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Nutritive and Antinutritive Values of Ready-To-Use Foods based on Local Ingredients for the Recovery of Moderate Acute Malnourished Children in Côte d'Ivoire

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Abstract

Moderate acute malnutrition is one of the most common nutritional disorders among young children in Côte d'Ivoire. For treating this condition, ready-to-use foods have been found to be the most effective. However, their high cost and the recurrent stock breaks lead to national unavailability whose local production can fill and ensure sustainable care. This study has been set to assess the nutritional and anti-nutrient value of ready-to-use foods formulated with locally available ingredients. For doing this, four formulae meeting the recommended nutritive needs for moderately acutely malnourished children aged 6 to 59 months have been produced using traditional methods and household equipment. The cocoa (LF-1 and LF-3) and cashew (LF-2 and LF-4) formulae contained rice, soy, sugar, oil, and egg. The latter has been added to FL-3 and FL-4. All formulae presented biochemical compositions (proteins, fats, carbohydrates, and energy except fiber and ash) close to Plumpy?Sup®.

Index terms— ready-to-use foods, moderate acute malnutrition, children from 6 to 59 months, enriched egg, cocoa, cashew nut, côte d?ivoire.

cette étude est d'évaluer la valeur nutritive et antinutritive des aliments prêts à l'emploi formulés à base d'ingrédients localement disponibles. Pour cela, quatre formules répondant aux besoins nutritionnels recommandés chez les enfants malnutris aigus modérés de 6 à 59 mois ont été produites en utilisant des méthodes traditionnelles et équipements domestiques. Les formules à base de cacao (FL-1 et FL-3) et d'anacarde (FL-2 et FL-4) contenaient du riz, soja, sucre, huile et oeuf. Ce dernier est uniquement ajouté aux formules FL-3 et FL-4.Les formules locales ont présenté des compositions biochimiques (protéines, lipides, glucides et énergétiques à l'exception des fibres et cendres) proches du Plumpy'Sup ® .

Cependant, leur profil minéral couvre partiellement les besoins recommandés; ce qui pourrait être corrigé par une supplémentation.

Par contre, la composition en phytonutriments révèle qu'elles sont aussi riches en polyphénols et flavonoïdes que le Plumpy'Sup ® mais avec des teneurs plus faibles en tanins, oxalates et phytates. Ce dernier anti-nutriment limiterait uniquement la biodisponibilité du fer. En définitive, la consommation d'aliments prêts à l'emploi élaborés à partir d'ingrédients locaux serait une alternative intéressante dans la prise en charge durable de la malnutrition aiguë en Côte d'Ivoire.

1 Introduction

ndernutrition is the most frequent nutritional disorder in developing countries. It remains one of the most common causes of morbidity and mortality in children under five worldwide [1].

Acute malnutrition remains one of the three forms of undernutrition that most degrades the lives of poor communities in low-and middle-income countries [2]. Globally, 52 million children (7.7%) under five that is one in twelve of this age group suffer from acute malnutrition [3,4], which is associated with 1 to 2 million preventable children deaths every year [5]. Among them, 34 million (or 14 million in Africa) are affected by moderate acute malnutrition (MAM), while 17 million suffer from severe acute malnutrition (SAM) [3].

In Côte d'Ivoire, the prevalence of acute malnutrition has decreased by 100% over five years U Resumé-La malnutrition aiguë modérée est l'un des troubles nutritionnels le plus rencontré chez les jeunes enfants en Côte d'Ivoire. Pour traiter cette affection, les aliments prêts à l'emploi s'avère être les plus efficaces. Cependant, leur coût élevé et les ruptures de stocks récurrents entrainent une indisponibilité nationale dont la production locale pourra combler et assurer une prise en charge durable. L'objectif de (from 7% to 6% between 2012 and 2016) [6]. Among the 6%, MAM affects 4.8%, that is 80% of cases, while SAM affects 1.2% (20% of cases). In addition, the prevalence of acute malnutrition from the 6 to 24 month age group is around 10% (9.77%) [6] which is considered by WHO to be a solemn threshold that requires emergency intervention [7]. Now, this age group included in the first 1000 days of life is considered to be the most decisive period for influencing long-term nutrition and health outcomes [5]. Also, to prevent a worsening of their nutritional state and their progression to the severe form, the management of MAM in Côte d'Ivoire should be considered a public health priority.

