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FERMENTED SORGHUM PORRIDGE FORTIFIED WITH MORINGA LEAF POWDER AND BAOBAB FRUIT PULP CURED CHILDREN FROM MODERATE ACUTE MALNUTRITION IN BENIN

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ABSTRACT

Inappropriate feeding, too early introduction of complementary foods and restriction in food selection are a major cause of malnutrition among young children in developing countries. Food-to-food fortification is a good strategy to enhance the nutritional quality of children's diet. This strategy is more and more promoted because it allows delivery of micronutrients to a large population in a cost-effective manner. The present study aimed at testing the effect of the consumption of sorghum porridge fortified with moringa leaf powder and baobab fruit pulp on the nutritional status of children aged 6 to 59 months in Northern Benin. A two-week intervention was implemented in Tanguiéta (Benin) among children affected by moderate acute malnutrition, using 400 g of fermented sorghum porridge fortified with 15 g of a designed mix of moringa leaf powder and baobab fruit pulp. Sixty-three children aged 6–59 months who had malnutrition assessed by anthropometry were randomly selected and assigned to a treatment or a control group. Children in the treatment group consumed the fortified formula daily for two weeks in a nutritional rehabilitation hearth whereas those in the control group had their habitual diet. Their nutritional status was evaluated using anthropometry. Recovery rate and average weight gain of children were computed. Results show that daily consumption of the fortified food for two weeks did not significantly (P> 0.05) increase children's weight in treatment vs. control. However, average weight gain was 9.85 g/kg/day in the treatment group and total recovery rate at risk of malnutrition and moderate acute malnutrition was 62.50% among children who fully complied with the intervention. Fermented sorghum porridge fortified with moringa leaf powder and baobab fruit pulp may be promoted to scale in more regions of Benin as a local affordable and effective therapeutic food against child acute malnutrition. Further investigation of its potential effect while accounting for parasitic infection is needed, to eliminate all risks of intestinal micronutrient malabsorption or malaria and enhance the effectiveness of the fortified food on children's weight as well as their iron status.

Key words: Food-to-food fortification, malnutrition, sorghum porridge, northern Benin

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INTRODUCTION

Malnutrition in all its forms remains one of the most serious and neglected health problems and causes every year millions of deaths among women and children under-five years in low- and middle-income countries [1]. Inappropriate complementary feeding practices, too early introduction of complementary foods, restriction in food selection and insufficient amounts of complementary foods were reported as major causes of malnutrition in young children in the developing world [2]. Food fortification can be used to correct or prevent nutrient intake shortfalls in their diet and associated deficiencies [3]. Classical interventions using foods fortified with micronutrients require the implication of healthcare systems which often, are not available to people living in remote rural areas. Therefore, the most practical and efficient strategy in these locations may be food-to-food fortification, using locally available, accessible and affordable foods consistent with contextual food habits.

Moringa and baobab are two local resources known for their proven nutritional quality but still underutilized in Benin. Moringa leaf powder is rich in various micronutrients and contains per 100 g edible portion, 1443 mg of calcium, 176 mg of magnesium, 53 mg of iron, 17. mg of zinc and 624 µg of β-carotene [4]. Chemical analysis of baobab parts revealed abundant amounts of proteins, amino acids, iron, vitamins C and A in leaves, seeds and fruit pulp [5]. Baobab fruit pulp contains up to 360 mg/100 g dw (dry weight) of vitamin C, 3272 mg/100 g dw of potassium, 702 mg/100 g dw of calcium and 10.4 mg/100 g dw of iron and exhibits 30 times more antioxidant activity than kiwi [6].

In this study, moringa leaf powder and baobab fruit pulp were used as fortificants in fermented sorghum porridge. Sorghum is an important staple cereal, especially in parts of Africa and Asia where it is widely grown due to its drought resistance [7]. In Northern Benin, it covers 40% of cereals cropping area, just behind maize, which accounts for 44%, and most of its production is locally consumed [8]. Fermented sorghum porridge is a common infant food in this area and deserves more attention for food-to-food fortification than has been to date. In a previous study, fortification of fermented maize porridge and fermented sorghum porridge with moringa leaf powder and baobab fruit pulp improved significantly micronutrient content (calcium, iron and zinc) of the food vehicles and the fortified fermented sorghum porridge was accepted by children [9]. The objective of this study was to test the effect of fermented sorghum porridge fortified with moringa leaf powder and baobab fruit pulp on the nutritional status of 6 to 59 months old children in Northern Benin.

