


Micronutrient intake of children in Ghana and Benin: Estimated contribution of diet and nutrition programs

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Funding information

European Commission Food Fortification Advisory Services (2FAS)

Abstract

We estimated how micronutrient needs of young children, aged 6–24 months were covered by the standard (traditional) diets in Ghana and Benin, and the contributions of partial breastfeeding and national nutrition programs aimed at improving micronutrient status to overall micronutrient intakes. Estimates of micronutrient intake from standard diets were based on previous surveys, using the food composition table of West Africa (INFOOD). Recommended micronutrient intakes were based on World Health Organization recommendations. Children were grouped in three age groups (6–8, 9–12, and 13–24 months) to capture the changing dynamics of the complementary feeding period. As expected, from 6 months of age onwards, breastmilk didn't cover the micronutrient needs. The standard diets contributed only minimal to micronutrient intakes of children ranging from 0% to 37% of recommended intakes for Ca, Fe, Zn, vitamin A, vitamin D and iodine depending on the micronutrient considered. The contribution of mass (bio)-fortification programs to the coverage of micronutrient needs varied widely, depending on the staple food considered and the country, but overall did not allow to fill the gap in micronutrient needs of children except for vitamin A in some contexts. In contrast, consumption of voluntary fortified complementary food, especially formulated for the needs in this age groups, contributed substantially to overall micronutrient intake and could fill the gap for several micronutrients. The development of young child-targeted programs including micronutrient-dense foods, associated with interventions to increase the diet diversity and meal frequency, could significantly improve micronutrient intakes of children in both Ghana and Benin.

KEYWORDS

breastfeeding, child nutrition, food and nutrients intakes, low and middle income countries, micronutrients, public health

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1 | INTRODUCTION

During the complementary feeding period, that is, from 6 to 24 months of age, children in Low and Middle-Income Countries (LMICs) are most at risk to develop nutritional deficiencies, as breastmilk alone is no longer sufficient to cover the higher absolute nutrient requirements, and complementary foods are often too low in nutrient density (Dewey & Adu-Afarwuah, 2008; Fewtrell et al., 2007; WHO, 2002). In both Ghana and Benin, chronic malnutrition (stunting) in children under 5 years of age is still prevalent with, respectively 21.4% and 32.2% of children stunted according to the latest national surveys (INSAE & ICF, 2019; University of Ghana et al., 2017). While only scarce subnational data on micronutrient deficiencies exist for Benin, the Ghana micronutrient survey (2017) indicated that 21.5% of children under 5 years of age were iron deficient (serum ferritin adjusted for inflammation status <12 µg/L) and 20.8% had vitamin A deficiency (retinol binding protein adjusted for inflammation <0.7 µmol/L). Several strategies have been implemented in both countries to improve micronutrient status, including high-dose vitamin A capsule distribution twice a year, zinc supplements in case of diarrhea and fortification of oil with vitamin A, salt with iodine, and wheat flour with multiple micronutrients. Published national dietary guidelines were developed for Benin (Conseil National de l'Alimentation et de la Nutrition, 2015) but not yet in Ghana. Additionally, in Ghana, biofortified maize and sweet potatoes are now released for commercialization (Harvest Plus, 2019).

Several studies have reported that in vulnerable populations in LMICs, the diets that are both available and affordable are not sufficient to cover nutritional needs of women or children (de Jager et al., 2018; Fahmida et al., 2014; Hlaing et al., 2016; Shi et al., 2010). Fortification programs have shown some successes in improving micronutrient intakes, but several gaps are still to be covered (Castillo-Lancellotti et al., 2013; Keats et al., 2019; Osendarp et al., 2018; Tong & Walker, 2021). For example, while fortified food has been shown to be major contributor to apparent intakes of vitamin A and iodine in women in four African countries, iron fortification programs appeared to underperform notably due to the low consumption of fortified flour (Friesen et al., 2020). Furthermore, fortification programs seem to rather benefit adults while impact in children appears limited, probably due to insufficient consumption levels (Keats et al., 2019).

The objective of this study was to estimate how breastmilk, standard usual diets and the different large-scale micronutrient programs in Ghana and Benin contribute to overall micronutrient intake of children during the critical period from 6 to 24 months of age.