For combatting this condition, Foods have been designed for Special Medical Purposes. Among them, Ready-to-Use Foods (RUFs) prove to be the most effective in managing acute malnutrition [8]. They improve the recovery rate of acutely malnourished children in sub-Saharan Africa [9]. However, shipping costs, delays, priority, as well as donor fatigue, lead to periodic unavailability of RUFs in Côte d'Ivoire, which compromises its effectiveness in fighting against malnutrition.

In addition, the milk-and peanut-based RUFs commonly known as Plumpy'Nut ® and Plumpy'Sup ® , respectively used in the treatment of SAM and MAM, are expensive [10,11]. As a result, sustainable treatment with these RUFs can be hard in the absence of local production [12]. For this production, replacing the milk in RUFs with soybeans could reduce its cost and and/or increase its availability.

For an ingredient to be described as local, a country must have 500 metric tons or more of a given available, whether nationally produced or imported, in the locale of RUTF production [14] with a regular supply. Thus, Côte d'Ivoire is the first producer of cocoa and cashew nuts in the world with respective productions of 2.2 million tons (Mt) for the 2018/2019 campaign [15] and 761,000 tons in 2018 [16]. According to the United States Department of Agriculture (USDA), Ivorian production of unhulled rice is around 2.231 Mt for the 2018/2019 season compared to 1.45 Mt of milled rice [17]. Côte d'Ivoire is also the second African producer of crude palm oil with 500,000 tons per year [18]. Soybean production data is not updated. However, the Office of Aid for the Marketing of Food Products (OCPV) reports a regular supply on local markets (Abidjan, Bouaké, Yamoussoukro, Man).

It is in this context that low-cost ready-to-use foods (RUFs) were developed using local ingredients. The objective of the present study is, therefore to assess nutritional and antinutritive quality of these RUFs in comparison with Plumpy'Sup ® to meet the nutrients recommended by the WFP for the management of moderate acute malnutrition in children aged six at 59 months.

2 II.

3 Materials and Methods

4 a) Materials

The raw materials used for the production of RUF in the form of spreads are cocoa pods (Theobroma cacao, var. Forastero), cashew paste (Anacardium occidental L.), milled rice (Oryza indica, var. Bouake), soya beans (Glycine sp), chicken eggs (ISA waren), sugar and refined palm oil.

The cocoa comes from the plantations of the Research and Experimentation Station of the National Agronomic Research Center (CNRA) in Divo. Cashew paste and white milled rice were purchased from the companies SARAYA in Bouaké and CODERIZ in Adzopé. Eggs enriched in omega three by the seeds of Euphorbia (Euphorbia heterophylla L.) were produced on the farm of the breeding center of the National Institute for Agricultural Vocational Training (INFPA) in Bingerville. Soybeans, sugar, and oil were bought from the local market. Finally, the Plumpy'Sup ® given by Nutriset® was used as a reference.

5 b) Methods

6 i. Formulation of RUFs

Theoretical formulation of RUFs was carried out using linear programming **??**19] to identify combinations of ingredients that meet the nutritional needs of children under five years suffering from acute malnutrition [20]. Thus, four (4) RUFs were formulated and noted local formulae 1, 2, 3, and 4 (LF-1, LF-2, LF-3, and LF-4). Except added egg in LF-3 and LF-4, all local cocoa formulae LF-1 and LF-3 and those containing cashew nuts LF-2 and LF-4 have used the following ingredients: soy, rice, oil, and sugar (Table I). ii. Ingredient treatments Rice flour has been obtained from the white milled rice. The latter, after having been cleaned (sorting, winnowing, and washing with water three times), was precooked in a microwave oven for 3 min. The precooked rice was then roasted in a frying pan at 120-130 ° C for 30 to 40 min [21], pulverized in a mill (PHILIPS ® , HR2056), and sieved using a 150 µm mesh sieve.

