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Acceptability of locally-produced Ready-to-Use Supplementary Food (RUSF) for children under two years in Cambodia: A cluster randomised trial

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Abstract

In Cambodia, existing food products for treating or preventing undernutrition have met with limited success. Therefore, in 2014, alternative ready-to-use foods were developed. This trial aimed to assess the acceptability of the novel ready-to-use supplementary food (RUSF) as a snack or mixed with *borbor* (white rice porridge), compared with corn–soy blend plus plus (CSB++) and *borbor* fortified with micronutrient powder (MNP). The nonblinded, randomised 4 × 4 crossover trial recruited 95 children aged 9–23 months from communities in peri-urban Phnom Penh. Small quantities (100 g for porridges, 42 g for snack) of each food were offered for three consecutive days at testing sites (homes of health volunteers). Main outcomes were children's consumption, caregivers' assessment of children's preferences, and caregivers' ranking of the foods. Median percentage consumed of the test food servings ranged from 21 to 50% (p = 0.003). The odds of children consuming over 50% were greatest for *borbor* fortified with MNP versus RUSF snack (unadjusted OR = 6.79, CI = 2.80–16.47, p < 0.001). However, the median energy children received when consuming the RUSF with *borbor* (57 kcals) or as a snack (48 kcals) was greater than with CSB++ (15 kcals) or *borbor* fortified with MNP (18 kcals; p < 0.001). Therefore, although children ate less RUSF, it provided approximately three times more kilocalories. Caregivers reported that their children had the highest preference for *borbor* fortified with MNP. Caregivers themselves ranked the novel RUSF snack highest. Thus, the innovative RUSF was considered sufficiently acceptable to proceed to an effectiveness trial.

KEYWORDS

Acceptability, Corn Soy Blend Plus (CSB++), Lipid-based nutrient supplement (LNS), Ready-to-use supplementary food (RUSF), Sprinkles micronutrient powders, Test feeding

1 | INTRODUCTION

Although Cambodia is transitioning to a middle-income country, progress in combatting undernutrition has slowed. In 2014, 32% of children under 5 years were stunted, 10% were wasted, and 24% were underweight (National Institute of Statistics, 2015). Undernutrition can be partly attributed to poor complementary feeding. The energy and nutrient density of traditional complementary foods, particularly *borbor* (white rice porridge, the traditional weaning food in Cambodia), is too low to sustain the high growth velocity during the first 2 years of life.

The various supplements and supplementary or therapeutic foods that have been used or tested in Cambodia have met with low levels of acceptability and success, in trial or in practice. In 2009, Plumpy'Nut® was trialled in Cambodia and was poorly accepted (Boudier, 2009), as was the case elsewhere in the region (Nga et al., 2013). The United Nations World Food Programme (WFP) had found corn–soy blend plus plus (CSB++, also known as Supercereal Plus) less acceptable and effective than expected (WFP, 2014a). Anecdotally, BP-100™, the therapeutic food that was used to treat severe acute malnutrition had also had limited acceptability (Wieringa, 2014). The limited acceptability of CSB++ and BP-100™ was confirmed in a taste trial (Ketsana, 2013). Meanwhile, the Vietnamese National Institute of Nutrition, with UNICEF and the French National Research Institute for Sustainable Development (IRD), had developed a ready-to-use food (RUF) called (RUF) called HEBI (High Energy Bar for IMAM – Integrated Management of Acute Malnutrition) in 2009 (Nga et al., 2013). HEBI was locally produced with rice, soy, mungbeans, and imported milk powder. It resembled the popular Vietnamese delicacy, "mooncake." It proved more acceptable than, and as effective as, Plumpy'Nut® and is now widely and successfully used in Vietnam's Integrated Management of Acute Malnutrition programming (Peters, 2014; Phuong et al., 2014). Based on the low acceptability and effectiveness of these imported products, it was determined that a local product was needed.