2 | PARTICIPANTS AND METHODS

2.1 | Target populations

Young children, aged 6–24 months, were the target population, divided into three age groups (6–8, 9–12, and 13–24 months), in

Key messages

- In both Ghana and Benin, the standard complementary diet does not cover the needs for most micronutrients of children aged 6–24 months, even when combined with continued breastfeeding
- Mandatory fortification programs do not allow to cover the gap in micronutrients needs mainly due to the low quantity of fortified food consumed by children, but child-specific fortified food could contribute substantially.
- Improvement of dietary diversity, quality and sustainability, and greater accessibility and affordability of child-specific foods rich in micronutrients is urgently needed.

concordance with recommended daily intakes for these age ranges. The sociodemographic and nutritional characteristics of the population are described in Table 1.

2.2 | Diet patterns

The scenarios built for each age group included breastfeeding according to World Health Organization (WHO) for partially breastfed children as follow: 660 g/day for 6–8 months children,

TABLE 1 Socio-demographic and nutritional characteristics of the population studied

	Benin	Ghana
% children 6–56 months stunted (severe + moderate)	32.2%	21.4%
% children 6–56 months wasted	5.0%	7.0%
Adequate dietary diversity (children 6–23 months)	25.2%	28.0% ^a
Minimum meal frequency (children 6–23 months)	44.9%	38.3%
% children 12–23 months currently breastfed	68.8%	75.9%
Proportion of children with low birth weight (%)	11.6%	14.9%
Main source of drinking water (household level)		
% improved	71.1%	90.7%
% nonimproved	22.5%	9.3%
% of population living in rural area (household level)	55.4% ^b	49.1% ^c

Note: Except when stated, Benin: Data from last national DHS in 2017 (INSAE & ICF, 2019) and Ghana: Data from micronutrient survey in 2017 (University of Ghana et al., 2017).

^aDonkor et al. (2021).

^bData from national census survey 2016.

^cData from national census survey 2010.

616 g/day for 9–12 months, and 549 g/day for 13–24 months. For each country, we selected diet patterns that could be regarded as typical for that age range and living area (urban/rural), based on data of food consumption surveys (Achigan-Dako et al., 2011; Bellon et al., 2016; de Jager et al., 2018; Galbete et al., 2017; Gamor et al., 2015; Greffeuille & Mouquet, 2010; Issaka et al., 2015; Levesque et al., 2015; Mitchodigni et al., 2017) and from meetings with local nutritionists. The meal quantity in each age group was estimated considering gastric capacity of children according to their age. The number of meals was set to 2 meals/day for 6–8 months, and 3 meals/day for children aged 9 months or older according to the results of Demographic and Health Surveys in both countries and the minimum meal frequency indicator (Ghana Statistical Service Services G. H. & International I., 2015; INSAE & ICF, 2019). The meals for children were built from popular dishes and contained a mix of cereal porridges and family meals consumed by all family members including infants after 6 months of age and young children (Table S1). In both countries, the diet is mainly based on cereals or roots and tubers with vegetables-based sauces and very few animal food sources (Ghana Statistical Service Services G. H. & International I., 2015; INSAE & ICF, 2019; Na et al., 2020).

2.3 | Micronutrients programs

A situational analysis of nutritional programs currently or recently implemented for reduction of children's micronutrient deficiencies in Benin and Ghana was completed as part of the INtegrated Strategies for MIcronutrient DEficiencies Reduction) project, funded by the European Commission under the Food Fortification Advisory Services. Different approaches were inventoried including food fortification, biofortification and supplementation programs, whether mandatory or voluntary. Dietary diversification approaches were also considered by including some nutrient-rich foods in the scenarios.

2.4 | Nutritional composition of diets

The micronutrient composition of breastmilk was obtained from FAO/INFOODS Food Composition Table for Western Africa (2019) for mature human breastmilk (reference10_004) (Grande et al., 2020). For iodine contents of breastmilk, a concentration of 62 µg/L was used as found in previous surveys (Dorea, 2002) and in accordance with a recent review of iodine breastmilk concentration (Dror & Allen, 2018b).

The impact of fortified staple foods, that is, oil, salt, and flour fortification on micronutrient intakes was estimated by replacing the basic micronutrient composition of food ingredients with the micronutrient contents of corresponding fortified product. For example, basic vegetable oil in a recipe was replaced by the same amount of fortified oil. In Benin, consumption of wheat-based dishes is much less frequent than maize or cassava dishes, in the standard scenario built initially, no wheat-based dish was included.

