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IMPACTS OF *MORINGA OLEIFERA* LEAF POWDER (MLP) ON THE PROTEIN CONTENT AND ENERGY VALUE OF *COLOCASIA ESCULENTA* (TARO) PORRIDGE: A TRADITIONAL INFANT FOOD IN GUINEA

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ABSTRACT

Moringa oleifera leaf powder (MLP) has exceptional nutritional properties due to its high content of micronutrients, fatty acids, and especially protein. This makes it a suitable ingredient for the fortification of taro flour. Taro is a high-energy product but low in protein and fat, which weanling children need for their normal development. This study aimed to evaluate the protein-energy contribution of MLP powder in infant taro porridge. Three fortified taro porridges named FTP10% (Taro + 10% of Moringa), FTP15% (Taro + 15% of Moringa) and FTP15% (Taro + 15% of Moringa) were performed. Their analyses indicated significant increases (P<0.05) in crude protein content, energy value and titratable acidity from 0.580 0±046% to 1.570 0±052%, 82.137 1±43% to 88.807 1±658% and from 0.130 0±017g/100g to 0.380 0±010 g/100 g respectively.

KEYWORDS: ***Proximal composition, taro porridge, Moringa oleifera.***

I. INTRODUCTION

Many children suffer the consequences of poor nutrition and a food system that does not take into account their nutritional needs (Heber, 2019). Globally, 240 million children under five are malnourished, of whom 22.2% are stunted, 7.5% are undernourished and 5.6% are overweight. These rates have remained almost constant over the past 20 years. Africa and Asia are the most affected continents (Aprifel, 2018). Traditional practices detrimental to child health are determinants of malnutrition that contribute to neonatal, infant, and child mortality (FMI, 2013).

In Guinea, the prevalence of global acute malnutrition and chronic malnutrition is respectively 14.4% and 37.5% among children aged 6-59 months; 8.3% for severe acute malnutrition and 6.1% for moderate malnutrition (ANASA, 2017). Malnutrition is influenced by the mother's level of education: from 34% among children of mothers with no education, the proportion drops to 25% among those whose mothers have primary education and 17% among those whose mothers have secondary education (FMI, 2013). Industrial infant flours cost from 20,000 to 59,000 Gnf, which is (2 to 6 dollars). The quantities imported were respectively 1,154,556 Kg in 2012; 1,028,626 Kg in 2013 and 1,503,039 Kg in 2014 (DND: Direction Nationale de la Douane, 2016). After six months, breast milk is insufficient to cover the child's protein and energy needs (Zannou-Tchoko Viviane Jocelyne, 2011). The consumption of poor quality complementary foods in insufficient quantity aggravates the growth delay (Olivier, 2006). Studies in different parts of Africa have shown that poor quality complementary foods are a major reason for the relatively high rates of malnutrition observed (Karimou, 2004).

To ensure a balanced diet, it is, therefore, necessary to offer the child meals that include both energy and protein nutrients necessary for growth (Delman Chantal, 2011).

Moringa oleifera leaf powder (MLP) has extremely high nutritional value; it is an important source of energy for human consumption (Martinus J.R. Nout, 2019). To date, it is used by the food and biochemical industries as a feed. However, their use as an ingredient in animal and human nutrition is being promoted (Wasif Noumana, 2016). It is an important source of chemical compounds: minerals, vitamins, fatty acids, amino acids, proteins, and glycosides (Wouyo Atakpama, 2014; Sofowora, 2010). In these leaves, linolenic acid (C18:3, cis-9, 12, 15) was found in the highest amount (49 - 59%), followed by palmitic acid (C16:0) (16 - 18%) and linoleic acid (C18:2, cis-9, 12) (6 - 13%). The powder contains very high proportions of good quality protein, vitamins, and minerals (Mpupu Lutondo Blaise, 2012). The fresh leaves contain a total nitrogen content of 1.42 g/100g (Belhi M., 2018). Studies in two regions of Nigeria indicated that the leaves, pods, and seeds of *M. oleifera* contain Ca, Mg, Fe, and Cu (Anjorin, 2010). This explains its use as a food supplement by rural populations (Houndje Bidossessi Victor Saturnin, 2013). Studies have shown significant improvement in WAZ, WLZ, and MUAC scores in infants who received the fortified food with MLP compared to those in the control group (Andrew, 2010).

