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Research Article

Effect of Traditional Complementary Porridges Enriched with Cashew Kernel (*Anacardium occidental*) and Vegetable Cortea (*Corchorus olitorius* L.) on the Nutritional Protein Profile and Inflammatory Status of Moderately Acutely Malnourished Children in Côte d'Ivoire

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Abstract

This study aims to study the effect of the enrichment of traditional porridge on the nutritional and inflammatory protein profile of Moderately Acutely Malnourished (MAM) aged 6 to 59 months with a view to their nutritional rehabilitation. To achieve this, four groups of 75 Moderately Acutely Malnourished (MAM) children were fed four types of porridge: non-enriched porridge (BC1), porridge enriched with *Anacardium occidentalis* (BC2), porridge enriched with *Corchorus olitorius* leaves (BC3) and porridge enriched with both *Corchorus olitorius* leaves and *Anacardium occidental* (BC4). Nutritional (Albumin, Transferrin, Prealbumin and Ferritin) and inflammatory (C-reactive protein, Orosomucoid) proteins were assayed in the serum before D0 and after 30 days (D30) of porridge consumption using Cobas C311 Hitachi from Roche diagnosis, France according to the method provided by the manufacturer. In terms of nutritional proteins, serum concentrations of pre-albumin or transthyretin which were below normal values on D0 with values between 0.11±0.01g/L (G1-BC1) and 0.19±0.47g /L (G4-BC4) experienced a significant increase at D30 in the groups of children who had consumed the enriched porridge (G2-BC2: 0.21±0.04g/L; G3-BC3: 0.25±0.38g/L; G4-BC4: 0.24±0.38g/L) compared to children in the control group (G1-BC1: 0.13±0.03g/L). Similarly, serum ferritin levels below normal values on D0 (G1-BC1: 49.45±7.25g/L; G2-BC2: 46.80±26.89g/L; G3-BC3: 35, 37±23.12g/L; G4-BC4: 38.18±12.81 g/L) underwent a significant increase at D30 but within the range of normal values (G1-BC1: 82.58±15.41g /l; G2-BC2: 93.90±47.20g/L; G3-BC3: 92.53±28.30g/L; G4-BC4: 100.79±28.57g/L). Albumin and transferrin concentrations remained within the normal range.

As for the proteins of the inflammatory reaction, the orosomucoid concentrations on D0, which were higher than the normal value in the children of the control group (2.87±0.45g/L), of the G2-BC2 group (2. 19±0.30g/L) and in the G3-BC3 group (2.99±0.21g/L) experienced a significant drop at D30 (G1-BC1: 0.80±0.84 g/L; G2- BC2: 0.74±0.09g/L; G3-BC3: 0.71±0.38g/L. Concerning the C-reactive protein, its serum concentration remained within the limits of normal values despite its significant decrease. the values of the inflammatory and nutritional prognosis index (PINI) remained normal with values between 1 and 10 on D0 and below 1 on D30. Cashew almonds have improved the nutritional status of MAMs and reduced their risk of infection. These porridges can therefore be recommended not only for the nutritional rehabilitation of MAMs, but also for the prevention of child malnutrition.

Keywords: Moderate acute malnutrition; Children; Nutritional and inflammatory proteins; PINI index; Côte d'Ivoire; Enriched porridges

Introduction

In Africa, the majority of malnourished children come from vulnerable families, living in an infectious environment with very little varied diets and poor in micronutrients [1-3]. In Côte d'Ivoire, the nutritional problems encountered in children are dominated by chronic malnutrition, acute malnutrition and micronutrient deficiencies. Chronic malnutrition affects more than 30% of children

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under five, including 18% in moderate form and 12% in severe form. Rural areas and particularly the northern regions are the most affected with prevalence rates approaching the critical threshold (40%). Regarding acute malnutrition, it affects 18% of children [4]. The most crucial periods are the periods of introduction of complementary foods. Poor households (56.8%) [5] Continue to feed children with traditional porridges that are generally poor in protein, energy and essential micronutrients, and are therefore not indicated for a diet of appropriate nutritional quality [6]. 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 [7]. The work of fokouo and al., 2022 [8] showed that the enrichment of traditional porridge with cashew kernels (*Anacardium Occidental*) and vegetable cortea (*Corchorus olitorius* L.) improved their nutritional qualities. The analysis results of these porridges revealed their richness in energy, in certain Essential Amino Acids (EAA) such as leucine, in vitamins B1, B2, B9, in minerals such as iron, zinc, and in essential fatty acids.