However, the potential contribution of a portion of wheat porridge made with fortified flour was also considered by replacing one maize-porridge by a wheat-based porridge in the fortification scenarios.

In the scenarios for Ghana, the impact of biofortification was evaluated by replacing white maize and white sweet potatoes by biofortified varieties. The retinol activity equivalent (RAE) set for biofortified maize and sweet potatoes were 1 µg and 7.91 µg RAE/g respectively (Harvest Plus, 2014).

Additionally, the contribution of multimicronutrient fortified porridge, specifically formulated for children, was also studied in Benin by inclusion of one portion of the porridge available in the country (Cerelac). In Ghana, the impact of using KokoPlus, a local protein-micronutrient powder to mix with a basic meal was estimated.

Finally, the impact of replacing basic oil by red palm oil in recipes, as well as consumption of a piece of mango (25 g) were also tested.

2.5 | Micronutrients intakes and comparison to recommendations

The total amount of micronutrient intake from diets was calculated by summing the micronutrient content of each individual food ingredient reported in the FAO/INFOODS Food Composition Table for Western Africa (2019) (Grande et al., 2020) or in the French Composition table Ciquel (ANSES Agence nationale de sécurité sanitaire de l'alimentation de l'environnement et du travail, 2020). When available, the micronutrient composition of ingredient after cooking was used.

The optimal ranges for consumption were defined following the WHO recommendations considering the recommended nutrients intakes (RNI), corresponding to the average daily nutrient intake level that meets the need of 97.5% of 'healthy' individuals (Table S2).

For iodine, the RNI was calculated according to WHO recommendations of 15 µg/kg/day (6–30 µg/kg/day for children 0–59 months) with an assumed body weight of 7.5 kg for 6–8 months, 9 kg for 9–12 months and 10.5 kg for 13–24 months. For iron and zinc, the RNI considered were those defined for a diet with low bioavailability, that is, 5% for iron and 15% for zinc (5).

3 | RESULTS

The contribution of breastmilk to the RNI's per age group and the different diet scenarios are reported in Table 2 for Benin and Table 3 for Ghana and illustrated for both countries in Figure 1.

Breastmilk consumption did not entirely cover the micronutrient needs of children except for vitamin A in the youngest age group (6–8 months). Breastmilk substantially contributed above 40% to the coverage of calcium and folate needs of the 6–8 months old children but the proportion of RNI covered by breastmilk decreased rapidly with increasing age. On the other hand, breastmilk's contribution to coverage of iron, zinc and vitamin D needs of children was less than 20% of the respective RNI's for each age group.

TABLE 2 Coverage of micronutrient's RNI by diet, including breastmilk and fortified foods, among children in Benin (grey cells indicate RNI are met)

Percentage of micronutrient RNI covered	6-8 months							9-12 months							13-24 months						
	Ca (mg)	Fe (mg)	Zn (mg)	Vit A-RAE (µg)	Vitamin D (µg)	Folate (µg)	Iodine (µg/kg/day)	Ca (mg)	Fe (mg)	Zn (mg)	Vit A-RAE (µg)	Vitamin D (µg)	Folate (µg)	Iodine (µg/kg/day)	Ca (mg)	Fe (mg)	Zn (mg)	Vit A-RAE (µg)	Vitamin D (µg)	Folate (µg)	Iodine (µg/kg/day)
Standard diet																					
Breastfeeding	57	7	20	107	13	41	36	40	7	15	94	12	39	28	29	9	13	84	10	18	53
Diet (basic)	5	5	8	2	5	13	4	10	23	30	0	0	117	0	32	21	12	27	4	21	0
Total breastfeeding + diet (basic)	62	12	28	110	19	54	41	50	30	45	94	12	155	28	60	30	26	111	14	40	53
Mass Fortification (additional micronutrient brought by fortification)																					
One portion of fortified wheat porridge instead of maize porridge		2	6			24			4	7			36		8	10				26	
Oil and salt fortification				25			3				29		24					21			37
Total fortified diet	5	6	13	25	5	36	7	10	25	36	30	0	150	24	31	23	20	48	4	44	37
Total breastfeeding + fortified diet	62	13	33	132	19	77	44	50	31	51	123	12	189	52	60	33	33	132	14	63	90
Fortified child-specific food																					
Specific complementary food (1 portion of Cerelac)	60	16	33	139	36	20	7	68	24	39	195	54	30	9	102	86	41	106	150	25	63
Total breastfeeding + diet (basic) + complementary food	122	28	61	248	55	74	48	118	54	84	289	66	185	37	162	116	66	216	164	64	116
Locally-available nutrient-rich food																					
One portion of mango	1	1	0	13	0	13	0	1	1	0	13	0	13	0	1	2	0	13	0	7	0
Replace vegetable oil by RPO				79							110							109			

Abbreviations: RNI, recommended nutrients intakes; RPO, red palm oil.

