Maternal & Child Nutrition

DOI: 10.1111/j.1740-8709.2010.00287.x

Original Article

Acceptability of zinc-fortified, lipid-based nutrient supplements (LNS) prepared for young children in Burkina Faso

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Abstract

Micronutrient deficiencies are a public health concern among young children in low-income countries, and novel strategies are needed to improve the nutritional status of children at risk. One promising approach is the use of lipid-based nutrient supplements (LNS), which can be added to complementary food at the time of consumption. The optimal amount of zinc to include in LNS is uncertain, and concerns have been expressed about possible adverse effects of zinc on sensory characteristics of LNS. We conducted a series of acceptability studies of LNS containing either 0 or 10 mg of zinc per daily 20 g LNS dose among Burkinabe children 9–15 months old and their mothers. These acceptability studies included observations of children's consumption, maternal and child sensory reaction to the products using a 5-unit hedonic scale, a triangle test for detection of differences and a review of maternal reports of their child-feeding experiences during a 2-week home-feeding trial. The LNS products were well appreciated by the mothers and children during the sensory trials and the 2-week home-feeding trial. The addition of 10 mg zinc to LNS did not affect the consumed proportion of the offered porridge-LNS-mixture ($P = 0.43$). Results of the triangle test with mothers confirmed that there was no detectable difference between products containing 0 or 10 mg zinc per 20 g LNS dose. Most importantly, interviews and focus groups following the 2-week home-feeding trial indicated good acceptability of the products by mothers and their children.

Keywords: complementary foods, point-of-use fortification, sensory trial, young children, zinc.

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Introduction

Infants from 6 to 24 months of age in lower income countries are especially vulnerable to deficiencies of zinc and iron because: (1) the rapid rate of growth during this period imposes relatively high requirements of these nutrients; (2) breast milk intakes decrease with age, and the zinc and iron contents of human milk decline to low levels in the second semester post-partum; and (3) most home-available complementary foods are limited in the amounts and bioavailability of these nutrients. Reviews of the theoretical nutrient requirements during the period of complementary feeding (Brown *et al*. 1998; Dewey & Brown 2003) indicate that it is very difficult for infants in lower income countries to meet their requirements for zinc and iron from home-available preparations alone unless these mixtures are fortified or contain considerable amounts of animal source foods, which tend to be expensive and therefore inaccessible. Thus,

various strategies for 'home' fortification, or point-of-use fortification (POUF), have recently been developed to ensure adequate micronutrient intakes by infants and young children (Nestel *et al*. 2003). One promising approach for POUF is the use of lipid-based nutrient supplements (LNS), which are designed to prevent malnutrition and contain a small amount of energy, protein and essential fatty acids in addition to the micronutrients (Adu-Afarwuah *et al*. 2007; Phuka *et al*. 2008).

Current formulations of LNS for young children, such as Nutributter (Nutriset SAS, Malaunay, France), contain 5 mg zinc per daily dose. A previously completed intervention trial using such a formulation in Ghana did not find significant changes in mean serum zinc concentrations (Adu-Afarwuah *et al*. 2007), and POUF trials using zinc-containing multiple micronutrient powders similarly failed to detect a significant impact on serum zinc concentration (Dewey & Adu-Afarwuah 2008; Hess & Brown 2009). Possible explanations for this lack of response are that the dose of zinc was inadequate because less zinc is absorbed from zinc-containing preparations that are provided with meals than from water-soluble zinc supplements provided between meals, and/or that zinc was taken up preferentially by non-metabolically active zinc pools. By contrast with the results using LNS, supplemental doses of zinc as little as 3 mg day^{-1} have been found to increase young children's serum zinc concentration and to reduce their incidence of diarrhoea (Brown *et al*. 2007; Wuehler *et al*. 2008). In contrast to the above-described lack of evidence of beneficial impacts of zinc-fortified complementary foods on zinc-related outcomes, zinc supplementation trials providing 5–10 mg zinc per day generally resulted in improved growth and reduced morbidity outcomes in young children (Brown *et al*. 2009). Thus, it is possible that the 5 mg dose of zinc provided in the previous LNS trials may have been inadequate. Therefore, we plan to test a 10 mg daily dose of zinc in LNS to compensate for the likely reduced bioavailability of zinc when given with food (http://www.ClinicalTrials.gov; NCT00944281). In preparation for this intervention trial, we conducted the present sensory evaluations to determine the acceptability of the proposed increased dose of zinc in LNS. Zinc is known for its metallic taste, which is a concern in dispersible zinc supplements and micronutrient powders, another POUF product. We hypothesized that products containing either 0 (LNS-Zn-0) or 10 mg added zinc (LNS-Zn-10) per 20 g dose of LNS in porridge would be well accepted by children and their mothers in rural Burkina Faso.

