMs and also to prevent certain chronic diseases such as obesity and cardiovascular diseases.

Keywords: Moderate acute malnutrition, Children, Côte d'Ivoire, nutrients, nutrition

1. INTRODUCTION

In most of the developing countries, child malnutrition represents a major public health problem that these States seem powerless to tackle. In Côte d'Ivoire, the forms of malnutrition commonly encountered are chronic malnutrition or growth retardation (30% including 12% of severe form) and deficiencies in micronutrients and more particularly in iron (75% anemia including 80% by lack of iron) [1]. Unfortunately, these different forms of malnutrition lead to delayed physical, physiological and cognitive development and high mortality in young children. The period that records the greatest number of malnourished children with a high death rate is the weaning period. Indeed, poor households (56.8%) [2] continue to feed children with traditional porridge made from cereals and local starchy foods that are poor in protein, energy and essential micronutrients, and are therefore not indicated for food of appropriate nutritional quality [3]. However, these traditional porridges can be improved because there is a diversity of local foods that are sources of energy, protein and healthy and inexpensive micronutrients [4]. Thus, controlling the nutritional quality of traditional porridge is an essential alternative for preventing nutritional deficiencies, treating malnutrition and effectively combating severe malnutrition, the consequences of which are irreversible [5, 6]. cashew kernels and leaves of *Corchorus olitorius* are widespread in Côte d'Ivoire but rarely introduced into infant food. Indeed, cashew nuts are good sources of energy (585 kcal per 100g of food), micronutrients (copper, zinc, iron, magnesium, manganese, vitamin B group) and complete proteins [7]. A recent study showed beneficial nutritional effects of using cashew seed flour in the diet of moderately acutely malnourished [8]. The availability of raw cashew nuts is high as the country is the world's largest producer with around 750,000 tons. As for the leaves of *Corchorus olitrius*, they are very widespread 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 (βcarotene 2360 µg per 100g of food) [8], in trace elements such as zinc, iodine, copper, manganese and some minerals like calcium, magnesium and potassium. A nutritional evaluation of its seeds has shown its appreciable content of nutrients, especially essential minerals [10]. Another study showed that this leafy vegetable has powerful antioxidant and organ-protective properties [11]. Also, it could be that 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. To this end, several scientific studies have focused on improving the nutritional quality of local infant flours by adding legumes and leafy vegetables [12]. This 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 powder of dried leaves of common knotweed, with a view to rehabilitating moderately acutely 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.

<u>Production of dried leaves from the *cochorus olitorius*</u>: 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 [13], the complementary porridges were nutritionally supplemented taking into account the recommended energy intake by age group for children aged 6-59 months [14]. 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 [15].

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 × 6.25) was determined by the Kjeldahl method in triplicate according to the Standard Association of Official Procedures for Analytical Chemists [15]. The total lipid content was determined by the cold extraction method in chloroform-methanol (v/v) [16]. The total sugar content was determined by the phenol-sulfuric method as described by Dubois et al. [17] after ethanosoluble extraction using the method described by Agbo et al [18]. The fiber content was determined using the method described by AOAC [19] 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 (%) = (m1-m2)/me ×100; me: mass of the sample, m1 dried residue, m2 calcined residue. The total carbohydrate content of the foods was calculated by difference according to the method recommended by FAO [20] and the energy density of the porridge samples was calculated according to the method proposed by Atwater and Rosa [21] and described by FAO [20]. 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 were determined according to the method described by AOAC [22], the zinc content according to the method described by AOAC [23] and the cobalt content according to AOAC [24].

Amino acid content: The amino acid content was determined by UHPLC-UV according to the method described by AOAC [25].

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%= (Area E*PT*100) / (Area T*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 vitamins 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 [26] 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., [27]. 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. [26], the tannin content was carried out in a sulfuric acid medium with vanillin according to the method described by Bainbridge et al., [28]. 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., [29] using 2.2-diphenyl-1-pycrilhydrazyl (DPPH). The antioxidant activity (AA) is expressed as a percentage of inhibition of DPPH according to the following relationship: AA (%) = ([DOc-(DOe-DOb)] ×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 [15]. 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 [30]. 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 ± standard deviation. Duncan's test at the 5% level is used to determine the significant differences between the means.