Malnutrition in young children leads to tissue loss which is generally accompanied by a decline in physical performance, the immune system and resistance to infection [9]. This deterioration in nutritional status is life-threatening and is believed to be the cause of increased morbidity and infant mortality in Africa and Côte d'Ivoire [10,11]. Hence, early detection of malnutrition in young children and its early management is important to prevent serious cases of malnutrition, the consequences of which are often irreversible. For this, many clinical and biological markers have been proposed to help detect undernutrition, to assess its severity, and to evaluate the effectiveness of a nutritional rehabilitation treatment [9,12]. Among these markers, nutritional and inflammatory proteins have proven to be very effective in the early diagnosis of malnutrition. Indeed, several studies have shown their sensitivity and variation during minor and moderate forms of malnutrition in young children [6,7,11]. This work aimed to evaluate nutritional and inflammatory proteins in Moderate Acute Malnutrition (MAM) rehabilitated by improved traditional porridge.

Methods

Type of Study and Sampling

This is a longitudinal study with a descriptive and analytical purpose. It was carried out between December 2018 and January 2021 on a total population of 300 children aged 6 to 59 months, divided into 4 groups of 75 children. The sample size was calculated using the following formula [13] (Schwartz, 1969):

$$N = T^2 x \frac{PQ}{D^2}$$

N = sample size; T = parameter linked to the risk of error, equal to 1.96; P= expected prevalence of malnutrition expressed as a fraction of 1. (P=4.8% prevalence of moderate acute malnutrition among children under 59 months in Abidjan [14]; Q=1-p, expected prevalence of people with no malnutrition expressed as a fraction of 1 D=desired absolute precision expressed as a fraction of 1 (5%) The size of each sample was 75 including 5% of non-responses.

Ethics and Informed Consent

This study took place in three pediatric and dietetic departments of the Urban Health Training (FSU) of Cocody, Yopougon (Port Bouet II) and the General Hospital of the municipality of Yopougon in the city of 'Abidjan. Before undertaking it, the permission of the Departmental Health Directors and the informed consent of each parent according to a signed form were obtained.

Inclusion and Exclusion Criteria

Were included in this study, moderately acutely malnourished children (MAM) in accordance with FAO/WHO/UNICEF standards. MAM is characterized by a weight for height Z score varying between -3 and -2 or an arm circumference between 115 and 125 mm. Children with HIV positive, malaria and those with signs of severe malnutrition (anorexia, edema, respiratory disorder, diarrhea) were not included in this study. On the other hand, children whose parents did not respect the instructions of the protocol during the nutritional intervention were excluded from the study.

Study Design

Type of food administered: As indicated in studies by fokouo and al., 2022 [8]:

BC_1 (Control): Supplementary porridge made from millet flour (20 g), groundnut paste (5 g), palm oil (1.5 g), sugar (5 g), water (218.5 mL), usually recommended in FSU Dietary Services;

BC_2 (BC_1+AC): BC1 porridge containing cashew almond paste (10 g). Composition: millet flour (20 g), groundnut (5 g), cashew kernel (10 g), palm oil (1.5 g), sugar (5 g) and water (208.5 mL);

BC_3 (BC_1+ FCOP): BC1 porridge containing powder of *Corchorus olitorius* leaf (2.5 g). Ingredients: millet flour (20 g), groundnut (5 g), palm oil (1.5 g), powdered of leaves of *Corchorus olitorius* leaf (2.5 g), sugar (5 g) and water (216 mL);

BC_4 (BC_1+AC+FCOP): BC1 porridge containing both cashew kernel (10 g) and *Corchorus olitorius* leaves powder (2.5 g). Composition: millet flour (20 g), groundnuts (5 g), palm oil (1.5 g), cashew kernel (10 g), powder of leaves of *Corchorus olitorius* leaf (2.5 g), sugar (5 g) and water (206 mL).