MATERIALS AND METHODS

Experimental design

The study was designed as a two-arm randomized controlled trial among children at risk of malnutrition or moderate acute malnutrition in two villages of Tanguiéta (a district of Benin), randomly assigned as treatment (Nontingou) or control village (Ouankou). The treatment group consumed the fortified formula daily in a nutritional rehabilitation hearth for two weeks whereas the control group kept on eating the common foods in the study area. To avoid discrimination, children in the control group received some moringa leaf

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powder and baobab fruit pulp at the end of the intervention. The study was approved by the National Ethic Committee for Health Research in Benin (N° 08 of March, 29th 2017).

Sampling

Exhaustive census of resident children aged 6 to 59 months was done in the two villages. One hundred and five children in the treatment village and ninety-five children in the control village were initially enrolled. Children's weight and height were taken using respectively a SECA scale and a sliding and graduated stadiometer made of wood. Their age was recorded from birth certificates. Weight-for-height Z-scores (WHZ) were calculated using WHO Anthro V3.0.1 software to diagnose wasting. Children with moderate (-3 SD <Z-score ≤ -2 SD) or risk of acute malnutrition (-2 SD <Z-score ≤ -1 SD) were included. Children with severe acute malnutrition (WHZ ≤ -3 SD) or without acute malnutrition (WHZ> -1 SD) were excluded. Sick children and those under a special diet or a treatment were also excluded. Severely malnourished children were referred to the therapeutic nutritional Centre of Tanguiéta and sick children to the district health centres. **Figure 1** summarizes participants' selection procedure.

The final sample size was judged sufficient as a minimum sample size of 47 children for both groups and was estimated using the proportion of children consuming moringa leaf powder and/or baobab fruit pulp in the study area, 6% margin error and 10% increase to account for eventual dropouts.

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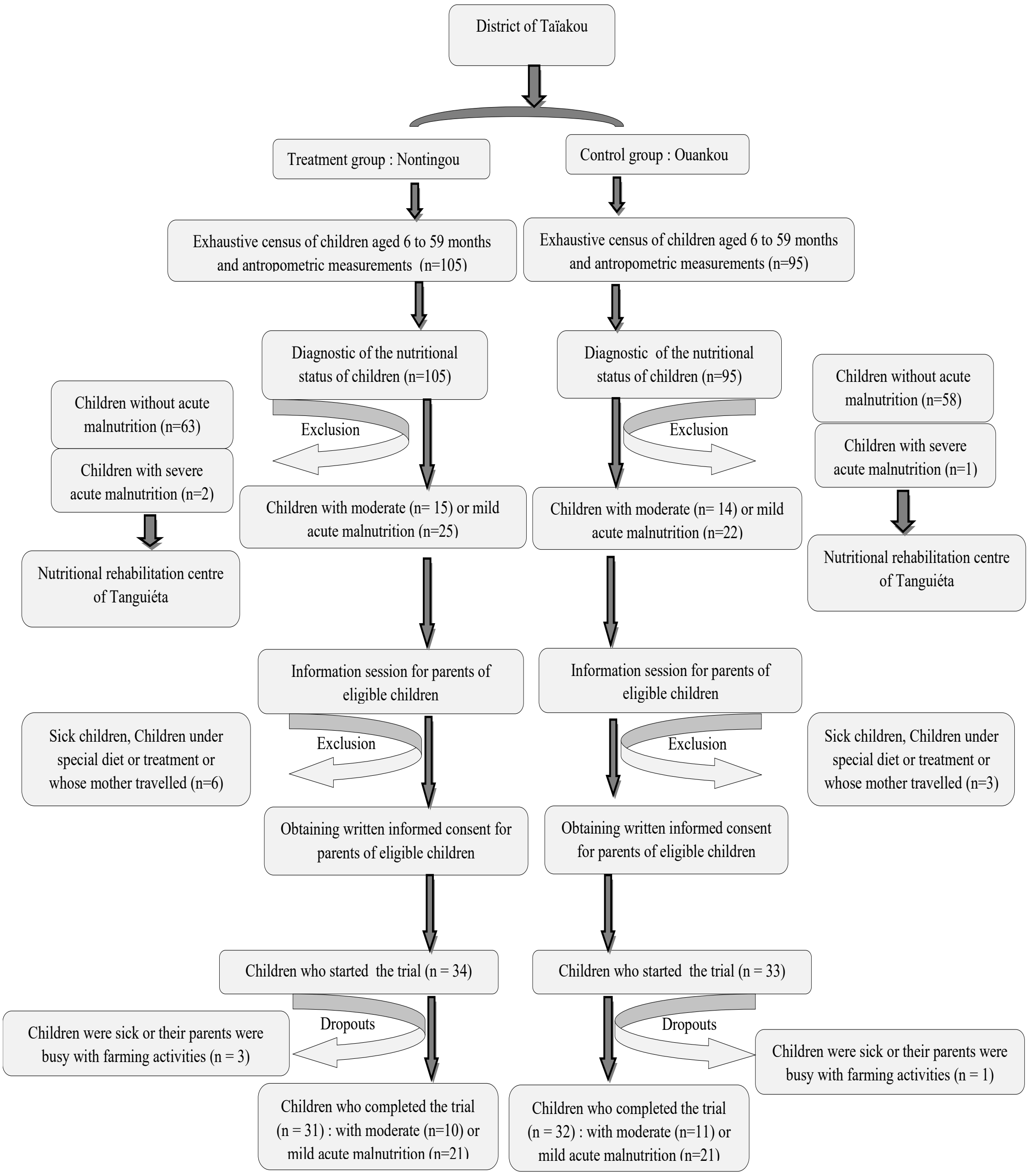