At the behest of the Ministry of Health (MoH), UNICEF, IRD and the Cambodian Department of Fisheries Post-harvest Technologies and Quality began collaborating on the development of a locally produced, culturally acceptable, multiple micronutrient-fortified RUF, in therapeutic and supplementary versions. The resulting product is unique in that it is one of the few RUFs using an animal source food other than milk. Milk powder, an expensive, imported ingredient, has been replaced with small freshwater fish. The latter are inexpensive, readily available and more adapted to local tastes, since Cambodians are the world's largest consumers of freshwater fish (Vilain, Baran, Gallego, & Samadee, 2016). Combined with rice, soy, mungbeans, oil, and sugar, this novel RUF should be less expensive and more acceptable to Cambodians. This trial tested the acceptability of the ready-to-use supplementary food (RUSF), whereas a separate trial tested the acceptability of the ready-to-use therapeutic version of the food with severely acutely malnourished children (Sigh et al., 2018).

Key messages

- Fish is a an organoleptically promising substitute for milk in a locally produced Cambodian ready-to-use supplementary food (RUSF).
- Even consumed in smaller quantities, the novel RUSF provided more energy than existing options.
- The novel RUSF snack was far more acceptable to caregivers than the existing supplementary food and supplements used in Cambodia.

1.1 | The role of RUSFs

It is widely accepted that specialised fortified products have a place in supplementing the traditional diet, thereby preventing growth faltering amongst children (S. de Pee, 2015; S. de Pee, Bloem, MW, 2009; Dewey & Young Child Nutrition Working Group: Formulation, 2009; Golden, 2009; Michaelsen, Grummer-Strawn, & Begin, Michaelsen, Grummer-Strawn, & Begin, 2017). RUFs that are formulated as lipid-based nutrient supplements (LNSs) are particularly promising, as they have a long shelf life and require no preparation (S. de Pee, Bloem, MW, 2009; S. de Pee, Manary, Mark, Ashorn, Per, de Pee, Manary, & Ashorn, 2011). There is an acknowledged need for the development of novel RUFs and their comparison with existing products (S. de Pee, Bloem, MW, 2009; Kuusipalo, Maleta, Briend, Manary, & Ashorn, 2006; Lazzerini, 2013; Manary, 2006; WHO, 2013). In the past decade, numerous studies have aimed to contribute to an understanding of the use of locally produced specialised foods (Ackatia-Armah et al., 2015; Ahmed et al., 2014; Anderson, Bediako-Amoa, & Steiner-Asiedu, Anderson, Bediako-Amoa, & Steiner-Asiedu, 2014; Arimond et al., 2015; Bauserman et al., 2015; Bogard et al., 2015; Flax et al., 2009; Hy Ta & Martinaud, 2014; Iuel-Brockdorf et al., 2015; Lagrone, Cole, Schondelmeyer, Maleta, & Manary, 2010; Lagrone et al., 2012; Skau et al., 2015; Weber et al., 2017).

Regardless of how effective a product may be, it must be acceptable in a given setting if it is to deliver nutritional benefits (Dibari et al., 2013; Iuel-Brockdorf et al., 2016). Because most research on supplementary foods is from Africa, this study is an important contribution to the body of evidence on food preferences from Asia (Lazzerini, 2013). As an early step in the product development and testing, we conducted an acceptability trial on the fish-based RUSF, to test whether the new product was acceptable to children and their caregivers. The RUSF was compared with products that are currently used to improve the nutritional status of young children, namely CSB++ and a MNP (Sprinkles), which are used as a home fortificant. Acceptability was assessed in terms of children's consumption (in percentage of the serving and calories consumed), caregivers' assessment of children's preferences, and caregivers' own ranking of the foods.

2 | METHODS

This trial aimed to establish the acceptability of the locally produced Cambodian RUSF for children under 2 years and their caregivers, with a view to proceeding to an effectiveness trial. The methods have been described in the protocol published previously (Borg et al., 2017).

2.1 | Trial design

The study was a cluster randomised, 4 × 4 crossover design comparing four food types. Each child tested each of the four foods. This was an open study with no blinding, since the four foods were visibly different to participants, data collectors, and the principal investigator (who was present during data collection).