The coverage of micronutrient needs by the basic usual diet was negligible for the youngest age group with coverages varying from 0% to 13% depending on the micronutrient considered. The percentage of RNI covered by the diet increased with age due to increasing portion size and number of meals. However, even in the older age groups (9–12 and 13–24 months), the percentage covered did not exceed 37% for any micronutrient except for folate in 9–12 months old children in Benin (117%). In this specific case, the presence of cowpeas in diet contributed greatly to folate intake. Consequently, when considering the basic diet of children including breastmilk consumption, the micronutrient intakes were all below the RNI except for (i) vitamin A in all age categories in Benin and in children <12 months in Ghana and (ii) for folate in 9–12 months children in Benin mainly because of the consumption of boiled cowpeas which bring 78 µg of folate/100 g (ref03_007 in the FAO/INFOOD food composition tables).

Mandatory vitamin A oil fortification programs provided between 24% and 36% of vitamin A RNI in Benin, and from 0% to 31% in Ghana. The lower contribution of vitamin A intakes in Ghana was due to lower amounts of oil used in the recipes. In both countries, fortified wheat flour contributed very little to micronutrients intake, except for folate, mainly because of the very small quantities consumed by these age groups. In the scenarios for Benin, the replacement of a portion of maize-based dish by a wheat porridge allowed to cover 24%–36% of the RNI for folate, but did not bring more than 10% of iron and zinc needs. Salt iodation provided

between 3% and 37% of the RNI for iodine in Benin and between 5% and 8% in Ghana.

In Ghana, the biofortification of maize and sweet potatoes increased vitamin A intakes to different extents: biofortified sweet potatoes can easily provide the recommended intake for vitamin A, while biofortified maize contributed much less (between 3% and 50%) depending on the amounts consumed.

Overall, even when breastmilk, basic usual diet, mandatory fortification, and biofortification were combined, RNIs were reached only for vitamin A in all age groups in Benin and in Ghana, while RNI for folate was only met in the 9–12 months of age group in Benin. All the other micronutrient intakes remained below the RNIs for each age group.

In the scenario for Benin, the consumption of one portion of a fortified porridge in addition to the basic usual diet and breastmilk resulted in a substantial improvement of the coverage of micronutrient intake, whatever the age group, while not necessarily meeting the RNI. In Benin, this combination allowed only to fill the gap to reach the RNI for Ca in all children, and for Fe, vitamin D and iodine in the oldest age group only. In Ghana, the addition of Kokopulus to the basic diet allowed only to fill the gap to reach the RNI for Ca, iodine and folate in the 6–8 months old children, for Ca and folate in the 9–12 months children and for iron and iodine in the oldest group.

The consumption of a piece of mango brought 7%–13% of the children needs for folate and 13% for vitamin A, but its contribution to the intakes of other micronutrients was negligible. The replacement of vegetable oil by red palm oil in traditional recipes allowed to

TABLE 3 Coverage of micronutrient's RNI by diet, including breastmilk and fortified foods, among children in Ghana (grey cells indicate RNI are met)