Mode of administration of fortified foods: Four groups of 75 children (G_1-BC_1; G_2-BC_2; G_3-BC_3 and G_4-BC_4) received enriched supplement porridge BC_1, BC_2, BC_3 and BC_4, respectively, in addition to family food. Each parent or carer received specific dietary advice for moderately malnourished children. All the children in the nutritional rehabilitation phase were invited for a check-up 15 days after the start of the experiment. Food administration was carried out over a period of 30 days. Each parent received a kit containing the food ingredients. A visit sheet has been drawn up to ensure the effective implementation of the dietary recommendations.

Biological markers: As albumin has a long half-life, serum albumin < 30 g/L has been used to define severe and prolonged malnutrition, and between 30 and 35 g/L to characterize moderate malnutrition [9]. A pre-albumin or transthyretin of less than 0.15 g/L is the characteristic of severe malnutrition, while moderate malnutrition is established for serum concentrations between 0.15 and 0.25 g/L [15]. Values between 2.2 and 3.6 g/L have been used to determine normal serum transferrin [16]. A ferritin level between 50 and 200 g/L was used as the normal range. Since the study location

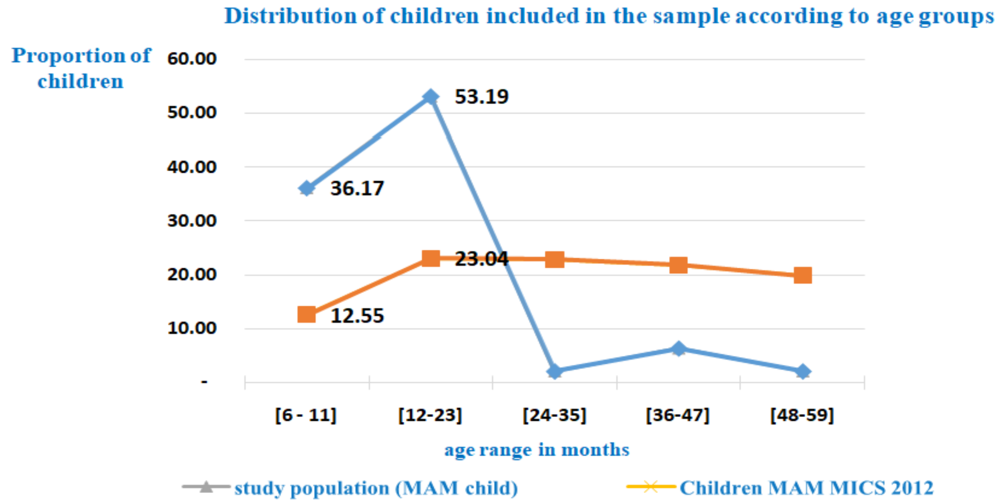

Figure 1: Distribution of children included in the sample according to age groups.

(Côte d'Ivoire) is in an area where infections are common, a serum ferritin threshold < 30 g/L instead of 12 g/L for children under five years of age was used to characterize a depletion of iron reserves [1,19]. A CRP >6mg/L obtained is the characteristic of an infectious or inflammatory state, while a serum concentration of orosomucoid > 1.2g/L has been used to characterize an acute inflammation [17]. The inflammatory and nutritional prognostic index (PINI Index = CRP X Orosomucoid / TBPA X Alb) was calculated to simultaneously assess the inflammatory and nutritional status. - Thus PINI <1: patient not infected, not malnourished; PINI between 1 and 10: low-risk patient; PINI included 11 to 20: moderate risk; PINI ranging from 21 to 30: high risk of complication; PINI > 30: vital risk [20,21].