Materials and methods

The purpose of the current study was to determine whether each of the different LNS formulations had adequate acceptability. The acceptability trial was conducted in the health centre of Sourkoudougou in Houet Province of western Burkina Faso. We conducted a series of acceptability studies to: (1) assess the amounts of low-zinc and high-zinc LNS consumed by children during direct observation; (2) assess their mothers' degree of liking of the respective products; and (3) review maternal reports of their child-feeding experiences during more prolonged home-feeding trials, as described in more detail below. In each case, the studies were conducted as double-masked com-

Key messages

- Deficiencies of zinc and other micronutrients among young children in low-income countries are a public health concern and strategies are needed to improve the nutritional adequacy of complementary foods in these populations.
- Lipid-based nutrient supplements (LNS) containing energy, protein, essential fatty acids and micronutrients have been developed to overcome nutrient shortfalls in existing diets.
- LNS was well accepted by young children and their mothers in Burkina Faso during sensory trials and a 2-weekly home feeding trial.
- The addition of 10 mg zinc per 20 g daily dose of LNS did not affect the acceptability.

Table 1. Nutrient composition of lipid-based nutrient supplements (LNS) products (amount per 20-day daily ration)

Nutrient	LNS
Ration (g/day)	20
Total energy (kcal)	118
Protein (g)	2.6
Fat (g)	9.6
Linoleic acid (g)	4.46
α-Linolenic acid (g)	0.58
Vitamin A (μg RE)	400
Vitamin C (mg)	30
Vitamin B_1 (mg)	0.3
Vitamin B_2 (mg)	0.4
Niacin (mg)	4
Folic acid (μg)	80
Pantothenic acid (mg)	1.8
Vitamin B_6 (mg)	0.3
Vitamin B_{12} (μg)	0.5
Vitamin D (IU)	200
Vitamin E (mg)	6
Vitamin K (μg)	30
Iron (mg)	6
Zinc (mg)*	0 or 10
Cu (mg)	0.34
Calcium (mg)	280
Phosphorus (mg)	190
Potassium (mg)	200
Magnesium (mg)	40
Selenium (μg)	20
Iodine (μg)	90
Manganese (mg)	1.2
Phytate (mg)	23.4

*Intrinsic zinc content is approximately 0.3 mg per 20 g LNS.

parisons. The study products contained either 0 mg or 10 mg added zinc, as zinc sulfate, but were otherwise identical (Table 1).

Product development

The products were formulated, developed and manufactured by Nutriset SAS (Malaunay, France), and delivered in coded packages labelled specifically for this study. Products used for this study contain the same nutrients as the ones being tested in Malawi and Ghana by iLiNS project teams (http://www.ClinicalTrials.gov; NCT00885144 and NCT00970866), apart from the zinc content. Zinc chloride, zinc gluconate, zinc oxide, zinc stearate and zinc sulfate are generally recognized as safe by the US Food and Drug Administration (2010). From the available evidence on the bioavailability of different forms of zinc (Hess & Brown 2009), and taking into account costs, both zinc sulfate and zinc oxide are suitable compounds for zinc fortification. For the present product development, zinc sulfate was chosen because it is more soluble than zinc oxide at neutral pH. The products are made of vegetable oil, dried skimmed milk powder, peanut paste, sugar, maltodextrines, and a mineral and vitamin mix. A major difference in the formula development, compared with previously tested LNS products (Adu-Afarwuah *et al*. 2007), is the use of soybean oil, to enable maximization of the content of both alpha linolenic acid and linoleic acid per daily dose.