Percentage of RNI	6-8 months						9-12 months						13-24 months								
	Ca (mg)	Fe (mg)	Zn (mg)	Vit A-RAE (µg)	Vitamin D (µg)	Folate (µg)	Iodine (µg)	Ca (mg)	Fe (mg)	Zn (mg)	Vit A-RAE (µg)	Vitamin D (µg)	Folate (µg)	Iodine (µg)	Ca (mg)	Fe (mg)	Zn (mg)	Vit A-RAE (µg)	Vitamin D (µg)	Folate (µg)	Iodine (µg)
Standard diet																					
Breast milk	57	7	20	107	13	41	36	40	7	15	94	12	39	28	29	9	13	84	10	18	53
Diet	4	3	7	2	0	8	0	13	12	12	7	0	37	0	11	25	19	3	0	26	0
Total breastfeeding + diet (basic)	61	10	27	109	13	49	36	53	19	27	100	13	76	28	39	34	32	87	10	44	53
Mass Fortification (additional micronutrient brought by fortification)																					
Fortification of oil, salt and wheat flour				31			7						5		7	5	7		20	8	
Total fortified diet	4	3	7	33	0	8	7	13	12	12	7	0	37	5	11	32	24	11	0	46	8
Total breastfeeding + fortified diet	61	10	27	140	13	49	43	40	7	15	94	12	39	28	39	41	37	94	10	65	61
Bio- fortification of crop (additional micronutrient brought by bio-fortification)																					
Biofortification of maize			3								38							50			
Biofortification of sweet potatoes											148							138			
Diet with biofortification	4	3	7	5	0	8	0	14	8	10	190	0	10	0	11	17	16	189	0	17	0
Total breastfeeding + biofortified diet	61	10	27	112	13	49	36	54	15	25	284	13	49	28	40	26	29	273	10	36	53
Fortified child-specific food																					
Specific complementary food (one dose of KokoPlus)	71	42	33	70	62	85	61	53	42	26	66	62	85	51	43	67	27	66	62	45	108
Total breastfeeding + diet (basic)+ KokoPlus	132	52	60	180	75	134	98	106	61	53	166	75	161	79	82	101	59	153	72	90	161
Locally-available nutrient –rich food (additional micronutrient brought by resource food)																					
Mango	1	1	0	13	0	13	0	1	1	0	13	0	13	0	1	2	0	13	0	7	0
Diet with red palm oil				180																	

Abbreviation: RNI, recommended nutrients intakes.

ensure the coverage of vitamin A needs in 9–12 months and 13–23 months old children in Benin and in the youngest group in Ghana. In the other groups in Ghana, no oil was used in the consumed dishes.

4 | DISCUSSION

The present study, which aimed to estimate the micronutrient intake from breastmilk and the basic usual diets, and the potential contributions of national programs to improve micronutrient status, shows that most children in Ghana and Benin have inadequate diets, providing insufficient amounts of most micronutrients, even when nutrition programs such as (bio-)fortification are in place.

Clearly, the micronutrient needs of children above 6 months cannot be covered by the sole consumption of breastmilk, with the exception of vitamin A. One main driver of milk composition is the mother's nutritional status, especially for most B vitamins, vitamin A, vitamin D, and iodine (Dorea, 2002; Dror & Allen, 2018a; Dror & Allen, 2018b; Pérez-Escamilla et al., 2019). For these micronutrients, improvements in maternal status could potentially lead to improved status in the lactating child through higher micronutrient concentrations in breastmilk. Other micronutrients such as iron, vitamin B9 and zinc are less dependent on maternal status

during lactation, and improvements in the intake for these nutrients should come from other sources. In addition, breastmilk is known to be a very poor source of iron (Domellöf et al., 2014; Friel et al., 2018). According to the scenarios presented here, children are not at-risk for vitamin A deficiency in the case that (i) children are effectively breastfed; (ii) the breastmilk consumption is sufficient and (iii) vitamin A status of mother is adequate. National surveys in Ghana (2014) (Ghana Statistical Service Services G. H. & International I., 2015) and Benin (2017) (INSAE & ICF, 2019) indicated that among 6–8 months children 99.5% in Ghana and 96.4% in Benin were breastfed, a proportion that decreased in 18–23 months children to 59.2% in Ghana and 50.9% in Benin. It is thus reasonable to think that the vitamin A intakes are adequate in breastfed younger children, but inadequate in the non-breastfed older children. Indeed, in Ghana, vitamin A deficiency prevalence in 2017 was shown to increase from 16% in the 6–8 months children to 25% in the 36–47 months children. This prevalence corresponds to a moderate to severe public health significance and is consistent with a decrease in the consumption of breastmilk, which was the major contributor to vitamin A intake in our study. Considering this relatively high prevalence of vitamin A deficiency in early childhood, although recent data on vitamin A status of lactating Ghanaian women is unknown, it is noteworthy that vitamin A deficiency is reported as low in nonpregnant women in Ghana (1.5%