Determination of concentrations of biological markers of under nutrition: The children included underwent blood samples on D0 (before consumption of porridge) and on D30 (after 30 days of consumption of porridge) in tubes without anticoagulant to obtain serum after centrifugation at 3000 rpm, necessary for biological analyses. In all groups of children, inflammatory proteins (C-Reactive Protein (CRP), Orosomucoid or α1-GPA), and nutritional proteins (Albumin (Alb), Transferrin (Tf), Prealbumin (TBPA) and ferritin) were dosed at using the Cob as C311 Hitachi from Roche diagnostic, France according to the method provided by the manufacturer.

Statistical analysis: The Wilcoxon tests on the SPSS-19, 2016 software were used to compare the means between D0 (before) and D30 (after 30 days of nutritional rehabilitation). As for the kruskal-wallis rank test, it made it possible to compare the different groups of children fed with these porridges. Finally, the level of effectiveness of the various nutritional rehabilitation treatments was carried out by comparing, two by two, the effects of the porridge on the nutritional parameters measured using the Wilcoxon-Mann-Whitney test. The difference between the groups is considered significant at the 5% risk.

Results

Characteristics of the Study Population

The study population consists of 300 moderately acutely malnourished children aged between 6 and 59 months. Children aged between 6 and 24 months had the highest proportion of children with acute malnutrition (36.17%) with a peak between 12 and 23 months (53.19%) (Figure 1). However, at the national level, this proportion is 12.55% between 6 and 11 months with a peak between 12 and 23 months of 23.04%) (Figure 1).

Assay of Biological Markers of Undernutrition

Overall, a significant variation is observed between D0 and D30 for all the proteins. Compared to the reference values, this variation differs according to the types of proteins. Thus, for albumin, on D0 (before nutritional rehabilitation), all the MAM children in the different study groups had normal albuminemia but with values close to the acceptable minimum (G_1-BC_1 (control): 35.12±4.66g/L; G2-BC2: 35.26±5.30g/L; G3-BC3: 35.82±7.19g/L; G4-BC4: 35.41±5.46g/L). At D30, albuminemia still normal (G_1-BC_1: 37.66±3.12g/L; G_2-BC_2: 40.13±3.31g/L; G_3-BC_3: 39.83±2.81g/L; G_4-BC_4: 38.95±4.41g/L) despite their significant increase compared to D0. Concerning pre-albumin or transthyretin, serum concentrations on D0 (G_1-BC_1: 0.11±0.01g/L; G_2-BC_2: 0.11±0.04g/L; G_3-BC_3: 0.02±0.47g/L; G_4-BC_4: 0.19±0.47g/L) were below normal values. However, at D30, a significant increase was obtained in the range of reference values in children who had consumed enriched porridge (G_2-BC_2: 0.21±0.04 g/L; G_3-BC_3: 0.25± 0.38g/L; G_4-BC_4: 0.24±0.38g/L) compared to children in the control group (G_1-BC_1: 0.13±0.03g/L). As for transferrin, its serum level on D0 was normal in all the MAM children and also close to the minimum (G2-BC_2: 2.41±0.47; G_3-BC_3: 2.08±0.61; G_4- BC_4: 2.31±0.64g/L) compared to the reference values except in children in the control group whose transferrinemia is low (G_1-BC_1: 1.13±0.06g/L). At D30, serum transferrin in all groups of children experienced a significant increase with values in the reference interval (G_1-BC_1: 2.18±0.23g/L; G_2-BC_2: 3.86±0 .93g/L; G_3-BC_3: 2.73±0.55g/L; G_4-BC_4: 2.50±0.79 g/L). As for serum ferritin, the concentrations that were initially below normal values (G_1-BC_1: 49.45±7.25g/L; G_2-BC_2: 46.80±26.89g/L; G_3 -BC_3: 35.37±23.12g/L; G_4-BC_4: 38.18±12.81g/L) underwent a significant increase at D30 but remained within the range of normal values (G_1-BC_1: 82.58±15.41g/l; G_2-BC_2: 93.90±47.20g/L; G_3-BC_3: 92.53±28.30g/l; G_4-BC_4: 100.79±28.57g/l L) (Table 1).