Figure 1: Participants' selection procedure

Preparation of the food vehicle and the fortificants

Fermented sorghum porridge was produced according to local practices. Sorghum grains were sorted, washed and soaked in water at ambient temperature (~32° C) for 24 hours. Grains were removed from the water and grounded, then mixed with water and filtered. The product was left to ferment for a few hours. The fermented product was poured into boiling water removed from the fire and stirred until the mixture was completely homogeneous. The two fortificants were also prepared. Moringa leaf powder was produced as described previously [10]. The baobab fruit pulp was extracted as recommended [11].

The fortified formula for daily consumption per child contained 400 g of fermented sorghum porridge, 15 g of a designed mix of moringa leaf powder and baobab fruit pulp and it cover rate was calculated taking into account Estimated Average Requirements (EARs) of 6–59 months old children for proteins, iron, zinc and calcium [12] and the fortified food nutritional value. Table 1 shows the contribution of the food formula for the 6–59 months old children daily Estimated Average Requirements without taking into account the bio-accessibility of minerals. These cover rates range from 1058–2433% for iron, 356–570% for calcium and 4178–6685% for zinc.

Running the nutrition rehabilitation hearth

In the treatment village, the nutritional rehabilitation hearth was installed in the chief's house. Mothers brought their children every morning to the hearth where they consumed the fortified formula for two weeks. The fermented sorghum porridge, the food vehicle, was cooked by the mothers every day in the hearth. The porridge was left to cool for a few minutes and moringa leaf powder and baobab fruit pulp were added in the pre-determined proportions. Each child had his/ her own bowl with his/her name written on it. In case a child was sick, refused or cannot finish the porridge before returning home, his/ her mother was asked to cover and bring the porridge home so that the child could finish it during the day.

A short questionnaire was also used every day during the trial to collect information from mothers on children's reaction. The questionnaire asked about vomiting, diarrhoea or allergies consecutive to the consumption of the fortified formula or refusal. Two categories of children were created in the treatment group: category I for children who consumed the fortified formula every day until the end of the trial, and category II for children who were not able to consume the fortified formula every day until the end.

Weight and height measurements were taken every day in the treatment group to monitor children's nutritional status. The same measurements were taken three times in the control group, at the trial baseline, mid-term and end. Children under 2 years of age or too weak to stand up were measured in a lengthened position. Older children were measured in a standing position. For each child, height and weight was measured twice and the mean value was used.

Evaluating the intervention

Children's average weight gain and recovery rate were calculated to assess the performance of the nutritional rehabilitation hearth [13].

Statistical analysis

The t-student test was used to find out weight, height and age differences between the two groups. The intervention effect from the baseline to the end was assessed using the difference in-differences (D.I.D) estimator under generalized estimating equations (GEE) framework [14]. For each variable (weight or height), the D.I.D estimator was calculated. The DID technic calculates the effect of a treatment (an explanatory variable) on an outcome (a response variable) by comparing average change over time (from the baseline to the endline) in the outcome variable for the treatment group compared to the control group [15]. Explanatory factors used in the models were time, treatment and sex. The covariate was children's age (continuous). The D.I.D estimator was the coefficient of the interaction term "Time × treatment". This coefficient was considered statistically significant when the slopes in the two groups were not parallel, what meant the intervention had affected the outcome (weight or height) in the treatment group differently than in the control group. In particular, if the D.I.D estimator were negative, the consumption of the fortified formula had negative effect on the children's nutritional status. On the contrary, if the coefficient were positive, the consumption of the fortified formula had improved the children's nutritional status. All statistical analyses were done in R software version 3.2.4, except the GEE models which were run in SPSS version 19.