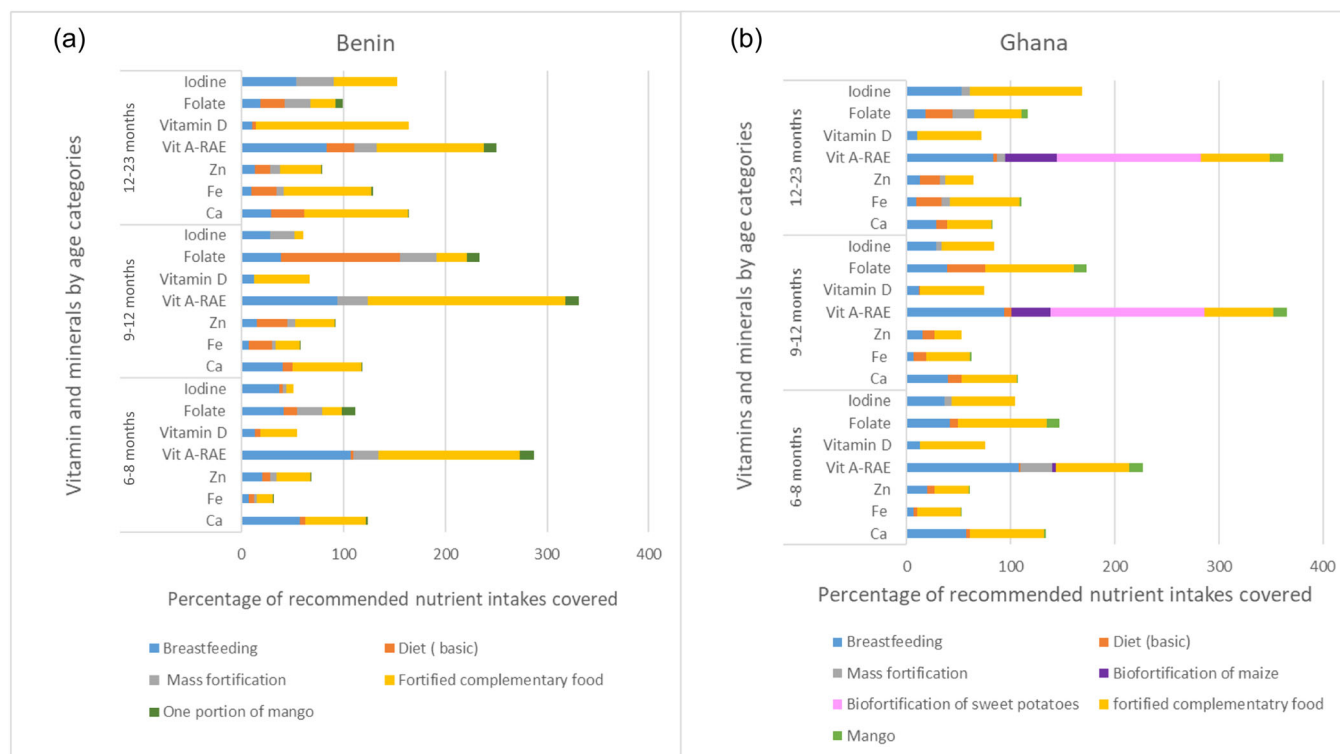


FIGURE 1 Estimated percentages of recommended nutrient intakes covered by different products consumed by children in (a) Benin and (b) Ghana.

VAD) (University of Ghana et al., 2017), hence breastmilk vitamin A concentrations are supposedly in the normal range. In 2006, a study in 167 postpartum Ghanaian women reported that 22% had marginal liver store of vitamin A (Tchum et al., 2006). It is conceivable that in the postpartum period, the prevalence of vitamin A deficiency is higher than in the nonpregnant women. Additional data of breastmilk composition in the specific contexts of Benin and Ghana are needed to better understand the potential contribution of breastmilk to micronutrient intake during the first 2 years of life and to better target and fine tune micronutrient interventions.

The decreasing contribution of breastmilk to overall micronutrient intakes highlights the essential role of complementary foods. However, our results showed that the basic usual diets in our scenarios were insufficient to fill the gap in micronutrient intakes. This is mainly due to the low amounts of food consumed, the low nutrient density, and the low diversity of the diet. In our study, the number and the composition of meals were set in accordance with the low prevalence of children who reach the minimum diet adequacy in both Ghana and Benin. Indeed, in Ghana, only 28% of children received diets with the minimum dietary diversity (Donkor et al., 2021). The minimum meal frequency was achieved in only 38% of the children, and significantly decreased with age. In Benin, the prevalence of children with minimum dietary diversity increased from 13.6% for the 6–8 months to 37.8% for the 18–23 months, while only 45% of the children achieved the minimum meal frequency leading to a low percentage of children attaining a minimum acceptable diet (15%) (INSAE & ICF, 2019). Improving micronutrient intakes in Ghana and Benin requires both an increase in dietary diversity

as well as the frequency of meals and in the micronutrient density of foods.