Table 1: Evolution of mean serum values of malnutrition proteins in moderately malnourished children (6 to 59 months) fed with porridges of enriched supplements.

	Parameters	Group of children by type of porridge	D0	D30	Change	P-value	Normal values
Nutritional proteins	Albumin (g/L)	G_1-BC_1	35.12±4.66	37.66±3.12	2.54	< 0,001	35 - 40g/L
		G_2-BC_2	35.26±5.30	40.13±3.31	4.87	< 0,001	
		G_3-BC_3	35.82±7.19	39.83±2.81	4.01	< 0.001	
		G_4-BC_4	35.41±5.46	38.95± 4.41	3.54	< 0.001	
	Pre albumin (g/L)	G_1-BC_1	0.11±0.01	0.13±0.03	0.02	< 0.001	0.20-0.40g/L
		G_2-BC_2	0.11±0.04	0.21±0.04	0.10	< 0.001	
		G_3-BC_3	0.02±0,47	0.25±0.38	0.23	< 0.001	
		G_4-BC_4	0.19±0.47	0.24±0.38	0.05	< 0.001	
	Transferrin (g/L)	G_1-BC_1	1.13±0.06	2.18±0.23	1.05	< 0.001	2-4g/L
		G_2-BC_2	2.41±0.47	3.86±0,93	1.45	< 0.001	
		G_3-BC_3	2.08±0.61	2.73±0.55	0.65	< 0.001	
		G_4-BC_4	2.31±0.64	2.50±0.79	0.19	< 0.001	
	Ferritin (µg/L)	G_1-BC_1	49.45±7.25	82.58±15.41	33.13	< 0.001	50-200µg/L
		G_2-BC_2	46.80±26.89	93.90±47.20	47.1	< 0.001	
		G_3-BC_3	35.37±23.12	92.53±28.30	57.16	< 0.001	
		G_4-BC_4	38.18±12.81	100.79±28.57	62.61	< 0.001	
Inflammatory proteins	C-Reactive Protein (mg/L)	G_1-BC_1	5.76±0.21	3.72±0.28	-2.04	< 0.001	< 6mg/l
		G_2-BC_2	4.78±0.93	1.66±0.58	-3.12	< 0.001	
		G_3-BC_3	5.49±1.87	2.55±1.41	-2.94	< 0.001	
		G_4-BC_4	5.61±0.43	2.23±0.72	-3.38	< 0.009	
	Orosomucoid (g/L)	G_1-BC_1	2.87±0.45	0.80±0.84	-2.07	< 0.001	0.5-1.2g/L
		G_2-BC_2	2.19±0.30	0.74±0.09	-1.45	< 0.001	
		G_3-BC_3	2.99±0.21	0.71±0.38	-2.28	0.007	
		G_4-BC_4	0.83 ±0.46	0.75±0.46	-0.08	< 0.001	
PINI INDEX		G_1-BC_1	4.82±0.30	0.61±0.06	-4.21	< 0.001	< 10
		G_2-BC_2	2.70±0.45	0.14±0,84	-2.56	< 0.001	
		G_3-BC_3	3.81±9.21	0.18±0.38	-3.61	< 0.001	
		G_4-BC_4	0.69±0.46	0.17±0.46	-0.52	< 0.001	