RESULTS AND DISCUSSION

Baseline characteristics of participants

Table 2 shows mean age, weight, height and weight-for-height Z-score of participants in the treatment and control groups at baseline. There was no significant difference between the two groups in these variables at baseline ($p > 0.05$).

Children's reactions towards the fortified formula

The refusal of the fortified porridge and adverse effects after consumption were noticed from some children, namely fever, diarrhoea or vomiting. In total, 54.84% of children in the treatment group were concerned (**Figure 2**). These effects may be due to the fact that the children were malnourished and could also have had other health issues, and not to the consumption of the fortified porridge. For instance, malaria would also have caused symptoms like fever or vomiting. The incidence of malaria was high in the study area like in other parts of sub-Saharan Africa which bears a high burden of this disease. Some malaria cases were reported by mothers during the intervention. For mothers, illness during the intervention was due to teething too. Supporting this, in a prospective study in 224 infants, mothers reported that respectively 74% and 100% of them suffered from an adverse health effect during the eruption of the front and back teeth [16]. Moreover, teething is known to induce loss of appetite in children [17]. Some mothers mentioned their children had no appetite. This may have negatively affected acceptability of the fortified food by these children as appetite is substantially associated with children's food preferences [18]. Failure to observe hygiene rules in the study area could partly explain cases of diarrhoea, which were observed during the study. As explained by mothers, rejection of the fortified porridge by some children could be explained by the fact that moringa leaves are commonly consumed in the study area as a vegetable sauce.

Zongo *et al.* [19] also pointed out the problem of acceptability to a porridge mixed with moringa leaf powder because of the green color induced by the moringa leaf powder but much fewer children were concerned (3.84% during the first week of consumption) and vomited, had diarrhoea or showed resistance, compared to 54.84% of children who had similar reaction during the 2-week intervention in the present study. Houndji *et al.* [10] did not find out any acceptability problem in their studies among children in Benin, when moringa leaf powder was mixed with any food and the quantity of moringa leaf powder

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consumed with a single food was lower than 10 g. Zongo *et al*. [19] did not highlight the composition of the vehicle food, the number of times the fortified food was eaten daily and the amount consumed. The vehicle food used in their studies could be more compatible with moringa leaf powder in terms of color and taste than the sorghum porridge used in the present study.