Soybean meal has been obtained from soybeans that were cleaned and then soaked in water containing 1% sodium bicarbonate [22]. The soaking has been carried out in a seed/water ratio of 3:10 (w/v) for eighth [23].

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The soaked seeds were then drained, skinned, and then precooked in a microwave oven for 3 to 5 min. The precooked seeds were finally roasted in a pan at 120-130 ° C for 50-70 min, respectively, cooling, grinding using a mill, and sieving at 300 µm.

The cocoa mass has been obtained from the cocoa pods. These are first podded to extract the beans, which will then be fermented under banana leaves for six days [24]. The fermented beans were oven-dried for 1 to 3 days, then roasted at 130 ° C for 30 to 40 min. The roasted beans were finally shelled by hand, winnowed with a hairdryer, crushed, and then ground in a mortar to obtain a paste.

Icing sugar has been obtained from powdered white sugar (? 1000 µm). The latter was crushed using a mill and then sieved to get a powder (150 µm).

Egg powder has been obtained from chicken eggs. These have first been broken to remove the shells. The liquid obtained was homogenized in a multifunction mixer. It was immediately oven-dried at 45° C for 24 to 48 hours and spreading it on aluminum trays. The dried eggs were ground using a mill and then sieved with a 300 µm diameter sieve.

Cashew nut paste and refined palm oil have been used as such without any treatment or processing.

7 iii. Preparation of RUFs

The preparation of RUFs has been inspired by the methods described by [21] and [25]. RUF's formulae have been prepared by combining the ingredients according to [26].

8 iv. Determination of the nutritional and anti-nutritional value of formulae produced

Water activity and pH were measured using a moisture meter (Moisture Balance, BM-50-1) and a pH meter (Benchtop / mV meter, 210), respectively. The dry matter, lipid, protein, ash, and dietary fiber contents have been determined according to [27] method in triplicate. The carbohydrate content was estimated by differential calculation [28]. The ash obtained was used to determine the mineral profile using the Scanning Electron Microscope, equipped with an X-ray detector (OXFORD Instruments). The calculation of the energy value has been carried out according to the relation given by the conversion coefficient of metabolized energy called general Atwater factors [29].

The phenolic compounds have been extracted with methanol according to the [30] method. These extracts have been used to determine the contents of polyphenols, flavonoids, and tannins according to the respective methods described by [30], [31], and [32]. On the other hand, the oxalate and phytate contents have been determined on the samples according to the methods described by [33] and [34]. The bioavailability of the minerals was determined by [35] and [36] by measuring the molar ratios Phytate/Iron, Phytate/Zinc, Phytate/Calcium, Phytate×Calcium/Zinc, and Oxalate/ Calcium.

v

9 . Statistical analyzes

The data collected was first entered in the Excel spreadsheet. Then, their statistical processing has been carried out using R software version 3.5.2. The results have been expressed as the mean ± standard error. After a one-way analysis of variance (ANOVA), the comparison of the means has been carried out by the Newman-Keuls test (at the 5% level) III. Analysis of macroelements, trace elements and then Ca/P and Zn/Cu ratios showed that all local formulae do not meet the limits of the recommendations. Likewise, these limits are not respected in the PS for the contents of K, Ca, P, and the Zn/Cu ratio. Source: * [38] ; ** [39] ; *** [40] Phytochemicals contents of all formulae have been presented in Table IV. Cocoa-based formulae (LF-1 and LF-3) had higher levels of polyphenols and flavonoids than those of PS and cashew-based formulae (LF-2 and LF-4). Local recorded lower levels of tannins, oxalates, and phytates than those of PS. Table IV Source: a [41] ou [42] ; b [43] ; c [44] ; d [45] ; e [46] IV.