Taro is an energy-rich tuber due to its high carbohydrate content, which is widely consumed in sub-Saharan Africa, both in villages and cities (Rabiou Maman Moustapha, 2019). It is consumed as a stew, boiled, baked, or added to sauces (Salunkhe D.K., 1998). Taro tubers are an important source of energy for human consumption because of their high starch content (Martinus J.R. Nout, 2019). Taro contains a lot of carbohydrates (82.34±3.53%), it is an essential energy food with a carbohydrate content of 60 to 90%, containing 66 to 86% starch (Aboubakar, 2009). Its edible part contains 26.2 g of carbohydrates per 100 g (Grubben, 2004). But taro is a low source of protein (1.0-4.5%) and fat (0.4-0.7%). Increased dietary fiber consumption may help to prevent diseases including diabetes, ischemic heart disease, colon cancer, and a variety of other digestive issues. Fiber appears to operate as a molecular sieve, trapping carcinogens that would otherwise circulate through the body; it also absorbs water, boosting stool production (Himeda, 2018).

In this study, we evaluated the protein-energy contribution of *Moringa oleifera* leaf powder to taro porridge, a food traditionally used in the care of weaning-age children in Guinea.

II. MATERIALS AND METHODS

2.1. Material

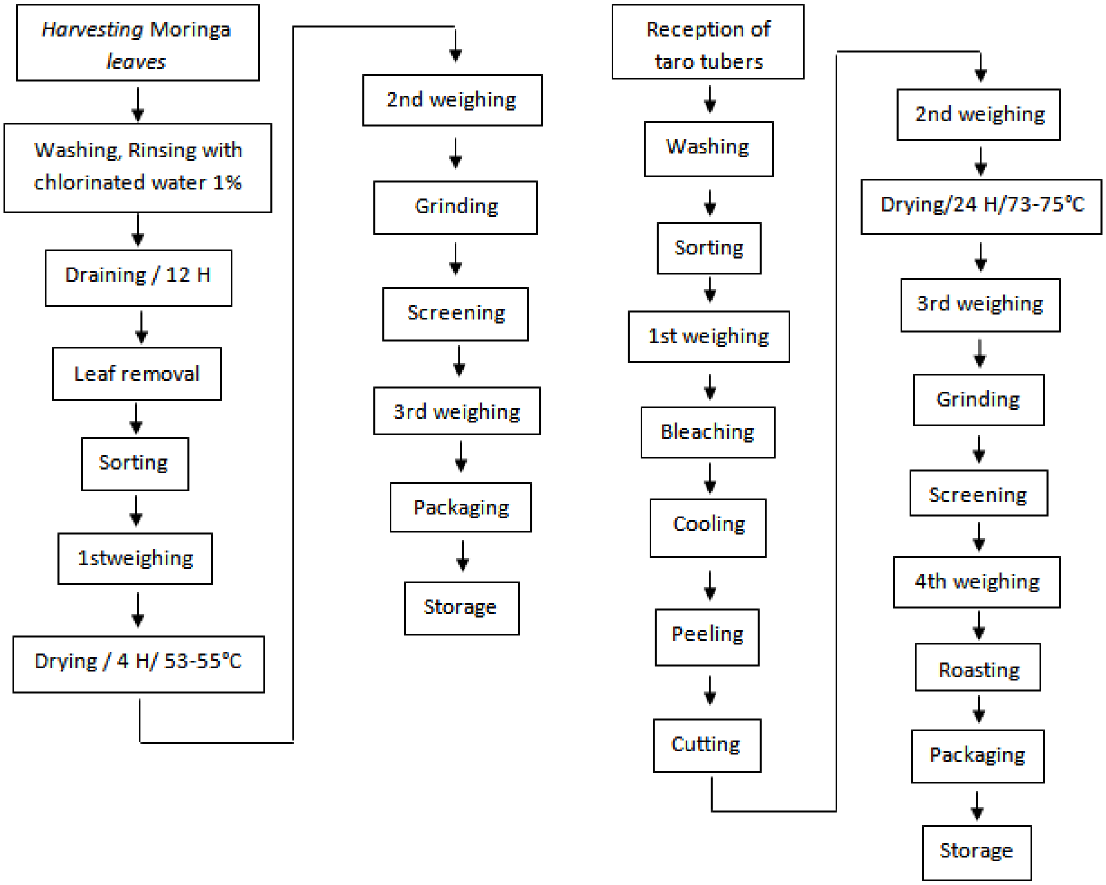
The respective quantities of 1295.01 g of taro tuber flour (*Colocasia esculenta*) and 848 g of Moringa leaf powder were used in this study. The Moringa leaves were harvested in Cobayah district of Conakry-Guinea. Taro tubers (Kissi variety) from the Forest-Guinea region were purchased in Tanery market in the same city.