TABLE 1 Energy and nutrient profile and characteristics of novel RUSF and comparators

	RUSF	CSB++	MNP
Recommended daily serving size	40–110 g depending on age of child	100 g dry CSB++ (made into porridge with added water)[a]	1 sachet (1 g)
Main ingredients of supplementary foods and supplements, not including *borbor* (g/100 g)[b]			
Ingredients	Rice 13.2 Soy and mungbeans 21.8 Fish 5.9 Sugar 26.8 Oil/shortening 18.1 Micronutrient mix 0.9 Coconut 8.7 Rice bran 2.2 Egg 2.5 Flavouring 0.1	Corn 58.3 Soy beans 20.0 Skim milk powder 8.0 Sugar 9.0 Oil/shortening 3.0 Micronutrient mix 0.2 Dicalcium phosphate anhydrous 1.23 Potassium chloride 0.27	Micronutrients only
Nutrient profile per 100 g of product (Dry CSB++)[b]			
Energy (kcal/100 g)	484	410	
Protein (g/100 g)	13.1	16	
Carbohydrates (g/100 g)	51.6		
Lipids (g/100 g)	24.4	9	
Fibre (g/100 g)	1.6	3	
Added multiple micronutrients per 100 g (dry for CSB++)[b]			
Vitamin A	1,080 μg	540 μg	400 μg
Vitamin D	58.4 μg	4.6 μg	5 μg
Vitamin B1 (thiamine)	0.28 mg	0.47 mg	0.5 mg
Vitamin B2 (riboflavin)	0.78 mg	0.84 mg	0.5 mg
Vitamin B6	0.65 mg	2.1 mg	0.5 mg
Phosphorus	246 mg	530 mg	-
Calcium	302 mg	260 mg	-
Pantothenic acid	0.75 mg	7.3 mg	-
Copper	0.75 mg	-	0.56 mg
Vitamin E	10.7 mg	9.8 mg	5 mg
Folic acid	94.2 μg	115 μg	150 μg
Iron	6.0 mg	8.9 mg	10 mg
Magnesium	48.4 mg		-
Vitamin B3 (niacin)	7.3 mg	7.2 mg	6 mg
Vitamin C	52.8 mg	100 mg	30 mg
Zinc	7.5 mg	7.5 mg	4.1 mg
Potassium	194.8 mg	990 mg	-
Vitamin B12	10.7 μg	2.3 μg	0.9 μg
Biotin	105.6 μg	-	-
Selenium	89 μg	-	17 μg
Iodine	-	60 mg	90 μg
Vitamin K	-	115 μg	-
Other characteristics/considerations			
Taste	Fishy	Creamy, sweet (Skau et al., 2012)	Should not have a taste (Salam et al., 2013)
Preparation	Ready to use	10 min cooking	Add to cooked food
Acceptability in Cambodia	To be tested	Acceptable in trial (Skau et al., 2012), but not in practice (WFP, 2014a)	Yes (Jack et al., 2012)
Effectiveness in reducing malnutrition	To be tested	Not inferior to peanut-based RUSFs, which are the most effective in promoting linear growth and weight gain (LaGrone et al., 2012; Manary & Yang, 2012)	Improves micronutrient status but not linear growth or weight gain (de Pee & Bloem, 2009; Dewey & Adu-Afarwuah, 2008; Jack et al., 2012)

(Continues)

TABLE 1 (Continued)

	RUSF	CSB++	MNP
Intra-household sharing	Unknown	Yes (LaGrone et al., 2012)	None noted (Jack et al., 2012)
Packaging	Unknown	Packaging may encourage sharing (de Pee & Bloem, 2009; Nackers et al., 2010)	Looks like "medicine," thus may discourage sharing (de Pee & Bloem, 2009; Nackers et al., 2010)
Local production capacity	Unknown	None (de Pee & Bloem, 2009)	None
Cost	To be determined. Goal is <US$0.10/day	Less expensive than peanut-based RUSFs if produced locally (Manary & Young, 2012), but also have to consider logistics, time to treat, and relapse (Nackers et al., 2010)	Very cheap to produce at US$0.025/daily dose (Zlotkin, 2009), but also have to consider logistics

Nutrient profile of daily serving in acceptability trial[abc]	**RUSF with *borbor***	**CSB++ porridge**	***Borbor* with MNP**	**RUSF snack**
Serving size of test meal	42 g RUSF +60 g *borbor*	100 g (17% dry CSB++)	1 sachet (1 g) + 99 g *borbor*	42 g RUSF
Energy (kcal/serving)	184	70	41	160
Protein (g/100 g)	5.9	2.7	1.1	5.2
Carbohydrates (g/100 g)	23.4	12.1	15.7	14.0
Lipids (g/100 g)	9.1	1.5	0.1	9.0
Fibre (g/100 g)	0.6	0.5	0.1	0.5

Note. CSB++: corn–soy blend plus plus; MNP: micronutrient powder; RUSF: ready-to-use supplementary food.