10 Results

11 Table

12 Discussion

Results of the physicochemical composition (Table II) show overall that all formula met WFP recommendations [20] for ready-to-use foods intended for malnourished children. They have been characterized by low water activity (<0.6), and low humidity (<5 g/100g) which are comparable to those found by [37], [47] and [48]. These low recorded rates could have been explained by the drying, roasting and grinding processes used in the production. These rates would therefore be beneficial for better and long shelf life. In addition, cocoa-based formulae (LF-1 and LF-3) recorded the lowest pH values, which could have been explained by fermented ingredients in the production process.

Protein contents of local formulae (14.39 to 15.42 g/100g) were higher than PS (13.86 g/100g). These values are lower than those determined by [49] (17.06 g/100g) and [48] (17.60 g/100g) respectively in RUFs based on soy and whey protein but fall within the range of 11.42 to 15.6 g/100g described by [47], [49] and [50] for RUFs based on whey protein.

However, our formulae had higher levels than those reported by [37] (13.4 to 14.1 g/100g) for sesamebased RUFs. In addition, the incorporation of egg powders in LF-3 and LF-4 formulae had higher protein contents than those made only from ingredients of plant origin (LF-1 and LF-2).

For lipid contents, cocoa-based formulae (LF-1 and LF-3) were higher than PAM recommendation (26 to 36 g/100 g). These high values compared to those formulae (PS, LF-2, and LF-4) would be due to the incorporation of the cocoa mass. Malnourished children have a high energy requirement [50]. They, therefore, need a diet rich in fat. These lipids are also necessary for the absorption of vitamins A and E [52], which are vital for rapid recovery and reducing the incidence associated with malnutrition.

Ash contents of all local formulae are much lower than that of PS because the latter has been supplemented with minerals and vitamins [53]. In addition, the high fiber contents of the cocoa-based formulae are close to those found by [51] (7.85 g/100 g) in Uganda in a therapeutic food based on sorghum and peanut for the treatment of MAM. Fiber plays an essential biochemical and physiological role indigesting foods. Unfortunately, due to the clear limitations of the evidence on the subject caused by insoluble or soluble fiber in these moderately malnourished children, no limits have been set [51]. However, extensive preclinical studies should have been carried out to establish a standard in this matter.

The carbohydrate content and energy density of all formulae are adequate to provide enough energy for a child to recover from moderate malnutrition. Finally, the physicochemical composition reveals except of the fiber and ash contents, that the protein, fat, carbohydrate, and energy values are generally comparable to those of Plumpy'Sup ® .

The results of the mineral profile (Table III) revealed a significant difference between local formulae and PS. This result is mainly due to the addition of mineral and vitamin supplements in PS. Thus, the mineral profile of our formulae does not meet the majority of recommendations for the care of children suffering from MAM. In practice, no food can provide the minerals necessary to correct such deficiencies and ensure de novo tissue synthesis. These results agree with the findings of [52], who reported that formulations using local foods do not achieve these recommendations except through supplementation. Thus, to cover all the target's needs and ensure rapid and efficient recovery, it would be essential to supplement our local formulae with minerals.

Some minerals can also compete, which could cause losses. Thus, ratios have been established to ensure adequate absorption and proper functioning of the body. The first ratio is that of Na/K. This is of great interest in preventing high blood pressure (HBP). Na/K ratio of less than one has been recommended [54]. Na/K ratios of all local formulae are less than 1, which suggests that they have a good capacity to prevent HBP and would therefore be beneficial for the health of children and particularly for the undernourished ones.

Second ratio is of Ca/P. Foods rich in protein and P may promote the loss of Ca in the urine [55]. [39] suggests that this ratio would be between 0.7 and 1.3 in children over six months for high quality absorption, while it would be between 0.5 and 1 [38]. However, the results showed a low Ca/P ratio, which could lead to a loss of Ca in the urine more than usual, hence the need to supplement local formulae. The third one is Zn/Fe ratio. A ratio of 0.8 to 3.5 has been established to ensure adequate absorption [40]. Thus, all formulae respected this standard. The last ratio is that of Zn/Cu. Reference and local formulae exhibited ratios varying from 0.86 to 3.43, which indicates that they should have been supplemented with Zn rather than Cu to meet the standard [40].