2.2. Methods

2.2.1. Preparation of enriched flours and porridges

Moringa leaves were oven-dried (Genlab Oven brand) for 4 hours at 53-55°C after washing, sorting, and draining, with an average drying density of 0.05 g/cm2. The taro tubers after being washed, blanched, and peeled, and cut into slices of about 3 to 5 mm thickness with a kitchen knife, were oven-dried for 24 hours at 73 - 75 °C. The average density was 0.20 g/cm2. The dried Moringa leaves and dried taro slices were ground in a traditional aluminum mortar and sieved through a 1.28 mm stainless steel kitchen sieve of the brand MATFER. Three fortified taro flours at 10%, 15%, and 20% with Moringa leaf powder and three corresponding porridges were prepared and analyzed. The enriched porridges were prepared by cooking the taro flour at a maximum temperature of 101°C, in potable water for 15 minutes. 22.50 g, 21.25 g, and 20 g of taro flour were added to 50 ml of drinking water respectively. 250 ml of water was boiled and the (flour + 50 ml of drinking water) was mixed with the boiled water and cooked for 15 minutes. After cooking, and cool for 15 minutes, the corresponding amount of Moringa leaf powder (2.5 g, 3.75 g, and 5 g) was added and homogenized. The manufacturing flow chart of Moringa leaf powder and taro flour are in figure 1 and the main manufacturing steps in figure 2.

Figure 1: Manufacturing flow chart and main manufacturing steps



a- Manufacturing flow chart for *Moringa oleifera* leaf powder

b- Manufacturing flow chart for taro flour

Figure 2: Products of the main manufacturing steps

2.2.2. Determination of physicochemical parameters

The products were subjected to physicochemical analyses at the Central Laboratory for Veterinary Diagnosis (LCVD) of the National Directorate of Livestock in Guinea.

2.2.2.1. Proximal composition

Dry matter, total ash, total fat, total carbohydrate, and total protein were determined by the AOAC method (AOAC, 1990). The dry matter was determined by drying in an oven at 105 °C to a constant weight. Total proteins were determined by the Kjeldahl method using a nitrogen-protein conversion coefficient of 6.25. Total lipids were determined by the Soxhlet method using hexane. Total carbohydrates were determined by the method of Gauss bonass which consists in transforming by acid hydrolysis (HCl 5%) the starch into glucose which is dosed by reduction of Fehling's Liquor (Jean-Louis, 1991). And the total ashes were determined by incineration in the Carboliter WF 1200 muffle furnace at 550-600°C.

2.2.2.2. Determination of pH and titratable acidity

The pH and titratable acidity were determined for only the taro porridge. The pH was determined by the electrode method (Kouassi, Traoré, & Sirpé, 2008). And the titratable acidity was determined according to the ISO 6091:2010 reference method.

2.2.2.3. Determination of energy value

The energy values of the enriched porridges were calculated by applying the heat coefficients of Atwater and Rosa (1889) with 4 Kcal for 1g protein, 9 Kcal for 1g fat, and 4 Kcal for 1g carbohydrate.

2.2.2.4. Statistical analysis

For statistical analyses, Minitab 18 software and one-way ANOVA test were used to compare the means of titratable acidity, moisture, and contents of crude protein, total fat, total carbohydrates, and energy value.

III. RESULTS

3.1. Drying and grinding of *Moringa oleifera* leaves and taro slices

The results of the drying of *Moringa oleifera* leaf powder and taro flour showed that the drying efficiency of Moringa leaves was higher than that of taro slices, 46.22±0.727% versus 25.306±0.084% respectively. This difference could be due to the high thickness of taro slices, its high moisture content compared to Moringa leaves (Maevalandy, 2016; Huang, 2007). It could also be due to the drying density, drying time, and drying temperature. The milling yield of taro slices was 78.69±0.54%, it was higher than 74.05±0.08% of Moringa leaves. This result could be due to the high loss of Moringa powder during milling because of the method used.