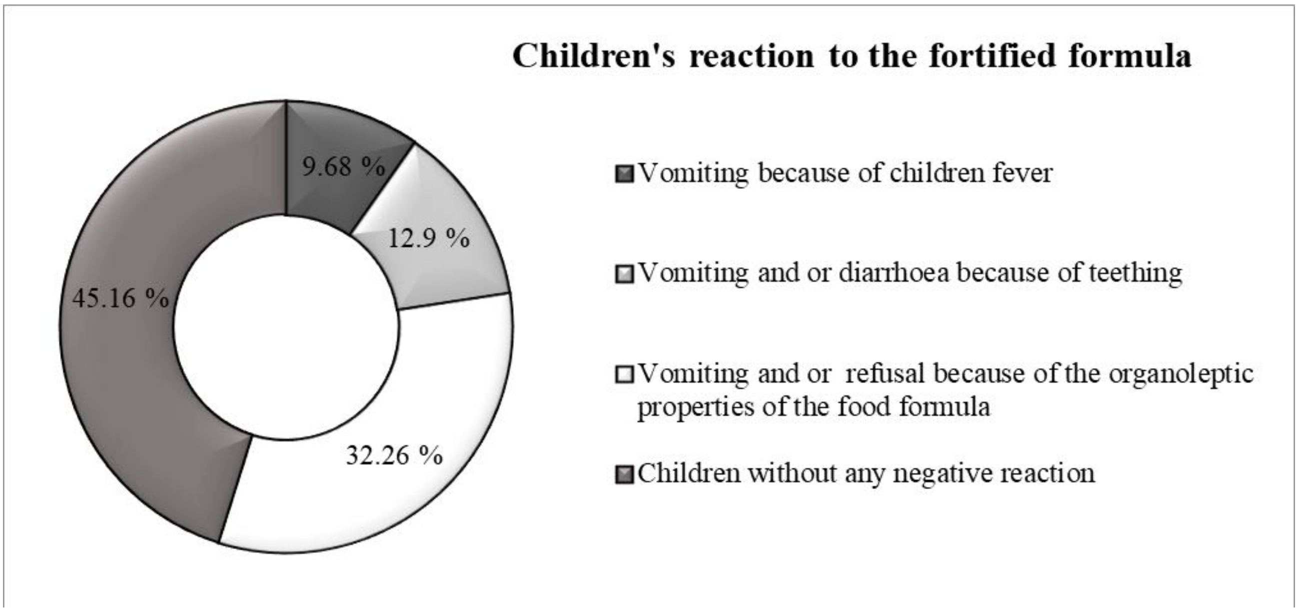

Figure 2: Reaction of children in the treatment group towards the fortified formula during the intervention

Effect of the intervention on the nutritional status of the children

Children's weight was the same in both groups at the end of the intervention (p=0.97; **Figure 3**). Overall, the intervention had no significant effect on children's weight (p=0.34) in the treatment group (**Table 3**). Note that the positive values of the estimates for treatment and DiD estimator indicate some improvement, even if not significant (Table 3). However, an acceptable average weight gain (9.85 g/kg/day) was obtained in the treatment group. This average weight gain is higher than in a previous study [19] where this was 8.9 g/kg/day after a 6-month trial with 10 g of moringa leaf powder administered to children. The recovery rate obtained in the treatment group at the end of the present trial was 45.16% whereas in the control group, it was only 18.75% (**Figure 4**). Within the treatment group, the intervention did not significantly affect (p=0.99) the weight of children in the category I (**Table 4**) and same for children in category II (p=0.06; **Table 5**). The negative value of the interaction term (DiD estimator) suggests a decrease in the weight in the category II, even not significant (Table 5). Results also showed more children recovered in the category I (62.50%) compared to children in the category II where the recovery rate was only 29.41% (**Figure 5**). At the end of the intervention, there was no more children with moderate acute malnutrition in the category I whereas in the category II, 11.76% of children still suffered from moderate acute malnutrition. The prevalence of risk of acute malnutrition decreased in both categories but more in the category I (Figure 5). Note that recovery rate should be 75% after 4 weeks of adequate nutritional rehabilitation [13]. Considering the result obtained in the category I despite the shorter duration of the intervention, it may be possible that

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an extension of the intervention up to 4 weeks would allow a higher recovery rate. Longer intervention duration could also significantly increase children's weight as in other studies, daily supplementation of 10 g of moringa leaf powder for six months significantly improved children's weight [19]. Furthermore, potential confounding factors, like parasitic infection, malaria and teething, might also have reduced the effect of the fortified porridge. For instance, parasitic infection could have induced intestinal nutrient malabsorption after consumption of the fortified food and a reduced effect.

Although the present study did not intend to assess the effect of the consumption of fermented sorghum porridge fortified with moringa leaf powder and baobab pulp on iron deficiency, it would be useful to investigate this as iron deficiency is prevalent in Benin as in other sub-Saharan Africa countries. Results reported elsewhere suggest supplementation of 10 g of moringa leaf powder for six months did not improve blood haemoglobin levels in children [19]. The fortified porridge used in the present study had high iron content and could cover from 1058.97 to 2433.33% of iron needs of children aged 6 to 59 months (Table 1). However, the in vitro solubility of this iron may be low as is generally the case in plant foods [20], and specifically in moringa leaves [21] due to a high phytic acid and iron ratio. Moreover, polyphenols, especially condensed ones such as tannins contained in sorghum grains, easily complex iron cations (Fe^{2+}), thus decreasing their bioavailability [22]. However, it is important to consider that the sorghum porridge used in this study as food vehicle was fermented and the baobab fruit pulp used is an acidulant which can enhance iron bioavailability in both moringa leaf powder and sorghum grains. Washing, soaking, sieving and fermentation significantly decrease phenols and anthocyanin contents in fermented sorghum porridge [22].