The results of phytochemical values (Table IV) indicated a high content of total polyphenols of local formulae, which would be beneficial for malnourished children who have a slowed metabolism and a weakened immune system. Indeed, polyphenols play several biological roles, notably in anti-inflammatory activity [56] and the prevention of cardiovascular diseases [57].

Regarding the flavonoid contents of formulae studied, they are higher than those reported by [58] and [59] respectively in infant formulae based yam/soy (3.35 to 76.58 mg / 100 g DM) and on corn/sesame/moringa (0.88 to 85.85 mg / 100 g DM). As for oxalate contents, they are much lower than those of [60] obtained in formulae based on cereals enriched with soya, egg yolks, and crayfish (780 mg / 100 g) and below the lethal dose (4000 at 5,000 mg/day) [61].

The low tannin contents recorded in local formulae could result from soybean soaking conditions carried out during production. Indeed, during steeping, the tannin contents are markedly lower than those of polyphenols, definitely because of their cooler solubility [62]. In addition, the use of bicarbonate in the soybean steeping solution must have increased its alkaline properties allowing greater solubilization of tannins. Indeed, [63] observed a reduction in tannins in sorghum grains after soaking in an alkaline solution before their malting. In addition, tannin contents of local formulae are lower than those of [64] obtained during the preparation of local formula based on sorghum, peanuts, whey, and honey (943 mg/100g).

The reduction in phytate content of all local formulae could be attributed to the phytase activity contained in soybean during their soaking. These results agree with the work of [65] and [66], who respectively reported that soaking reduced phytate content by 28% in pigeon peas and by 25-30% in mung beans. Although we did not determine this particular amount in our study, some information inthe literature [67] suggests that this may indeed be the case.

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However, the exact effect of anti-nutritional compounds on mineral absorption depends on their relative concentration in formulae. Thus, a theory has been advanced, supported by several animal experiments [61,68], that the phytate/iron, zinc, or calcium (Phy/Fe, Phy/Zn, or Phy/Ca) molar ratios of food can serve as an index of respective assimilability of iron, zinc, and calcium. The results of Table V indicated that Zn and Ca have been easily assimilated in all formulae. On the other hand, Phy/Fe ratios of local ones (1.29 to 1.59) and PS (1.77) are higher than the standard [41,40], which could lead to a marginal iron deficiency resulting from its poor assimilation.

This finding was also reported by [69] for the reference formula (Plumpy'Nut ®) used in severely acutely malnourished children. However, [70] and [71] suggest that the bioavailable iron content of food has been expressed by taking into account compounds that can positively influence iron absorption. These are vitamin C, citric acid, animal proteins, and sugars (lactose and maltodextrins).

Thus, the absorption of iron in subjects consuming meals containing corn, wheat, and rice, is approximately doubled by the addition of 25 mg of vitamin C and can be multiplied by 3 to 6 times when 50 mg are added [72]. This favorable effect of vitamin C, due to the preferential affinity of iron for this compound over chelating compounds, is most evident when foods are rich in phytates or phenolic compounds [73,74]. These conclusions agree with the results of studies carried out in severely acutely malnourished children comparing the effectiveness of a local formulation based on corn/sorghum/soya and Plumpy'Nut ® . Their vitamin C contents were respectively 329 and 53 mg/100g, those of phytates were 420 and 255 mg/100g while those of iron were 43.8 and 12 mg/100g [69]. Therefore, the amount of vitamin C contained in PS (60 mg/100 g) [53] may promote iron absorption despite their high phytate content (239.23 mg/100 g).