3.2. Physicochemical analysis of taro flour and *Moringa oleifera* powder

The results of the physicochemical analyses of taro flour and Moringa leaf powder are reported in Table 1. Analysis of these results showed that there was a significant difference ($p<0.05$) between *Moringa oleifera* leaf powder and taro flour. Taro flour was significantly richer than Moringa powder in total carbohydrates, respectively 73.16 ± 0.28% and 31.40 ± 0.10% and in energy value ($p = 0.000$) respectively 313.58 ± 1.06% and 248.60 ± 1.15. However, *Moringa oleifera* leaf powder was significantly richer ($p<0.05$) than taro flour in dry matter, total ash, crude protein, and total fat. This significant richness could be explained by the enrichment of taro flour (a product with high energy value) by Moringa powder, which is a product rich in proteins, fats, and minerals compared to taro flour.

3.3. Physicochemical analyses of enriched taro porridge

The results of the physicochemical analysis of the enrichment of taro porridge with *Moringa oleifera* leaf powder are presented in Table 2. The results indicated a significant ($p<0.05$) decrease in the moisture content and pH of the fortified porridges. The decrease in pH could be a limiting factor for the fortification as the infant foods should be slightly acidic. However, dry matter, crude protein, titratable acidity, and the energy value of the porridge increased significantly ($p<0.05$). In contrast, increasing the amount of Moringa leaf powder did not affect the total lipids, total carbohydrates, and total ash.

Table 1: Means of proximate content and energy value of *Moringa oleifera* powder and taro flour.

	Moisture content (%)	**Total ashes content (%)**	**Total proteins content (%)**	**Total fates content (%)**	**Total Carbohydrates content (%)**	**Energy value Kcal/100g**
MOLP	7.247±0.300^{b}	4.357±0.275^{a}	23.970±0.090^{a}	3.013±0.170^{a}	31.400±0.174^{e}	248.600±1.990^{d}
TF	8.030±0.245^{a}	2.490±0.216^{b}	4.050±0.052^{e}	0.523±0.055^{c}	73.167±0.485^{a}	313.580±1.840^{a}
FTF 10%	7.930±0.296^{a}	2.643±0.150^{b}	6.003±0.221^{d}	0.753±0.181^{bc}	68.630±0.280^{b}	305.310±1.820^{b}
FTF 15%	7.907±0.188^{ab}	2.760±0.115^{b}	6.967±0.133^{c}	0.887±0.096^{bc}	66.633±0.300^{c}	302.380±0.445^{bc}
FTF 20%	7.863±0.208^{ab}	2.823±0.176^{b}	8.017±0.410^{b}	1.010±0.225^{b}	64.447±0.352^{d}	298.940±3.150^{c}

[1] *Means that do not share a letter are significantly different,*
[2] MOLP: *Moringa oleifera* leave powder,
[3] TF: Taro flour,
[4] FTF 10%: Fortified taro flour at 10% of *Moringa oleifera* leaf powder,
[5] FTF 15%: Fortified taro flour at 10% of *Moringa oleifera* leaf powder,
[6] FTF 20%: Fortified taro flour at 10% of *Moringa oleifera* leaf powder.

Table 2: Means of proximate content, energy value, pH and Titratable acidity of the fortified taro porridges.

	Moisture content (%)	**Total ash content (%)**	**Total protein content (%)**	**Total fat content (%)**	**Total Carbohydrate content (%)**	**Energy value (Kcal/100g)**	**pH**	**Titratable acidity**
TP	81.140±0.160^{a}	0.407±0.081^{a}	0.580±0.046^{d}	2.777±0.211^{a}	13.707±0.280^{a}	82.137±1.43^{c}	5.91±0.00^{a}	0.130±0.017^{d}
FTP 10%	80.257±0.297^{b}	0.423±0.150^{a}	1.076±0.090^{c}	2.937±0.116^{a}	13.670±0.245^{a}	85.417±0.66^{b}	5.55±0.00^{b}	0.213±0.015^{c}
FTP 15%	79.780±0.157b^{c}	0.460±0.080^{a}	1.310±0.090^{b}	3.037±0.232^{a}	13.650±0.265^{a}	87.170±0.861^{ab}	5.41±0.00^{c}	0.260±0.017^{b}
FTP 20%	79.337±0.367^{c}	0.370±0.080^{a}	1.570±0.052^{a}	3.113±0.067^{a}	13.627±0.470^{a}	88.807±1.658^{a}	5.32±0.00^{d}	0.380±0.010^{a}