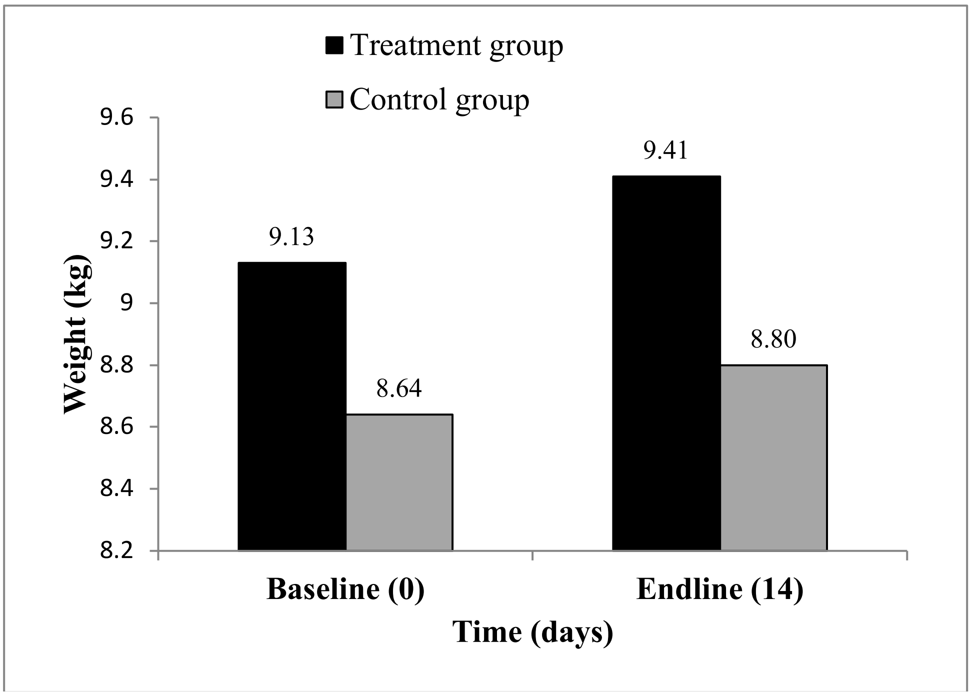

Figure 3: Children's weight at baseline and endline in the treatment and control groups

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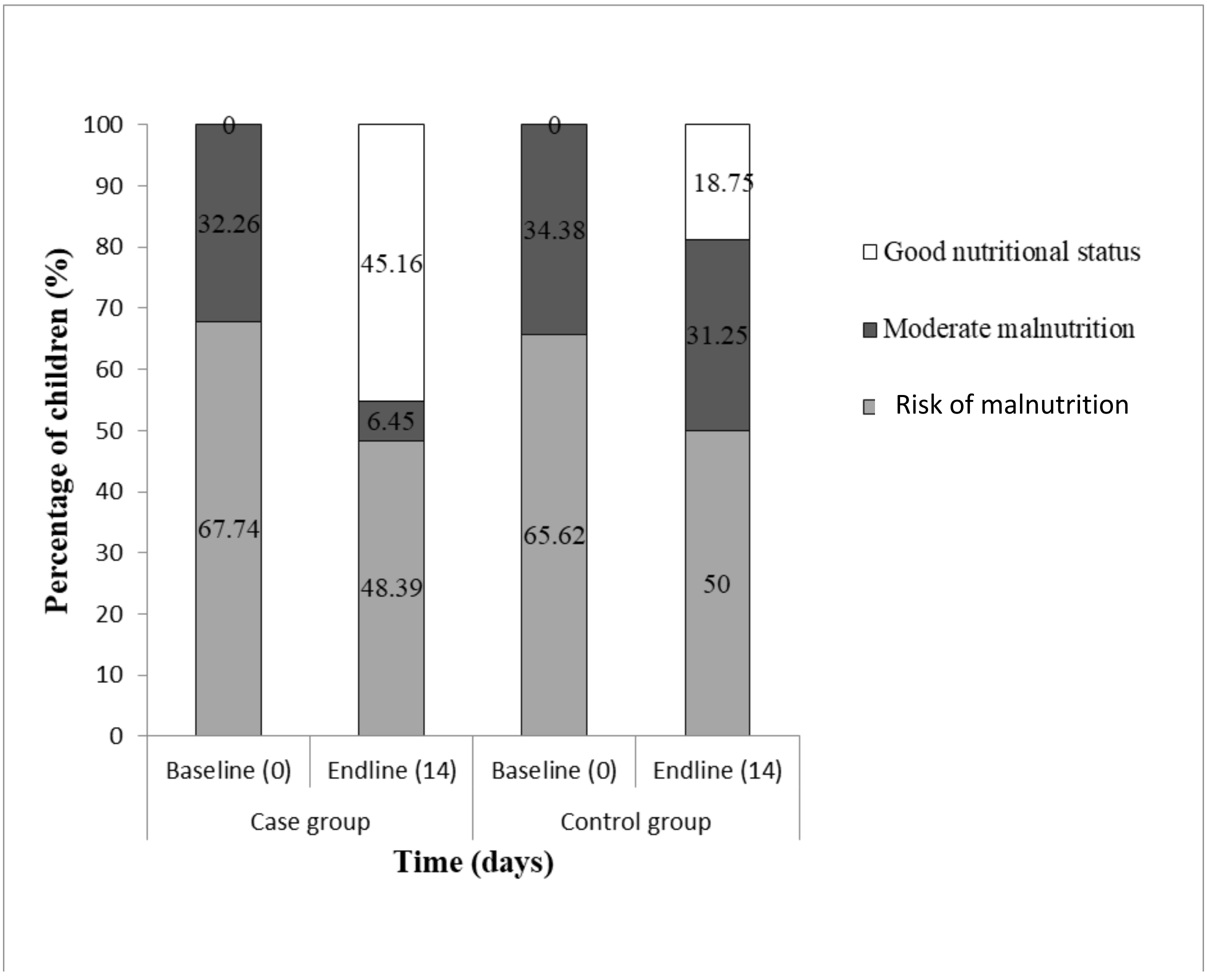