Subjects

Subjects were 9–15 months old, currently breastfed children and their mothers. Children had to be receiving semi-solid or solid complementary foods at least once per day for at least 30 days prior to the start of the study. Exclusion criteria for children were: height-for-age (HAZ), weight-for-age (WAZ) or weight-for-height (WHZ) Z-scores <–3 with respect to World Health Organization growth standards (World Health Organization 2006), presence of oedema, diarrhoea or other ailments that might affect appetite during the previous 7 days, congenital abnormalities and current severe systemic illness. Children were also excluded if there was a history of allergy towards peanuts or serious allergic reaction requiring emergency medical care. Eligible children and their mothers who provided written consent were invited into the study. The study was approved by the Ethical Committee of the Centre Muraz in Bobo-Dioulasso, Burkina Faso and the Institutional Review Board of the University of California Davis, USA. The study was registered with the U.S. National Institute of Health as a clinical trial (http://www.ClinicalTrials.gov; NCT00944814).

Assessment of child consumption of test meals, using direct observation

Upon arrival at the study unit, mothers were asked to breastfeed their child. No other food or liquids were

given for the following 60 min, after which the test meal was offered to the child. The test meal was prepared from 150 g wet weight of prepared porridge, which was formulated to contain 32 g dry weight millet (~116 kcal), and 15 g (~1.5 teaspoons, containing ~88 kcal) LNS, with or without added zinc. The total original serving size for the child was 165 g, containing ~200 kcal. The porridge was prepared following a local recipe commonly consumed in the study area. The porridge and LNS mixture were served in pre-weighed bowls, and the mother was asked to try a spoonful of LNS porridge mixture for the subsequent preference testing of the mother, as described below. The bowl was weighed again before feeding the child. The amount of porridge offered was determined in preliminary field testing to ensure that the portion size was similar to what mothers would offer at home. The rationale for providing 15 g of LNS was that the subsequent intervention trial will recommend that the daily 20 g dose of LNS be divided into two servings. If the daily allotment is divided unevenly, we speculated that mothers could feed as much as 15 g in a single serving. Because any decreased acceptability of the LNS-containing porridge might be more likely to occur when more LNS is added, this proposed amount would have provided the greatest chance of detecting any decrease in product acceptability due to the added zinc.

The caregiver was asked to feed the child, using a spoon, until either the child finished or refused further food. In cases when the child did not want to eat more, the researchers instructed the mother to wait ~30 s and then offer the food a second and final time. If the feeding continued for more than 15 min, the feeding was stopped at 15 min and the amount consumed was assessed. The meals were supervised by study personnel, and the total amount of food consumed was determined by reweighing the feeding bowl (to 1 g precision) and calculating the difference from the initial weight. Any amounts spilled or regurgitated were measured by mopping the spillage on pre-weighed towels, and the amounts lost were considered in the calculations. The total duration of the meal was also recorded. The identity of the LNS products was concealed from the mothers and the study personnel. The same protocol was repeated on 3 consecutive days. The purpose of day 1 was to allow children and mothers to adjust to the new food, the new environment and the study protocol. Children were randomly assigned to one of the two products on day 1 and day 2 independently. On the third test day, the child was fed the product not fed on day 2. Before feeding, mothers completed a brief questionnaire on child illness symptoms during the past 24 h and were asked whether their child's appetite appeared to be normal.

Preference testing with mothers

On each of the test days described above, the mother was asked to taste a spoonful of the LNS-porridge mixture before feeding her child. At the end of the feeding, the mother was asked to indicate how she liked the product, using a 5-unit hedonic scale with 'smiley faces', as previously found to be useful in non-literate and semi-literate individuals (Coetzee 2001). The purpose of this test was to assess the mother's liking of the product, based on both her tasting and her perception of her child's reaction to the food.