In addition, the work of [75] has shown that the inhibitory role of phytate in the absorption of zinc has been accentuated by the calcium content in food. [45] suggested that the assimilability of zinc in food could be estimated more satisfactorily by calculating the Phy*Ca/Zn ratio. Analysis of the results indicates that this ratio is less than 3.5 in all local formulae. Thus, the phytate contents of these formulae could not interfere with the absorption of zinc. Regarding the Oxa/Ca molar ratio, it appears that this ratio should be of the order of 2 for oxalic acid to significantly interfere with calcium absorption [46]. The results of all formulae indicate that these ratios oscillate between 0.11 (PS) and 0.62 (LF-2), which would show that the oxalate contents of these formulae could not interfere with the bioavailability of calcium.

V.

13 Conclusion

Local production of RUFs is crucial for the sustainable management of malnutrition. This study demonstrated that it is possible to produce RUF from locally available ingredients while using traditional methods and domestic equipment. For doing this, four local formulae have been produced, two of which are based on cocoa (LF-1 and LF-3) and two others are based on cashew nuts (LF-2 and LF-4). Analysis of the physicochemical composition of these formulae revealed that except fiber and ash contents, protein, lipid, carbohydrate, and energy values are closed to those of Plumpy'Sup ® while respecting WFP standards for the preparation of supplementary ready-to-use foods (RUSF). However, a mineral profile of local formulae indicates that they only partially cover the mineral needs recommended by WFP. These formulae could have been corrected by supplementation to ensure rapid and effective recovery.

The study of phytonutrient composition shows that local formulae are an excellent source of polyphenols and flavonoids with values sometimes higher than those of Plumpy'Sup ® . In addition, tannin, oxalate, and phytate contents of local formulae are lower than those of Plumpy'Sup ® . Apparent bioavailability assessment indicates that except the Phy/Fe ratio, all local formulae have a good absorption capacity of zinc and calcium.

Ultimately, consumption of RUFs made from local ingredients would be an attractive alternative in the sustainable management of acute malnutrition. However, it would be necessary to continue this study by seeking to supplement these RUFs in vitamins/minerals and evaluate their shelf life and microbiological quality. Sensory analyzes should also have been carried out.

I

Ingredients (%)	LF-1	LF-2	LF-3	LF-4
Rice flour	24	22	23	23
Soya flour	29	30	28	26
Cocoa paste	17		17	
Cashew paste		17		17
Egg powder			03	03
Refined palm oil	20	21	19	21
Ice sugar	10	10	10	10
Total	100	100	100	100

Figure 1: Table I :

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II

Parameters	PAM recommendations		Plumpy Sup ®	LF-1	LF-2	LF-3	L 4
	Min	Max					
pH	_	_	6.25 ± 0.01 a	5.70 ± 0.02 c	6.17 ± 0.02 b	5.73 ± 0.02 c	6 ± 0 b
A w	_	0.6	0.26 ± 0.02 d	0.30 ± 0.02 c	0.41 ± 0.01 b	0.29 ± 0.02 c	0 ± 0 a
Humidity (%)	2.5 *	5 *	2.05 ± 0.07 b	2.20 ± 0.02 b	2.40 ± 0.18 a	2.23 ± 0.03 ab	2 ± 0 a
DM (%)	_	_	97.95 ± 0.07 a	97.80 ± 0.02 a	97.60 ± 0.18 b	97.77 ± 0.03 a	9 ± 0 b
Protein (g/100g)	11	16	13.86 ± 0.07 d	14.39 ± 0.02 c	15.22 ± 0.07 b	15.42 ± 0.03 a	1 ± 0 a
AC (%)	_	_	42.24 ± 0.28 a	35.76 ± 0.08 d	39.87 ± 0.19 c	35.06 ± 0.11 e	4 ± 0 b
Lipid (g/100g)	26	36	34.97 ± 0.25 c	37.28 ± 0.05 a	35.44 ± 0.02 b	37.14 ± 0.16 a	3 ± 0 d
Ash (g/100g)	_	_	4.70 ± 0.01 a	1.87 ± 0.01 b	1.81 ± 0.05 b	1.85 ± 0.06 b	1 ± 0 b
Fiber (g/100g)	_	_	2.18 ± 0.04 e	8.49 ± 0.02 a	5.25 ± 0.05 c	8.3 ± 0.02 b	4 ± 0 d
EV (kcal/100g)	510	560	539.11 ± 1.11 a	536.15 ± 0.18 b	539.34 ± 0.98 a	536.19 ±	