3. RESULTS

3.1. Physicochemical characteristics of the various supplementary porridges

Analysis of the results showed that the moisture content of the control porridge BC_1 (86.76 ± 0.41%) was significantly higher than that of the enriched porridges BC_2 (82 ± 0.5%), BC_3 (85.36 ± 0.56%) and BC_4 (82.66 ± 0.83%) ($p < 0.05$). Among the enriched porridges, the humidity levels of the BC_2 and BC_4 groups are similar but lower than that of BC_3 ($p < 0.05$) (Table 1). The dry matter content of enriched porridges BC_2 (18.0 ± 0.5%), BC_3 (14.63 ± 0.56%), and BC_4 (17.33 ± 0.83%) is significantly higher than that control porridge BC_1 (13.23 ± 0.41%) ($p < 0.05$). There is no significant difference between porridge BC_2 and BC_4. The ash content of BC_4 enriched mixture (2.0 ± 0.00%) is higher than that of BC_2 enriched mixture (1.55 ± 0.19%), BC_3 (1.33 ± 0.00%) and control porridge BC_1 (1.33 ± 0.33%) without significant difference (Table 1).

The mean pH value of the control porridge BC_1 (5.71 ± 0.01) was similar to that of the enriched porridge BC_2 (5.67 ± 0.01) but higher than the pH values of the enriched porridge BC_3 (4.81 ± 0.01) and BC_4 (5.12 ± 0.01%). A significant difference was only observed between the BC_4 porridge and the other porridge groups ($p < 0.05$) (Table 1).

Table 1: physicochemical parameters of the different complementary porridges

Physicochemical parameters	Porridge BC_1 (Control)	Porridge BC_2 (BC_1+AC)	Porridge BC_3 (BC_1+FCOP)	Porridge BC_4 (BC_1+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 BC_2 (16.00 ± 0.00 g/100g), BC_3 (13.75 ± 0.25 g/100g), and BC_4 (19.25 ± 0.35 g/100g) and those of proteins BC_2 (3.06±0.04 g/100g), BC_3 (2.66±0.08 g/100g), and BC_4 (3.08±0.05 g/100) are significantly higher than that of the control porridge BC_1 (Lipids: 12.75 ± 0.25 g/100g; Proteins: 2.15 ± 0.05 g/100g) ($p < 0.05$) (Table 2). The energy value in enriched porridges BC2 (473.76±0.77 Kcal/100g), BC_3 (463.43±1 Kcal/100g), and BC_4 (488.21±1 Kcal/100g) is significantly higher than that of the control porridge BC_1 (458.39 ± 0.33 Kcal/100g) ($p < 0.05$) (Table 2).

Table 2: Macronutrient contents of supplementary porridges enriched with cashew kernels and leaves of Corchorus olitorius leaf

Settings	Porridge BC_1 (control)	Porridge BC_2 (BC_1+AC)	Porridge BC_3 (BC_1+FCOP)	Porridge BC_4 (BC_1+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 BC_2, BC_3, BC_4 was observed compared to that of the control porridge BC_1 ($p < 0.05$). the BC_4 porridge contains the highest levels of zinc (5.05 mg/100g) and copper (1.63 mg/100g) while the BC_3 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 BC_1 and the enriched porridge BC_2, also for the enriched porridges BC_3, BC_4 (Table 3).

Table 3: Mineral content of additional porridges enriched with cashew kernels and leaves of Corchorus olitorius leaf in mg/100g of porridge

Parameters	Porridge BC_1 (control)	Porridge BC_2 (BC_1+AC)	Porridge BC_3 (BC_1+FCOP)	Porridge BC_4 (BC_1+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 BC_2 BC_3 BC_4 are significantly higher than those of the control porridge BC_1 ($p < 0.05$). Leucine content doubled in porridge BC_2 (37.78±0.05 g/100g) and tripled in porridge BC_3 (78.31±0.9 g/100g) and BC_4 (73.77±0.09 g/ 100g) compared to the control (18.51±0.05

g/100g). In addition, the BC_2 and BC_4 enriched porridges contain 5 essential amino acids whose values are higher than the recommended dietary intakes (Table 4).