Triangle test among mothers

Following each day's child-feeding session, mothers of the children enrolled in the sensory study protocol completed a triangle test with the two study products (Gallagher 2004). The purpose of this test was to assess whether the mothers could detect any difference between the LNS porridge mixture with or without added zinc. Mothers were served a tray with three bowls of porridge placed in random order and identified only by a code. Each of the bowls contained 30 g of porridge and 15 g of LNS. One of the samples contained LNS-Zn-0 and the other two samples contained LNS-Zn-10 or vice versa. The mothers were asked to examine and taste each of the three samples and then specify which was different from the other two. They were further asked to indicate whether the difference was large, medium or uncertain. Each mother participated in a triangle test on each of the 3 consecutive test days scheduled at the health centre.

2-Week feeding trial

Mothers and their children who completed the 3-day acceptability trial were invited to participate in the subsequent 2-week feeding trial. The mother–infant pairs ($n = 36$) were randomly assigned to one of two different groups: (1) LNS-Zn-0 or (2) LNS-Zn-10. The mothers were provided with a plastic cup containing 140 g of LNS, the ration for 1 week. They were advised to wash their hands before serving any food, to serve the daily portion of LNS in two divided doses mixed in a small portion of the child's food and to feed the LNS only to the study child. Because eating from a common dish is customary in West Africa, we provided the mothers with a bowl and a spoon and suggested that the child be fed LNS from a separate bowl, with the LNS mixed in a small portion of porridge (or any other food). If the child was still hungry, the mother was advised to provide additional food without LNS until satiety was reached. The mothers were further instructed to store the LNS out of children's reach. The mothers were asked to note each day on a pictorial chart whether the child consumed none, some or all of the two servings of the LNS-containing porridge. After 1 week, the study team visited the household to provide another week's supply of the same (zinc-containing or non-zinc containing) LNS for the second week, to evaluate how much LNS remained from the previous week and to assess the mothers' subjective reports of their children's willingness to consume the product, their experience regarding the ease or difficulty feeding LNS and their perception of the child's degree of liking.

At the end of the 2-week feeding trial, mothers were invited to participate in focus groups to describe their impressions regarding the children's willingness to eat the LNS-containing porridge and their own experiences in feeding their children.

Sample size estimates and statistical analysis

For the consumption test in children, we initially estimated the sample size required to determine whether the mean intake of each LNS product/porridge mixture was at least 50% of the amount offered. Although we did not have explicit prior information on the within-subject variability of intake of these preparations, it was our judgement that the standard deviation (SD) would not exceed 25%. We estimated that a sample size of at least 16 children was needed per group to test whether the mean intake was greater than 50% of the amount offered (i.e. >82.5 g). With that sample size the null hypothesis could be rejected with 80% power if the true mean intake was at least 70% of the amount offered.

For the preference tests with the mothers, a sample size of 36 was required to detect a prevalence of 80% of mothers liking the products with a confidence interval (CI) of 67–93%. The final sample size of 36 child–mother pairs was determined by this sample size required for the preference testing in mothers, and was more than adequate for the consumption test in children. For the triangle test, a total sample size of 89 would have been required to assess the difference between samples (80% power). However, as the results of the triangle test were not considered a primary outcome, the sample size was not increased. Instead the triangle test was repeatedly administered on each of the 3 test days and participants were considered as individual panellists, which resulted in a total sample size of 108.

Data analyses were conducted using SPSS version 17.0 and 18.0 (SPSS Inc., Chicago, IL, USA). Statistical analyses for the consumed proportion of offered food were performed using an analysis of variance. Results of these analyses are presented as the mean (±SD) of the per cent of the serving consumed. Secondary analyses of the feeding tests were performed using the General Linear Model Univariate procedure. Results of amounts of food consumed within 15 min, the feeding duration and the intake velocity expressed as g of food consumed per minute are presented as mean (95% CI). The following main effects were included in the models: LNS study product (i.e. LNS-Zn-0; LNS-Zn-10), test day and subject (as a random effect). We tested for interactions between the LNS study product and day. When there was a marginal or significant interaction it was included in the final model. For the consumption test, results of children were excluded on test days when their mother reported that the child's appetite was abnormal or the child was reported to be ill (fever, diarrhoea, flu-like symptoms) on that specific

day. Differences between individual feeding days were tested by independent *t*-test using the same exclusion filters as described above.