Effect of Porridges on Nutritional Protein

The results of the effectiveness of the various nutritional rehabilitation treatments were assessed from comparative statistical analyses. Regarding nutritional proteins, enriched porridge resulted in a more significant increase in albumin, transferrin and ferritin in MAMs than those in the control group. Among the enriched porridges, porridge BC_4 had a more significant effect ($P < 0.05$) on the variation of nutritional proteins, followed by porridge BC_3 (Table 2). Regarding inflammatory proteins, enriched porridge led to a more significant drop in their serum levels in the groups of MAM children than those in the control group. Among the enriched porridges, porridge BC_4 has the most significant effect, followed by porridge BC3. As for the PINI INDEX, the study indicates a more significant drop ($P < 0.05$) with the consumption of enriched porridge compared to that of the control porridge. The BC_3 and BC_4 porridge would have more significant effects than the BC_2 porridge (Table 2).

Discussion

This study showed that diet had a significant influence on the variation of the nutritional and inflammatory protein profile during the nutritional rehabilitation of moderately malnourished young children [10]. Regarding nutritional proteins, on D0, serum albumin levels were close to the required minimum and those of pre-albumin below the reference value in all MAMs. This suggests early undernutrition in all children. This early malnutrition would reflect a protein-energy deficiency [17,18] due to insufficient or unbalanced food intake. After 30 days of nutritional rehabilitation, serum albumin was significantly increased in all children. This intake of albumin could be of dietary origin either directly in the form of phytonutrients (vegetable albumin, carotenoid) or under the action of micronutrients contained in the diet [9]. For transferrin, the study showed that 75% of the children (G1-BC1, G3-BC3, G4-BC4) had transferrinemia in the range of normal values at the beginning of the study, but all (100%), had serum ferritin below the reference range. This suggests a deficit of iron stores in these children which would be the consequence of iron deficiency. This negative iron balance at this stage occurs when the intestinal absorption of iron is insufficient to meet the body's needs. This induces a mobilization of iron reserves

Table 2: Comparison of the effect of fortified porridge consumed by moderately acutely malnourished children on nutritional and inflammatory proteins.

			Rehabilitation porridges compared 2 to 2					
Biological parameters		**Evolution between D0 and D30**	**BC_1 – BC_2**	**BC_1 - BC_3**	**BC_1 - BC_4**	**BC_2 - BC_3**	**BC_2 - BC_4**	**BC_3 - BC_4**
Nutritional proteins	Albumin	Increase	BC_2	BC_3	BC_4	NS	NS	NS
	Pre albumin	Decrease	BC_1	NS	NS	BC_3	BC_4	NS
	Transferrin	Increase	BC_2	BC_3	BC_4	NS	BC_4	BC_4
	Ferritin	Increase	BC_2	BC_3	BC_4	NS	NS	NS
			BC2* **	**BC3*** **	**BC4*** **	**BC3***	**BC4** **	**BC4***
Inflammatory proteins	Orosomucoid	Decline	BC_2	BC_3	BC_4	BC_3	BC_4	NS
	C-Reactive Protein	Decline	BC_2	BC_3	BC_4	NS	BC_4	BC_4
			BC2 **	**BC3** **	**BC4** **	**BC3***	**BC4** **	**BC4***
	PINI Index	Decline	NS	BC_3	BC_4	BC_3	BC_4	NS
			BC_2*****	**BC_3*******	**BC_4*******	**BC_3****	**BC_4******	**BC_4***

The NS sign indicates that there is no significant difference between the effects of the two types of porridge according to the Wilcoxon-Mann-Whitney test at the 5% level. The letter BC with a number indicates the type of porridge having a more significant effect (P <0.05) for a given parameter. The letter BC with numbers and stars (*) at the bottom of each column indicates the most effective porridge taking into account all the nutritional parameters. The stars indicate the number of parameters with a more significant effect.