[a]World Food Programme (2014b).

[b]Manufacturers.

[c]2007 Vietnamese food composition tables.

2.2 | Comparators—The four foods

The first version of the novel RUF was developed in 2014 (Peters, 2014) by a local, quality-certified food factory, Vissot, which produced the food using readily available Cambodian ingredients—rice, freshwater fish, soy, and mungbeans—as well as oil, sugar, and micronutrient premix. Based on initial acceptability testing, the product was refined to improve the smell and form. Snack consumption, even amongst young children, is common in Cambodia (Pries et al., 2016; WFP, 2014b; World Vision, 2015). Therefore, to improve the likelihood of acceptability (Nga et al., 2013), we took a Cambodian snack, a wafer approximately 9 cm long with an internal diameter of 0.5 cm, and filled it with the RUF paste.

The RUSF was compared with other supplementary foods or supplements, which have been used in Cambodia. The first was CSB++, which is the United Nations World Food Programme's standard supplementary food to prevent undernutrition in children aged 6–23 months. The second was MNPs, supplements that have been promoted and distributed by the MoH to improve the micronutrient status of children aged 6–23 months. The novel RUSF was served in two different ways—as a snack or mixed with *borbor*. One objective was to ascertain which way of serving was more acceptable. The characteristics of each food, including energy and nutrient profile, and a description of the test food serving, are described in Table 1.

2.3 | Study site, subjects, and sample size

The study took place over 2 weeks in June–July 2015 in four test-feeding sites selected for convenience in peri-urban Phnom Penh (see Figure 1). Sites were the homes of health volunteers who invited caregivers and children from the community to participate.

Our protocol defined acceptability as a mean consumption of at least 50% of the test food serving. Thus, our sample size was calculated based on the main outcome, consumption of more than 50% of the serving. Based on a recent similar study in Cambodia (Skau, Sok, & Wieringa, 2012), we assumed an *SD* of 30%, and aimed to detect a difference in consumption of 20%. To ensure a precision of 0.05, power of 0.8, and $p < 0.05$, the required sample size was 44 children, or 53 children if we assumed 20% attrition. A typical commercial hedonic test sample is 75–150 consumers (Stone, Bleibaum, & Thomas, 2012), and recent crossover trials of acceptability had samples of 50–100 children (Anderson et al., 2014; Konyole et al., 2012; Nga et al., 2013; Skau et al., 2012; Weber et al., 2017). Therefore, we aimed to recruit 100 caregiver-child pairs, and ultimately recruited 95.

Only healthy singletons aged 9–23 months who were not severely acutely malnourished (mid-upper arm circumference (MUAC) greater than 115 mm, weight-for-height z-score, (WHZ) greater than −3) and with no known food intolerances who had been eating solids for at least 3 months were included. Thus, subjects were less likely to reject the food simply because they were not yet familiar with solids, or because they were experiencing any lack of appetite due to illness or undernutrition.

The four sites were randomly allocated to begin on one of the foods using an Excel random number table generated by the principal researcher. Thus, children were not individually randomised to a food, and all children at a given site were eating the same food over the same period. This reduced bias related to social interaction and varied responses to different foods. Each site tasted each food in a different