Figure 4: Nutritional status of children in the treatment and control groups at baseline and endline based on anthropometric measurements

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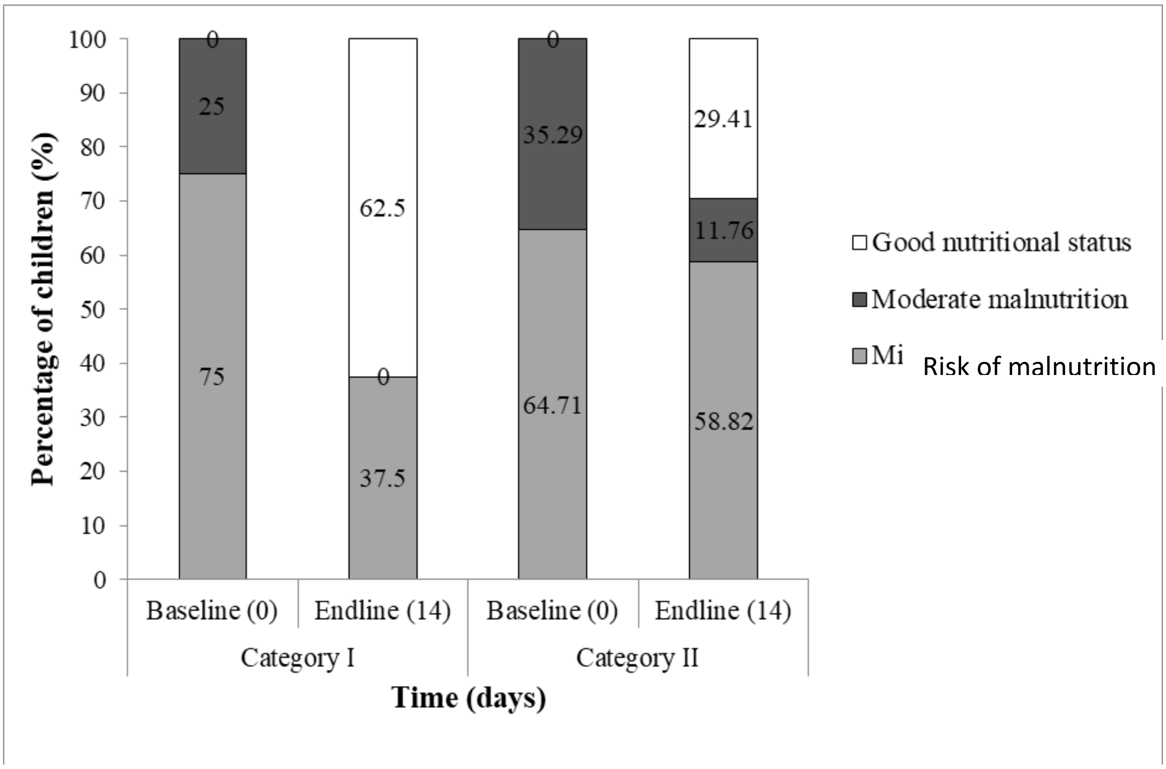

Figure 5: Nutritional status of children in categories I and II of the treatment group at baseline and endline

Category I: children who consumed the fortified formula every day until the end of the trial

Category II: children who were not able to consume the fortified formula every day until the end of the trial

CONCLUSION

The study was designed to test the effect of the fortified food on the nutritional status of children. The daily consumption of the fermented sorghum porridge fortified with 15 g of a designed mix of moringa leaf powder and baobab fruit pulp for two weeks did not improve significantly the children weight at the end of the trial. However, an acceptable recovery rate and average weight gain were obtained. Further investigation accounting for parasitic infection is needed to eliminate all risks of intestinal micronutrient malabsorption or malaria and enhance the effectiveness of the fortified food, not only on children's weight but also on their iron status. In addition, the fortified food may be improved in order to make it more acceptable to children.