stored in the form of ferritin. Indeed, ferric iron (fe3+) associated with ferritin in enterocytes is transported in the form of ferrous iron (Fe2+) in the plasma via an export protein, ferroportin; ferrous iron (Fe2+) is then oxidized to ferric iron (Fe3+) by hephaestin (a ferroxidase). Finally, ferric iron rebinds to blood transferrin, which transports it to different sites in the body to meet needs [17,19,21]. This drop in ferritin observed at beginning of the study in 75% of children is accompanied by an abnormally high level of orosomucoid or α1-GPA (inflammatory protein). It can be said that this early malnutrition is accompanied by inflammation in these children [9]. The appearance of the inflammatory process observed in 75% of MAM children at the beginning of the study clearly shows that malnutrition is accompanied by inflammation, as indicated by the work of Yapi [11] and Money [21]. Indeed, the inflammatory process is triggered with the secretion of interleukin 1 following a drop in serum albumin [22,23]. These results once again confirm the usefulness of blood assays for markers of nutritional and inflammatory status during the moderate phase of malnutrition. In an infectious environment, these tests make it possible to detect protein energy malnutrition at an early stage in order to prevent serious forms, the negative consequences of which on the cognitive development of children and the appearance of chronic diseases in adulthood are widely documented [24]. The inflammatory and nutritional prognostic index between 1 and 10 at the start of the study shows that the inflammatory and nutritional risks are still low [25,26]. After 30 days of nutritional rehabilitation, the study indicated a significant increase in nutritional proteins and a significant decrease in inflammatory proteins in all children except in the children in the control group where prealbumin remained below the minimum required value. This suggests that the children in the control group are still mildly malnourished but without inflammation despite porridge consumption (BC_1). The disappearance of the inflammatory process observed in the children of the G_1-BC_1, G_2-BC_2 and G_3-BC_3 groups could be explained by the significant increase in albumin which, by induced effect, led to a significant drop in the proteins of the inflammation (C-reactive protein and orosomucoid). To better understand this mechanism, it is important to specify that the biosynthesis of inflammatory proteins is carried out under the action of cytokines of the inflammatory reaction (TNF α, interleukin 1 and interleukin 6) produced by phagocytic cells. These cytokines are metabolic messengers emitted by the inflammatory focus to hepatocytes [27]. At the level of activated hepatocytes, there will be an increased production of inflammatory reaction proteins, including C-reactive protein and orosomucoid, which will mobilize the body's immune defenses. On the other hand, cytokines (IL1 and TNF α) have a negative effect on albumin synthesis [28]. In response to the inflammatory process, the clinical signs such as pain, redness, heat and swelling appear. Several studies have shown that inflammation leads to a decrease in the synthesis of nutritional proteins, in particular albumin, but an increase in the synthesis of inflammatory proteins by hepatocytes [10,29]. Indeed, other studies have shown that in a cancer patient, serum albumin remains low until the inflammation is resolved, even if nutritional support is put in place [30]. The beneficial effect of nutritional supplementation leading to an end of the inflammatory process is marked by the increase in albumin and the significant decrease in CRP and the drop in orosomucoid. The improvement in the serum level of these proteins would be due to the dietary intake of porridge with type I nutrients (iron, vitamin A, B2, B9, E) and especially type II nutrients (zinc, phosphorus, Essential Amino Acid (EAA), Essential Fatty Acid (AGE)) and antioxidant compounds [1,8]. Indeed, type II nutrients are tissue-building nutrients and are required for almost all biochemical pathways and contribute to the development of skeletal tissues [1]. As for type I nutrients, they contribute to the development of functional tissues. All these nutrients contribute to the rapid renewal of cells with a short lifespan, in particular the enterocytes of the intestine, immune and inflammatory cells. Their deficiencies can therefore lead to poor absorption and dysfunction of the immune system [1].