[1] *Means that do not share a letter are significantly different,*
[2] TP: Taro porridge,
[3] FTP 10%: Fortified taro porridge at 10% of *Moringa oleifera* leaf powder,
[4] FTP 10%: Fortified taro porridge at 10% of *Moringa oleifera* leaf powder,
[5] FTF FTP 10%: Fortified taro porridge at 10% of *Moringa oleifera* leaf powder

IV. DISCUSSION

4.1. Proximal composition

4.1.1. Moisture content of flours and dry matter of fortified porridge

The moisture content of the flours obtained was below 10%. These results are consistent with those of Ndong Noussa, (2007), and Rabiou Maman Moustapha, (2019). This match could be due to the relatively low drying temperature and the relatively short drying time. That is, 73-75°C for 24 hours for taro slices and 53-55°C for 4 hours for Moringa leaves. These values indicate that the raw materials have been properly dried and can therefore be stored without major risk.

4.1.2. Total ashes

The total ashes contents of Moringa leaf powder were much lower than the values of 6.47, 7.29, 10.00 and 10.68% found by Camara D. Aurelia, (2015), Mpupu Lutondo Blaise, (2012), Ndong Noussa, (2007), and Rabiou Maman Moustapha, (2019) respectively. This difference could be due to the harvest area. Results of a compositional study indicated that Ca, Mg, Fe and Cu in leaves, pods and seeds of M. oleifera from the Sheda area were relatively higher than those from the Kuje area (Anjorin T. S., 2010). The total ash contents of taro flour were higher than the respective values of 1.54 to 2.18% and 0.80 to 0.99%, for large and small tubers obtained by Rabiou Maman Moustapha, (2019), but corroborates with the results reported by Ndabikunze et al. (2011) and Njintang and Mbofung (2006). The total ash of the fortified porridges was low compared to the range of 0.64 to 5.00% observed by Boureima Kagambèga, (2019). Fortification produces no significant change in total ash of the three enriched porridges. These results indicate a low fortification rate (2.5 g, 3.75 g, and 5 g) of Moringa powder, and also the low energy densities of the porridges. The energy density of a cooked infant porridge should be 1KCal/ml.

It has been reported that children consume 5g of Moringa powder per day. This amount has been estimated at 10, 15, 20 and 30 g (Barichella, 2019; Boateng, 2018). However, it has been reported that Moringa oleifera leaf contains anti-nutrients. Anti-nutritional factors are generally understood to play negative roles by chelating the nutrients and forming a biding factor with the food values thereby making the nutrients non-bioavailable in the system (Stevens, 2016).

4.1.3. Total proteins

The crude protein contents of Moringa leaf powder were lower than 27.10% and 28.72% reported by Mpupu Lutondo Blaise, (2012) and Manzo ML., (2016) respectively. But they were higher than 10.71±0.81%, obtained by Boureima Kagambèga, (2019). For the taro flour, the crude protein contents were higher than 1.02±0.12% for small tubers and 0.67±0.11% for large tubers obtained by Rabiou Maman Moustapha, (2019). They were also higher than 0.74±0.06% indicated by Gnahé Dago André, (2019). They were in the range of 1.0% to 4.5% reported by Himeda, (2018). The total protein contents of the porridges were lower than the range of 7.22 to 10.22% found by Boureima Kagambèga, (2019).

4.1.4. Total lipids

For the Moringa oleifera leaf powder, the lipid levels were lower than the 7.50±0.27% reported by Ndong Noussa (2007), 10.31±1.2% given by Boureima Kagambèga, (2019) and 8.93% obtained by Camara D. Aurélia, (2015). But higher than 2.30%, found by Mpupu Lutondo Blaise, (2012). The total lipid contents of taro flour were within the range of 0.4% to 0.7% given by Himeda, (2018), but lower than the value of 0.87±0.02% obtained by Gnahé Dago André, (2019). The total lipids of the fortified porridges were also low compared to those of 6.60 to 18.26% reported by Boureima Kagambèga, (2019).