In Ghana and Benin, mass fortification refers to interventions such as addition of vitamin A to oils, iodine to salt and multimicronutrients to flour. This strategy has been found to reduce risk of micronutrient deficiency in several African population (Engle-Stone et al., 2017; Friesen et al., 2020; Keats et al., 2019). Contrary to what we observed for women in Ghana and Benin (Dass et al., 2021), our results showed that this strategy may not be so efficient for children. Undeniably, the very low amounts of fortified foods consumed by children are not sufficient to cover the gap in micronutrient intakes. On the other hand in Benin, where oil is an important ingredient in many tradition dishes, fortification of oil resulted in incremental intakes of vitamin A, and could thus benefit children groups who are more at risk of vitamin A deficiency such as nonbreastfed children. In Benin, maize and cassava-based dishes, which are not fortified and contributed only trace amounts of micronutrients, are preferred to wheat flour-based dishes. The low consumption of this food vehicle thus limits the impact of flour fortification. This has been reported in other African contexts and therefore, these foods need to be reconsidered as vehicle for fortification in these countries (Aaron et al., 2017; Friesen et al., 2020). Overall, these results of the present study show that there is a need to adapt micronutrient strategies to the different age ranges, since both the amount of micronutrients and the food vehicles used for fortification are not adapted to the children's needs.

One strategy to improve dietary adequacy and diversity of complementary diet is the promotion of locally nutrient-rich,

available and affordable foods. The present study shows that red palm oil consumption could cover a large part of children's vitamin A needs while consumption of mango did not substantially contribute to micronutrient intakes for vitamin A and folate. Additionally, consumption of cowpeas could substantially increase the folate intake, as shown in the scenario for Beninese children aged 9–12 months. The optimization of the use of locally-available foods was tested in other contexts (Fahmida et al., 2014; Hlaing et al., 2016; Levesque et al., 2015; Shi et al., 2010; Skau et al., 2013). In Indonesia for example, it was shown that even when complementary food of children 9–16 months of age was optimized by linear programming, the micronutrient intakes in children did not increase enough to reach the recommendations (Fahmida et al., 2014). In Benin, using the same methodology, it was not possible to reach the RNIs of calcium, iron, zinc, vitamin B12 and folate (<70% of RNIs) by using local resources (Levesque et al., 2015). In Ghana, a study in the Northern region showed that, even the best optimization of the diet of nonbreastfed children 12–24 months of age covered less than 50% of the RNI of calcium (33%), vitamin A (30%), iron (31%) and vitamin B₁₂ (2%) (de Jager et al., 2018). Thus, children's diet must be improved through other interventions in addition to the use of local food to meet dietary adequacy. The development of nutrition-sensitive strategies such as agricultural strategies to improve the availability of nutrient dense-food are very crucial in terms of sustainability, but this will require time. It is therefore imperative that such strategies are backed with nutrition-specific interventions and tailored toward the needs of children (child-targeted).

In our study, we evaluated the impact of young child target foods, by including micronutrient-enriched porridge (Benin) and protein and micronutrient-enriched powder (Ghana) to be used as food additive. The results showed that this strategy may be efficient to meaningfully increase the micronutrient intakes of children and contribute to decrease the gap in the RNI for most micronutrients, when used in addition to the breastmilk and the basic usual diet. But, RNIs for iron and iodine were attained only in the oldest group of children in both countries as well as vitamin D RNI in Benin. In contrast, the RNIs for zinc were never attained. This strategy nevertheless showed to be the most efficient in our scenarios to complement the basic usual diet and breastmilk intakes. Thus, specific foods, targeted for the children needs and taste should be developed to better address the public health problem of micronutrient deficiency in West Africa. In Ghana, fortification of complementary food have shown to be acceptable by the population (Adu-Afarwuah et al., 2008) and efficient to improve micronutrient status and growth of children (Lartey et al., 1999). According to a systematic review of the efficacy and effectiveness of complementary feeding interventions, improved complementary feeding has been shown to be effective to improve child health and development in several settings, but results were very dependent of the context and no universal solution for adequate complementary feeding exists (Dewey & Adu-Afarwuah, 2008). Increasing density of both macro- and micronutrients seems to be necessary to improve the overall coverage of RNI's during the first 2 years of life in both Ghana and Benin, and most likely other countries in West Africa. Efforts should be made in the formulation of complementary foods