Data from the triangle tests were analysed using a binomial probability model at a significance level of $P = 0.05$ and 80% power. The maximum allowable false positive rate (α) was set at 0.05 and the maximum allowable false negative rate was set at 0.1. Using these criteria, at least 44 of 108 subjects (40.7%) would have to have identified the odd sample correctly to reject null hypothesis at a 5% level of significance.

Results

A total of 43 child–mother pairs were screened for eligibility. Three were excluded because their HAZ, WAZ or WHZ was below the cut-off (<–3 SD), three because the child did not yet consume solid foods, one due to a reported peanut allergy, and one because the mother was ill. A total of 35 mother–infant pairs completed all of the above-described sensory tests and 36 participated in the triangle test and the 2-week feeding trial. Demographic and socio-economic characteristics of study participants are presented in Table 2.

The mean consumption of the porridge-LNS-mixture did not differ significantly by the zinc content of LNS. The mean (±SD) per cent of the porridge-LNS-mixture that was consumed was 54.7 ± 22.1% of product LNS-Zn-0 and 59.3 ± 22.9% of product LNS-Zn-10 ($P = 0.43$). As shown in Table 3, during the test days 2 and 3, the children consumed an average (95% CI) of 90.4 (77.0, 103.9) g of product LNS-Zn-0 and 97.8 (84.6, 111.0) g of product LNS-Zn-10 ($P = 0.30$). These results were independent of the type of product received on day 1. The duration of consumption ranged from 2 to 15 min with a mean duration (95% CI) of 10.0 (8.8, 11.3) and 9.9 (8.7, 11.1) for the products LNS-Zn-0 and LNS-Zn-10, respectively ($P = 0.41$). This resulted in a mean velocity of food intake (95% CI) of 10.1 (7.9, 12.4) g min^{-1} and 11.2 (9.0, 13.4) g min^{-1} for LNS-Zn-0 and LNS-Zn-10 over the test days 2 and 3 ($P = 0.037$). There were no significant interactions between test day and product for any of these outcomes.

Mothers not only indicated that they evaluated both products very positively, but they also perceived that their children liked both products 'a lot'. Using a 5-unit hedonic scale to grade the mothers' perception of their child's degree of liking, there was no perceived difference between the products ($P = 0.97$; Table 4). There was also no significant difference in the mothers' own degree of liking of the two study products ($P = 0.31$). In both cases, the majority of the mothers (93.3%) ranked their child's degree of liking as 'like it a lot', and 85.7% said that they themselves liked the product 'a lot'. In addition, all mothers (100%) indicated that they would like to offer the product to their child again in the future.

There were no detectable differences between the two products in the triangle test. Although the majority of the women indicated that there was a large difference between the samples they compared, 66.2% still picked the odd sample incorrectly. Combining all responses of the 3 test days, the odd product was correctly identified during 29.6% of tests. Based on the sample size, these results indicate there was no

Table 2. Demographic and socio-economic characteristics of study participants ($n = 35$)

Infant breastfeeding, no. (%)	35 (100.0)
Infant sex, male no. (%)*	11 (31.4)
Infant age (months)†	12.1 ± 2.0 (9.0–16.0)
Infant weight (kg)	8.2 ± 1.6 (6.2–11.2)
Infant length (cm)	72.4 ± 3.0 (65.6–77.6)
Infant WHZ	–0.8 ± 1.3 (–2.9 to 2.85)
Infant HAZ	–1.2 ± 1 (–2.9 to 1.6)
Mothers' age (years)	26.3 ± 6.7 (17–43)
Mothers' occupation, no. (%)	
Farmer	16 (45.7)
Vendor	6 (17.1)
Farmer and vendor	5 (14.3)
Farmer and housewife	4 (11.4)
Housewife and vendor	2 (5.7)
Housewife	1 (2.9)
Other	1 (2.9)
Mother's education, no. (%)	
None	24 (68.6)
Primary incomplete	7 (20.0)
Primary complete	2 (5.7)
High school incomplete	1 (2.9)
Other	1 (2.9)

HAZ, height-for-age Z-score; WHZ, weight-for-height Z-score. *Number (percent in brackets); all such values. †Mean ± SD (range); all such values.