Table 4: Content of Essential Amino Acids (EAA) of the different supplement porridges in g/100g of porridge

Essential Amino Acids (EAA)	**Porridge BC_1 (control)**	**Porridge BC_2 (BC_1+AC)**	**Porridge BC_3 (BC_1+FCOP)**	**Porridge BC_4 (BC_1+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 4). 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 5: Content of some vitamins in the various supplement porridges

Vitamin levels	**Porridge BC_1 (control)**	**Porridge BC_2 (BC_1+AC)**	**Porridge BC_3 (BC_1+FCOP)**	**Porridge BC_4 (BC_1+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*
VitaminB_{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 6). In addition, the mean values of saturated fatty acid SFA (palmitic acid and stearic acid) of the enriched porridges BC_2, BC_3, BC_4 were significantly higher than those of the control porridge BC_1 ($p < 0.05$) (Table 6).

Table 6: Essential fatty acid content of different complementary porridges

Fatty acid (g/100g)	**Porridge BC_1 (control)**	**Porridge BC_2 (BC_1+AC)**	**Porridge BC_3 (BC_1+FCOP)**	**Porridge BC_4 (BC_1+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 BC_2, BC_3, BC_4 enriched porridges compared to those of the controls ($p < 0.05$) (Table 7). Porridges enriched BC_3 (56.91 ± 1.55%) and BC_4 (52.91 ± 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 BC_3 porridge (80.66±2.59 mg/100g), and in phytates in the BC_4 porridges (14.79±0.24 mg/100g) (Table 7)

Table 7: Composition of porridge in antioxidant and anti-nutritive substances

Bioactive parameters	**Porridge BC_1 (control)**	**Porridge BC_2 (BC_1+AC)**	**Porridge BC_3 (BC_1+FCOP)**	**Porridge BC_4 (BC_1+AC+FCOP)**
	Antioxidant compounds			
Total polyphenol (mg/100g)	102.18±16.83^b	**139.55±8.66^a**	**158.73±9.54^a**	**145.83±7.72^a**
Flavonoid (mg/100g)	13.39±0.20^d	15.45±0.00^b	**17,66±0.00^a**	14.71±0.20^c
Tannin (mg/100g)	14.56±0.56^d	20.79±0.29^c	**59.38±0.86^a**	49.37±0.97^b

Anti-OX (DPPH) %	41.58±4.34^{b}	47.52±3.47^{ab}	**56.91±1.55^{a}**	**52.91±5.71^{a}**
		Anti-nutritive compounds		
Oxalate (mg/100g)	42.6±2.52^{c}	60.5±4.49^{b}	**80.66±2.59^{a}**	55.00±4.49^{b}
Phytate (mg/100g)	7.08±0.10^{d}	12.62±0.82^{b}	11.03±0.38^{c}	**14.79±0.24^{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 8).

Table 8: Molar ratios of mineral elements

Molar ratios	Threshold value	Porridge BC_1 (control)	Porridge BC_2 (BC_1+AC)	Porridge BC_3 (BC_1+FCOP)	Porridge BC_4 (BC_1+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 (BC_2, BC_3 and BC_4) 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 BC_4 porridge which outlined a higher proportion. The BC_4 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 [31]. These values are similar to the results of studies by Treche [3] in Congo and Azagoh [32] 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 [33] in Côte d'Ivoire. The lipid contents of enriched porridge are consistent with those of fats recommended for moderately acutely malnourished (MAM) children [34]. These porridges may contribute to the strengthening of the defence system, the brain development and allow better bioavailability of fat-soluble vitamins in young children [35]. As for proteins, the levels increased after supplementation, but these values are still below the minimum required for MAM children [34]. 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 [36]. 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 [37]. Indeed, fibers are recognized for their water retention capacity, their positive effects on intestinal transit, the digestion of fats and carbohydrates [38]. 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) [37]. Similarly, the EFA contents of porridge are well above those required by the WHO for MAM children [34]. 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 [35].

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 [39]. Regarding micronutrients, the trace element iron, zinc and copper contents of the supplemented porridge are above the minimum required for MAM [34]. 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 [40]. 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 [34]. 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 [41] with meals made from Corchorus Olitorius leaves. Thus, enriched porridges containing *Corchorus olitorius* BC_3 and BC_4 could be beneficial in the fight against both malnutrition and nutritional diseases (cancer, obesity, type I diabetes) [42]. 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 [41] and Fofana [33]. 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 [38]

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 [43]. On the other hand, the [vitamin C]/[iron] molar ratios with indices lower than the required minimum [34] 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 [43]. 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 [33]. 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 [34]. 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 as part of efforts to reduce child malnutrition.

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