to better equilibrate the intakes in micronutrients by focusing on the most deficient micronutrient in the diet. The development of child-specific food needs to be supervised and supported to better adjust the micronutrient content and ensure both efficacy and safety of micronutrient levels. Indeed, a recent study showed that most of the available cereal-based porridge in Ghana and Benin were of limited nutritional quality underscoring the need for better technical support to producers and processors (Dimaria et al., 2018). In our scenarios, we did not identify any risk of micronutrient intakes above the recommended upper limits even in the case all the interventions studied overlap, but the existing micronutrients programs should be considered when formulating new fortified products to avoid the risk of excess intakes. Additionally, the availability of child-specific fortified products must also be expanded to cover rural communities who have poor access to manufactured foods (Nordhagen et al., 2019).

Finally, in both countries, other nutrition intervention programs such as supplementation were documented but not discussed in our scenarios due to the scope of the study. For both countries the main supplementation programs were vitamin A and zinc for diarrhea treatment. Our results indicated that zinc a short-term (10–14 days) supplementation during diarrheal episodes seems crucial due to lack of dietary intake and its crucial role for recovery (Imdad et al., 2011; Villamor & Fawzi, 2005). On the other hand, high dose vitamin A supplements (200,000 IU for children above 1 year) have been shown to have only a transient impact on vitamin A status.

5 | CONCLUSION

In Benin and Ghana, meeting the high micronutrient needs of children in the first 1000 days of life (window of opportunity) still remains a challenge. After 6 months of age, breast milk is no longer sufficient to cover all micronutrient needs of infants, and the basic diet, which is of low dietary diversity and consumed at low frequency, does not allow to fill the gap. Mass fortification strategies are not much effective to complement the basic diet because of micronutrients contents are not adapted to the needs of this specific population. Complementary food specifically developed for children, that are dense in macro- and micronutrients appeared to be a more efficient strategy to substantially improve the micronutrient intake of children in both countries. The development of child-specific foods and food products must focus on the lacking/limiting micronutrients, and be adapted to the context of each country, valorizing as much as possible the nutrient-rich available resources. In a complementary manner, efforts should be made to support increased dietary diversity and frequency, particularly in the youngest children.

AUTHOR CONTRIBUTIONS

Valérie Greffeuille and Frank T. Wieringa were involved in the conceptualization of this paper. Mamta Dass, Valérie Greffeuille, Jacques Berger and Frank T. Wieringa were involved in methodology. Mamta Dass, Valérie Greffeuille, Jacques Berger and Frank T. Wieringa were involved in the formal analysis. Mamta Dass, Nadia

Fanou-Fogny, Jolene Nyako and C.T. were involved in the investigation of this paper. Valérie Greffeuille was involved in the writing, original draft preparation of the manuscript. Mamta Dass, Valérie Greffeuille, Jacques Berger, Frank T. Wieringa, Nadia Fanou-Fogny and Jolene Nyako were involved in the writing, review and editing of this manuscript. Frank T. Wieringa and Valérie Greffeuille were involved in the project administration. Frank T. Wieringa and Valérie Greffeuille were involved in the funding acquisition. All authors have read and agreed to the published version of the manuscript.

ACKNOWLEDGMENTS

The authors would like to thank Dr Waliou Amoussa Hounkpatin for personal communication on preliminary results of surveys in Benin and its deep knowledge of traditional food habits in Benin. The authors would like to acknowledge Mohamed Mansour for its reviewing of the manuscript and constructive feedback. This research was funded by European Commission under their Food Fortification Advisory Services (2FAS). No specific grant number.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

Not applicable.

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How to cite this article: Greffeuille, V., Dass, M., Fanou-Fogny, N., Nyako, J., Berger, J., & Wieringa, F. T. (2023). Micronutrient intake of children in Ghana and Benin: estimated contribution of diet and nutrition programs. *Maternal & Child Nutrition*, 19, e13453. <https://doi.org/10.1111/mcn.13453>