Table 3. Children's consumption of lipid-based nutrient supplements (LNS)-porridge mixture by study product

	LNS-Zn-0	LNS-Zn-10	P*†
	n = 31	n = 32	
Amounts consumed			
Day 2 (g)‡	96.7 (78.3, 115.1)	84.5 (66.7, 102.4)	0.341
Day 3 (g)	85.0 (64.9, 105.1)	103.8 (84.2, 123.3)	0.182
Pooled (g)	90.4 (77.0, 103.9)	97.8 (84.6, 111.0)	0.300
Feeding duration			
Day 2 (min)	9.6 (7.8, 11.3)	9.8 (8.0, 11.5)	0.878
Day 3 (min)	10.5 (8.6, 12,4)	9.6 (7.8, 11.4)	0.466
Pooled (min)	10.0 (8.8, 11.3)	9.9 (8.7, 11.1)	0.411
Velocity of food intake			
Day 2 (g min^{-1})	11.6 (8.6, 14.6)	9.7 (6.7, 12.7)	0.370
Day 3 (g min^{-1})	8.6 (5.2, 12.0)	12.3 (9.1, 15.5)	0.110
Pooled (g min^{-1})	10.1 (7.9, 12.4)	11.2 (9.0, 13.4)	0.037

*Results of day 1 are not shown as the sole purpose of the first day was to allow mothers and children to adjust to the study protocol and the new environment. †Univariate General Linear Model with LNS product and day (for pooled analysis) as main effects, and subjects as a random effect. The level of significance for all tests is $P < 0.05$. ‡Mean (95% confidence interval); all such values.

Table 4. Product preferences of mothers by study product

	LNS-Zn-0	LNS-Zn-10	P*
Mother's perception of child's degree of liking†			0.966
Like it a lot, no. (%)	34 (97.1)	32 (91.4)	–
Like it, no. (%)	1 (2.9)	3 (8.6)	–
Indifferent, no. (%)	0 (0)	0 (0)	–
Do not like it, no. (%)	0 (0)	0 (0)	–
Do not like it at all, no. (%)	0 (0)	0 (0)	–
Mother's degree of liking†			0.310
Like it a lot, no. (%)	33 (94.3)	33 (94.3)	–
Like it, no. (%)	2 (5.7)	2 (5.7)	–
Indifferent, no. (%)	0 (0)	0 (0)	–
Do not like it, no. (%)	0 (0)	0 (0)	–
Do not like it at all, no. (%)	0 (0)	0 (0)	–

*Univariate General Linear Model with cereal and day as main effects, and subjects as a random effect. The level of significance for all tests is $P < 0.05$. †Degree of liking assessed by a 5-unit hedonic scale.

detectable difference between the LNS products without added zinc and the LNS with 10 mg zinc added per 20 g dose.

Because mothers did not perceive a difference between the two test products in their child's liking nor in their own liking, and there was no detectable difference between the study products based on the triangle test, the reported experiences of the 2-week feeding trial were combined for the two products (Table 5). Following 1 and 2 weeks of feeding LNS at home, the majority of the mothers reported that both

Table 5. Triangle test of lipid-based nutrient supplements with and without added zinc

Extent of perceived difference by mothers	Odd sample incorrect	Odd sample correct
Large difference	49 (66.2)*	25 (33.8)
Medium difference	16 (72.7)	6 (27.3)
Chosen by chance	11 (91.7)	1 (8.1)
Total responses	76 (70.4)	32 (29.6)

*Number (percent in brackets); all such values.