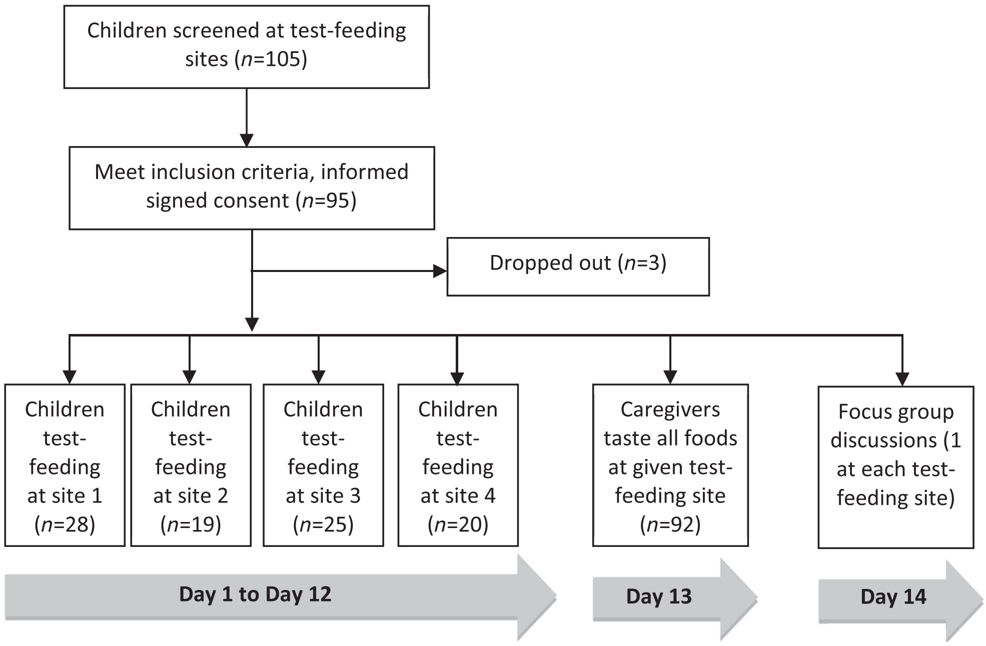

FIGURE 1 Enrolment in acceptability trial

sequence to balance for carry-over effects, as in Supplementary Figure 1.

Following recruitment, caregivers were asked to bring their child to their designated test-feeding site for the next 12 days. Children and caregivers came at the same time each day (either at 8 a.m. or 10 a.m.), which reduced bias related to feeding times. They were asked not to feed their child for the preceding hour, if possible. All children at a given site ate the same food for three consecutive days to allow averaging of results and to reduce the effect of chance findings.

2.4 | Children's consumption and caregiver assessment of acceptability

The health volunteers had been trained to prepare the *borbor* and the CSB++ porridges according to instructions to ensure consistency. They prepared the porridges in their homes, just before the children and caregivers arrived. The prepared food was served in small bowls (labelled with the child's code). Each bowl contained 100 ± 1 g of CSB++ porridge (17% dry CSB++ with water added), RUSF (two pieces weighing approximately 22 g per piece, or ~42 g total) added to *borbor (~58 g)*, or MNP (1 g sachet) added to *borbor (99 g)*. When served as a snack, the two pieces of RUSF weighed approximately 42 g.

The bowl, spoon, napkins, and food were weighed on an electronic kitchen scale to the nearest 0.1 g. The test food was added (100 g of the porridges, or two pieces of the snack) and the weight was recorded. Caregivers were asked to feed their child for 15–30 minutes or until the child refused to eat any more. After the child has finished eating, the bowl with remaining food, spoon, and tissues (used to clean the child's mouth and catch spits and spills) were weighed to the nearest 0.1 g. The difference gave the number of grammes consumed.

During statistical analysis, the consumption in grammes was converted to the percentage of serving consumed, in order to be able to compare the servings of the different foods, which were of different initial weights. The kilocalories consumed per serving were calculated using information provided by the manufacturer and the 2007 Vietnamese food composition tables.

After 3 days eating the same food, caregivers were asked to assess how they thought the child liked the food, taking into account the amount eaten and the child's reactions and emotional state during feeding. This subjective caregiver assessment of child preference is considered an appropriate method of determining acceptability of a food to a young child (Pachón et al., 2007). Responses were recorded using a five-point hedonic scale (1 [*Disliked a lot*], 2 [*Disliked a little*], 3 [*Neither liked nor disliked*], 4 [*Liked a little*], and 5 [*Liked a lot*]), a standard tool for measuring food acceptability (Stone et al., 2012). A score of 3 or more was considered acceptance of the food.