The study found more significant variation in inflammatory proteins in children in the G_3-BC_3 and G_4-BC_4 groups. This phenomenon can be explained by the content of these porridges in leaves of vegetable cortea(*Corchorus olitorius*) and cashew kernel (*Anacardium Occidental*). Indeed, several studies have shown that the leaves of *Corchorus olitorius* have anti-inflammatory, anti-bacterial and antifungal properties [31,32]. In traditional medicine, these leaves are used to treat gonorrhea, pain and fever [32]. Other studies have shown that the aqueous extracts of these leaves have high antioxidant properties [34] and are used to prevent anemia [35,36]. As for the cashew kernel (*Anacardium Occidental*), a resent study has shown that it neutralizes oxidative stress and tissue inflammation [37]. In addition, the study showed that it causes a significant increase in ferritin and transferrin in the blood within the limits of normal values with normal serum levels of inflammatory proteins (CRP and α1-GPA) in MAMs. supplemented. These results could be explained by the absorption of dietary iron in the intestine and its increasing use by the body of young MAM children in an increased phase of renewal of deficient tissues [38]. Indeed, the iron ingested in the diet comes in two forms (heme and non-heme). In the case of the study, non-heme iron in the ferric state (Fe 3+) in the duodenum is first reduced to ferrous iron (Fe 2+) at the level of the apical membrane of the enterocytes, and then is transported inside enterocytes thanks to a divalent metal transporter. Once in the enterocyte, part can be stored in ferritin and the other transported in the plasma by a ferroportin in the form of ferrous iron (Fe 2+). In the plasma, this ferrous iron is oxidized to ferric iron (Fe 2+) by hephaestin. Finally, ferric iron (Fe 2+) binds to transferrin to be transported to different sites in the body to meet needs. In case of excess iron, the synthesis of ferritin is activated to store iron and the synthesis of transferrin is inhibited. The opposite happens with iron deficiency. Senescent enterocytes are destroyed by macrophages releasing ferritin. Plasma ferritin can come from the cells of damaged cells [17,19]. In view of the foregoing, it could be said that the dietary intake of iron contained in porridge has improved the iron status of children. In addition, the levels of vitamin B2 contained in enriched porridge [8] would allow greater availability of iron stored in the form of ferritin, which would help to potentiate the immune system, the synthesis of red blood cells and to create the conditions for harmonious growth of young children. By consuming these enriched porridges, we would help to fight against anemia in Ivorian children because more than 75% are anemic with 80% of anemia of iron deficiency [4]. The significant drop in the PINI index below 1 after consumption of enriched porridge clearly shows an improvement in the nutritional status and health of MAM children. It can therefore be said that the consumption of enriched porridge improved the nutritional and inflammatory status of MAMs, thus confirming the relationship between malnutrition and the inflammatory state [39]. Another study by Youan (2018) [18] showed a significant evolution of nutritional proteins following MAM supplementation using porridge enriched with legumes and green algae (spirulina).

Concerning the effect of porridges on the biological parameters of malnutrition, the statistical results indicated that the enriched porridges had a more significant effect in the positive variation of nutritional proteins than the control porridge. Among the enriched porridges, the BC_4 porridge enriched with both cashew kernels and *Corchorus olitorius* leaves would be the most effective according to statistical tests. Then comes the BC_3 porridge. Indeed, these two porridges are the richest in micronutrients [8]. These statistical tests also indicate that the BC_4 and BC_3 porridges have a more beneficial effect in reducing inflammation at the MAM level. These results can be explained by the nutritional, anti-inflammatory and antioxidant properties acquired by the porridges following their enrichment with cashew kernels and *Corchorus olitorius* leaves [1,8,32,33].

Conclusion

This study showed that the enrichment of traditional porridge supplements from local ingredients such as cashew kernel (*Anacardium Occidental*) and dried leaves of *Corchorus olitorius* has a beneficial effect on the variation of nutritional proteins and inflammatory conditions, and improved iron stores in the MAM children's bodies. This improvement in the nutritional status and the reduction in the risk of infection of young MAM children would be due to the richness of porridge in type I nutrients (Vitamin B2, B9, iron) and II (zinc, AAE, phosphorus), and probably to the antioxidant, antibacterial and anti-inflammatory properties that the porridges would have acquired following their fortification. Thus, the consumption of these enriched porridges could make it possible to fight effectively against child malnutrition in underprivileged areas and prevent iron deficiency anemia in young children.

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