their children and they themselves liked LNS 'a lot'. Almost all caretakers indicated that they followed the instructions given by the study team and fed LNS only to the study child. Only one person reported that the person feeding the child also consumed some of the LNS. Based on the mothers' reports, all children consumed LNS on a daily basis, once in the morning and once in the afternoon. The majority of the mothers mixed LNS in porridge, but some also mixed it with other foods ($n = 10$) or fed LNS by itself ($n = 2$) on some occasions. All mothers reported that they served the LNS from a separate bowl. Interestingly, significantly more mothers reported that the child generally finished the LNS portion in the second week then in the first week (97.2% vs. 77.8%; $P = 0.013$). However, ~15% of the mothers reported that the child had problems after eating LNS and reported various illnesses, such as cough, fever, malaria. All named illnesses were highly unlikely to be related to LNS consumption. When the LNS cups were collected at the end of each week, only 7% ($n = 5$) and 3% ($n = 2$) had an estimated amount of 25% or 50% of LNS remaining, respectively.

The focus group discussions confirmed that LNS (locally called '*fanga deguê*') was well accepted. The mothers associated LNS with vitamins, and some considered it like medicine that protects children from illnesses rather than food. Several mothers reported that LNS increased their child's appetite and many reported that their child 'had more energy' and 'was more joyous' than prior to the 2-week feeding trial. Although the majority of mothers experienced LNS as beneficial for their children, a few mothers did associate LNS with diarrhoea and a lack of appetite. The mothers reported that they generally followed the feeding instructions. Contrary to our concerns, the request to feed the child from a separate bowl did not cause any problems. The mothers explained that young children consume different foods or different amounts of food, which makes feeding them separately acceptable, even in the local setting, where a common food bowl is usually shared by the family. Overall, the study participation was a positive experience for the mothers, and the consumption of LNS was perceived as very beneficial for their children. However, some women mentioned that others in the community expressed jealousy because they had not received LNS for their children, and some mothers reported difficulties with feeding LNS exclusively to the study child because of pressure to share the product with other children in the family compound. To facilitate future LNS trials, the mothers suggested to involve influential persons in the villages more intensely and to inform the whole family about the purpose, benefits and the need for age-targeting of LNS.

Discussion and conclusions

The LNS products were well appreciated by the mothers, both during the sensory trials and during the 2-week feeding trial. None of the sensory tests identified a significant difference in amounts consumed by children or the degree of liking reported by mothers and in reference to their children. Thus, the LNS with and without added zinc appeared to be equally acceptable to young Burkinabe children.

The amounts consumed of the two LNS formulations were not significantly different. Overall, the product containing 10 mg zinc was consumed in slightly larger amounts. If there would have been a negative organoleptic effect of the added zinc, we would have expected the children to consume less of LNS-Zn-10. Thus, we believe that the small observed differences in consumed amounts and feeding duration are of no practical importance and that the products were both well accepted. Only the velocity of food intake was significantly different between the two products when pooled over the 2 test days. On average, children consumed about 1 g min^{-1} less of product LNS-Zn-0. This finding was mainly due to the results of day 3, as on day 2, children tended to consume the other product (LNS-Zn-10) less quickly. Because none of the other sensory tests found a significant difference between the two products, the significant difference in food intake velocity is not considered to be important with regard to the acceptability of the LNS products, as the velocity was likely influenced by factors other then the zinc content of the product. The results of the triangle test with mothers confirmed that there was no detectable difference between products containing 0 or 10 mg zinc per 20 g LNS dose.

Most importantly, the 2-week feeding trial revealed that mothers generally appreciated feeding LNS to their child at home. Most women reported that they followed the instructions provided, namely to feed LNS to the child twice per day mixed with either porridge or other foods, such as rice. Whether that is true or whether the mothers aimed to please the study team is difficult to assess because we were not able to complete observations in the home. Moreover, it is uncertain whether appreciation and feeding practices change when these products are available for a longer time period.