Source: * [37]; Aw: Water activity; DM: Dry matter; AC: Available Carbohydrates; EV: Energy Value; LF-1 cocoa / rice / soybeans; LF-2: Local formula based on cashew / rice / soybeans; LF-3: Local formula based egg; LF-4:

II composition of the local (LF-1, LF-2, LF-3, and LF-4) s

values than those of PS (6.25; 4.70 g/100g and 42.24%). L activity (Aw) (0.49) and dietary fiber (8.49 g/100g), respe (DM) with respective rates of 97.77, 97.80, and 97.95%.

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Formulae, including egg powder (LF-3 and LF-4), had the highest protein content (15.42 and 15.34 g/100g), followed by LF-1, LF-2and that of PS, which had the

III

Minerals (mg/100g)		PAM recommendations Min	Max	Plumpy'Sup ®	LF-1
	Na	_	270	48.74 ± 4.11 bc	45.68 ± 2.62 c
Macro-elements	K	900	1400	841.75 ± 8.41 a 437.54 ± 2.59 b 335.54 ± 7.87 a 59.72 ± 0.68 b 3	
	Ca	535	750		
	P	450	750		
	Mg	150	225	167.07 ± 5.41 a	90.24 ± 0.97 b
Oligo-elements	Zn	11 10	14	10.50 ± 0.27 a	3.12 ± 1.51 bc
	Fe	1,4	14	11.44 ± 0.98 a	2.37 ± 0.39 b
	Cu		1,9	3.13 ± 0.72 a	2.43 ± 0.32 abc
RatioNa/K*			1	0.05	0.10
Ca/P**		0.7	1.3	0.88	0.31
Zn/Fe***		0.8	3.5	0.91	1.32
Zn/Cu***		5	20	3.35	1.28

Figure 3: Table III :

Formulae	Polyphenols	Flavonoids	Compounds (mg/100g) Tannins	Oxalates	Phytates
Plumpy'Sup ®	483.38 ± 8.63 b	164.64 ± 2.08 bc	154.40 ± 10.36 a	82.00 ± 4,00 a	239.23 ± 14.85 a
LF-1	581.28 ± 13.81 a	186.58 ± 1.10 a	73.50 ± 1.76 b	44.00 ± 0.00 d	36.48 ± 0.64 b
LF-2	305.33 ± 3.47 c	166.71 ± 12.14 bc	59.08 ± 1.43 c	66.73 ± 1.27 b	38.59 ± 2.52 b
LF-3	554.92 ± 30.36 a	175.54 ±1.10 ab	64.53 ± 1.31 c	34.10 ±1.10 e	33.05 ± 0.83 b
LF-4	284.45 ± 3.81 c	151.25 ± 9.94 c	55.23 ± 1.73 c	55.00 ± 0.00 c	35.47 ± 0.83

[Note: b The Phy/Fe, Phy/Zn, Phy/Ca, Phy×Ca/Zn, and Oxa/Ca molar ratios, indicative of the bioavailability of Fe, Zn, and Ca are given in TableV.]

Figure 4: :

V

Formulae	Phy/Fe	Phy/Zn	Molar Phy/Ca	Ratios	Phy×Ca/Zn	Oxa/Ca
Plumpy'Sup ®	1.77	2.26	0.04		18.89	0.11
LF-1	1.30	1.16	0.04		1.73	0.33
LF-2	1.59	1.58	0.05		1.88	0.62
LF-3	1.29	0.74	0.03		1.15	0.24
LF-4	1.52	1.58	0.04		2.37	0.41
Normes	< 0.5 ou 1 a	< 15 b	< 0.17 c		< 3.5 d	< 2 e

Figure 5: Table V :

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.2 Conflict of Interest

Authors declare that they have no conflict of interest.

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