4.1.5. Total carbohydrates

The carbohydrate contents of Moringa leaf powder were low compared to the value of 57.61±2.19% found by Boureima Kagambèga, (2019), and the 60.85% given by Camara D. Aurélia, (2015). This disparity could be explained by the age or region of harvest. The total carbohydrate contents of taro flour were within the range of 60-90% by Aboubacar, (2009). They were higher than the values of 23.80±1% and 22.47±0.33%, respectively for small and large tubers obtained by Rabiou Maman Moustapha, (2019). These results could be due to the species of taro, its state of maturity. With a linear correlation ($r = 0.96$; $P<0.05$), these values of available sugars and crude protein increased significantly with maturity level (Himeda, 2018).

The total carbohydrate levels of the fortified porridges were very low compared to the values of 30.61 to 80.52% of cereal porridges found by Boureima Kagambèga, (2019).

4.2. pH and titratable acidity

The pH values of the enriched porridges were slightly acidic. They were in the range of 3.31 to 6.31 found by Michel Elenga, (2009) for fermented maize porridges. But slightly above the lower limit and much lower than the upper limit of 4.00 to 9.55 for cereal porridges reported by Boureima Kagambèga, (2019).

The lower limits of the pH values given by these authors could be due to the fermentation of the cereals used. The production of organic acids from lipids would justify the drop in pH during fermentation (Soro S, 2013). Progressive pH adjustment respects stomach and intestine pH, with a pH 2 for peptic digestion and a pH 6.7-7.2 for pancreatic digestion (Ndong Noussa, 2007).

The titratable acidity values were much higher than those of cereal porridges of 0.04 to 0.23g/100g obtained by Boureima Kagambèga, (2019). The pH and titratable acidity values of the fortified porridges could be explained by the pH of Moringa leaf powder, which was 8.70.09 and 7.30.05 for 7-day and 18-month storage periods, respectively, with titratable acidities of 0.71±0.02 and 0.75±0.02 (Bidossessi Victor Saturnin HOUNDJI, 2013). This would contribute to the conservation of the Moringa leaf powder. According to Soro et al (2013), flours with an acidic pH are better preserved against microorganism attacks.

4.3. Energy values

The energy value of *Moringa oleifera* leaf powder was lower than the values of 360.46, 391.85 and 281.90 Kcal/100g obtained respectively by Mpupu Lutondo Blaise, (2012), Camara D. Aurélia, (2015) and Ndong Noussa, (2007). The energy value of taro flour was also below the range of 396.85 to 417.98 Kcal/100g reported by Aboubakar, (2009). But it was higher than the 109.43±6.97 and 101.03±1.36 Kcal/100g for small tubers and for large tubers respectively obtained by Rabiou Maman Moustapha, (2019). These disparities could be explained by the species of taro and the climatic influence of the area where the tubers were harvested.

For the fortified porridges, the energy values were slightly lower than the 105.4±0.1 and 108±0.14 Kcal/100g found by Soro S, (2013) in yam porridges fortified at 10% and 20% with soy flour respectively. These values were within the range of 17.82 to 114.73 Kcal/100g observed by Boureima Kagambèga, (2019). Our porridges have a low energy value. They do not support the claim that the consumption of energy and nutrient rich porridges contributes significantly to the nutritional needs of children. They must be given at a very high daily frequency to cover the child's energy needs. Porridges with an energy content of 100 to 120 kcal/100 ml should be given multiple times a day, especially to children who exhibit signs of malnutrition or who have lost their breast milk. The quantity of energy a child can get from porridges each day is determined by the number of meals consumed, the amounts consumed at each meal, and the porridges' energy density.

CONCLUSION

Three formulations of infant taro porridges fortified with *Moringa oleifera* leaf powder were performed. Significant increases in total ash, crude protein, and energy value of the fortified porridges were observed. By minimizing dependence on imported mineral complexes, fortification of taro flour with Moringa leaf could help reduce malnutrition in developing countries. However, as compared to taro flour, the high protein and lipid content of Moringa leaf powder is still insufficient to meet the demands of children at weaning age. Taro flour supplementation with Moringa leaf should therefore be mixed with other high-protein local products.

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AUTHOR'S CONTRIBUTIONS

Daniel Mamy edited the article. The co-authors: Xiumin Chen, and Aboubacar Sangaré, read the document.

CONFLICT OF INTEREST

There is no conflict of interest between the authors of this article.

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