Although we tried to assess possible perceived adverse effects of LNS consumption, it is difficult to draw specific conclusions. Although ~15% of the mothers reported that their child had difficulties after consumption of LNS, they listed illnesses, such as cough, fever, and malaria, which are highly unlikely to be associated with LNS. Whether the mothers truly thought the illnesses were related to LNS was not appropriately assessed with the data collection tools used during the weekly household visits. The issue of perceived adverse effects needs to be explored in more depth to help with future social marketing of the product. During the focus group discussion, very few mothers spoke of digestion or health problems related to LNS. Moreover, the mothers' degree of liking was either 'like it a lot' (95.8%) or 'like it' (4.2%), which indicates that the experience with feeding LNS was positive overall. It can be assumed that if the mothers had perceived any adverse effects due to the products, their preference would have been substantially reduced. One concern raised by several women was related to the age-targeting of the LNS product. The mothers reported having difficulties with the instructions to feed LNS only to the study child. The main concern raised was peer pressure from other family members to share the product with other children in the family compound.

One of the weaknesses of the feeding trial study design was that LNS was mixed in a large portion of porridge (150 g wet weight). The reasoning at the time was that the portion should be sufficiently large so that not all children would be able to finish the quantity offered, which would more likely allow the detection of any potential differences between products. This feeding style, however, is in contrast to the feeding instructions generally given with POUF, where mothers are instructed to mix LNS in a small portion of food to ensure that the child consumes the complete daily dose and to continue feeding additional food without LNS until satiety is reached. Whether we would have come to different conclusions if we would have mixed LNS in a smaller portion of millet porridge remains uncertain. However, such differences seem to be unlikely, as mothers found no significant difference between products during triangle tests where they were served 30 g portions of porridge with 15 g portions of LNS. Moreover, during the 2-week feeding trial mothers were instructed to mix LNS in a small portion and some mothers reported feeding LNS by itself. Thus, the products were tested with these instructions and were reported as highly acceptable. Another weakness of the sensory trial was that mothers and children were invited to the health centres for the feeding trials. Ideally the feeding trial should have been done in children's home as previously done by Bovell-Benjamin *et al*. (1999). It is possible that children's consumption was influenced by the new environment and presence of the study staff. Because observed feeding tests at home were logistically difficult in rural Burkina Faso, the 2-week feeding trial was included as part of the acceptability assessment to evaluate mother's experiences at home.

Millet is the most commonly used cereal to prepare porridges for young children in the study area of Burkina Faso. Nevertheless, some mothers also reported that they fed LNS mixed in other foods, such as rice. Similarly, LNS products were well accepted when mixed in local maize porridges in Malawi (Phuka *et al*., unpublished data) and in Ghana (Adu-Afarwuah *et al*. 2010). Based on these reported results, it can be assumed that the tested LNS products would have been equally accepted when mixed in porridges made of other cereals. The findings of the present acceptability tests indicated that the addition of 10 mg of zinc per 20 g LNS dose is not detectable by mothers and children. The high acceptability of the tested products and the high stunting rates in children in western Burkina Faso confirm the need to assess the impact of zinc-containing LNS on children's growth and overall health.

Acknowledgements

We greatly appreciate Rosemonde Guissou (Institute de Recherche en Sciences de la Santé, Bobo-Dioulasso, Burkina Faso) and Shelby E. Wilson (University of California Davis, USA) for assisting with the study preparations, Roger Zerbo (Institute de Recherche en Sciences de la Santé, Bobo-Dioulasso, Burkina Faso) for facilitating the focus group discussions and Janet M. Peerson (University of California Davis, USA) for statistical advice. We further appreciate valuable comments on the manuscript provided by Kathryn G. Dewey and Mary Arimond (University of California Davis, USA).

Source of funding

The project was funded by a grant from the Bill & Melinda Gates Foundation to the University of California, Davis.

Conflicts of interest

SYH, LB, GJA, JBO, KHB have no conflicts of interest. MZ is employed by Nutriset SAS, which is the manufacturer of the LNS products that were tested.

Contributions

The authors' responsibilities were as follows – SYH, KHB, GJA: designed research; MZ developed the test products; LB, SYH, JBO, KHB: conducted research; GJA, SYH, LB, KHB: analysed data; SYH: prepared manuscript; all authors reviewed the manuscript; SYH: primary responsibility for final content.

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