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Table 1:Contribution of the food formula to the children daily Estimated Average Requirements

	Protein	Iron	Zinc	Calcium
Estimated Average Requirements				
Children (6–12 months)	NA	6.9 (mg/d)	2.5 (mg/d)	NA
Children (12–36 months)	7.72 (g/d)	3 (mg/d)	2.5 (mg/d)	500 (mg/d)
Children (36–59 months)	6.75 (g/d)	4.1 (mg/d)	4 (mg/d)	800 (mg/d)
Nutritional value				
400 g of fermented sorghum porridge + 15 g of a designed mix of moringa leaf powder and baobab fruit pulp	46 (g)	73 (mg)	167 (mg)	2852 (mg)
Cover rate without taking into account the bioavailability of micronutrients (%)				
400 g of fermented sorghum porridge + 15 g of a designed mix of moringa leaf powder and baobab fruit pulp	602–688	10587-2433	4178–6685	356–570

d: day, NA: Not available

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Table 2: Comparison of baseline characteristics of children from the two intervention groups

	Treatment group (n=31)	Control group (n=32)	T-Value	P-Value
Age (months)	25.4 ± 2.8	23.7 ± 2.5	-0.06	0.959
Weight (kg)	9.1 ± 0.4	8.6 ± 0.4	-0.04	0.971
Height (cm)	80.2 ± 1.9	78 ± 1.7	-0.02	0.986
Weight-for-height Z-score	-1.70	-1.78	-0.02	0.988

Table 3: Coefficient, standard error and significance level of the generalized estimating equations models in the treatment and control groups

Terms in the model	Df	Weight		Height	
		est (SE)	p-value	est (SE)	p-value
Intercept	1	5.902 (0.318)	0.000	63.994 (1.491)	0.000
Sex (1)	1	-0.083 (0.357)	0.816	1.257 (1.693)	0.458
Time (1)	1	0.100 (0.052)	0.054	-0.257 (0.036)	0.000
Treatment (1)	1	0.281 (0.296)	0.343	1.233 (1.373)	0.369
DiD	1	0.141 (0.128)	0.272	0.133 (0.071)	0.061
Age	1	0.030 (0.004)	0.000	0.140 (0.016)	0.000

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Table 4: Coefficient, standard error and significance level of the generalized estimating equations models in category I compared to the control group

Terms in the model	Df	Weight		Height	
		est (SE)	p-value	est (SE)	p-value
Intercept	1	5.877 (0.3624)	0.000	640.186 (1.5877)	0.000
Sex (1)	1	0.289 (0.4395)	0.511	20.861 (2.0867)	0.170
Time (1)	1	0.105 (0.0523)	0.044	-0.230 (0.0394)	0.000
Treatment (1)	1	0.047 (0.3396)	0.988	-0.381 (1.5081)	0.800
DiD	1	0.401 (0.1496)	0.007	0.018 (0.0287)	0.523
Age	1	0.027 (0.0043)	0.000	0.126 (0.0182)	0.000

Category I: children who consumed the fortified formula every day until the end of the trial

Table 5: Coefficient, standard error and significance level of the generalized estimating equations models in category II compared to the control group

Terms in the model	Df	Weight		Height	
		est (SE)	p-value	est (SE)	p-value
Intercept [status=1]	1	5.797 (0.4030)	0.000	62.878 (1.7713)	0.000
Sex (1)	1	0.069 (0.3992)	0.862	2.230 (1.8748)	0.234
Time (1)	1	0.100 (0.0523)	0.055	-0.267 (0.0447)	0.000
Treatment (1)	1	0.599 (0.3188)	0.060	2.950 (1.5078)	0.050
DiD	1	-0.059 (0.1189)	0.618	-0.022 (0.0275)	0.430
Age	1	0.030 (0.0049)	0.000	0.144 (0.0211)	0.000

Df=degree of freedom, est=estimates, se=standard error of estimates, p-value=significance level
Reference: for sex was 0 (male), for time was 0 (baseline), for treatment 0 (control)
DiD is the estimator of the difference in-differences
Category II: children who were not able to consume the fortified formula every day until the end of the trial

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