2.5 | Caregivers' ranking and focus group discussions

On the 13th day, the caregivers were asked to rank all four foods (1 [*best*], 2 [*second best*], 3 [*third best*], and 4 [*least good or worst*]) based on their own perception of each product. On the 14th day, four focus group discussions (FGDs) were conducted (one at each feeding site) with a smaller number of caregivers (usually 8–12). Discussions were led in Khmer language by a Cambodian facilitator. A Cambodian notetaker made a written and audio record, which was transcribed and translated into English.

2.6 | Outcomes

The main outcome of interest was how much the children consumed of each test food. In the absence of clear guidelines on acceptability for supplementary food, our protocol defined acceptability as mean consumption of at least 50% of the food offered. Because

TABLE 2 Baseline characteristics of enrolled children

Characteristic at baseline	Total N = 92[a]	Site 1 n = 28[a]	Site 2 n = 19[a]	Site 3 n = 23[a]	Site 4 n = 20[a]	P value
Sex (N = 90[a])						
Female, n (%; 95% CI)	48 (53.3%; 43.1–63.5)	16 (57.1%; 47.0–67.2)	10 (52.6%; 42.4–62.8)	13 (56.5%; 46.4–66.6)	9 (45.0%; 34.8–55.2)	0.845
Age in months, mean and SD	15.4 ± 4.6	15.2 ± 5.0	13.9 ± 2.7	16.3 ± 5.1	15.9 ± 4.8	0.370
Anthropometry						
WAZ (N = 90[a]), mean and SD	−1.1 ± 1.1	−1.1 ± 1.1	−1.1 ± 1.3	−0.8 ± 1.1	−1.4 ± 0.6	0.350
HAZ (N = 90[a]), mean and SD	−0.9 ± 1.4	−0.9 ± 1.5	−1.0 ± 1.2	−0.5 ± 1.6	−1.3 ± 1.4	0.309
WHZ (N = 90[a]), mean and SD	−0.8 ± 1.0	−0.9 ± 0.9	−0.8 ± 1.3	−0.7 ± 1.0	−1.0 ± 0.6	0.843
MUAC, cm (N = 91[a]), mean and SD	14.1 ± 1.0	14.0 ± 1.0	13.9 ± 1.5	14.5 ± 0.8	14.1 ± 0.6	0.294
Breastfeeding status (N = 90[a])						
None, n (%; 95% CI)	55 (61.1%; 51.0–71.2)	18 (64.3%; 54.4–74.2)	12 (63.2%; 53.2–73.2)	16 (69.6%; 60.1–79.1)	9 (45.0%;34.7–55.3)	0.387
Some, n (%; 95% CI)	35 (38.9%; 28.8–49.0)	10 (35.7%; 25.8–45.6)	7 (36.8%; 26.8–46.8)	7 (30.4%; 20.9–39.9)	11 (55.0%; 44.7–65.3)	0.387
Age starting complementary feeding (N = 87[a])						
<6 months, n (%; 95% CI)	26 (29.9%; 20.3–39.5)	11 (40.7%; 30.4–51.0)	5 (26.3%; 17.1–35.6)	4 (19.0%; 10.8–27.4)	6 (30.0%; 20.4–39.6)	0.422
≥6 months, n (%; 95% CI)	61 (70.1%; 60.5–79.7)	16 (59.3%; 49.0–69.6)	14 (73.7%; 64.5–83.0)	17 (81.0%; 72.8–89.2)	14 (70.0%; 60.4–79.6)	0.422
Prior use of supplements or supplementary foods (N = 88[a])						
No, n (%; 95% CI)	77 (87.5%; 80.6–94.4)	22 (78.6%; 70.0–87.2)	18 (94.7%; 90.0–99.4)	18 (81.8%; 73.7–89.9)	19 (100.0%; 100–100)	0.097
Yes, n (%; 95% CI)	11 (12.5%; 5.6–19.4)	6 (21.4%; 12.8–30.0)	1 (5.3%; 0.62–10.0)	4 (18.2%; 10.1–26.3)	0 (0.0%; 0.0–0.0)	0.097

HAZ: height-for-age z-score; MUAC: mid-upper arm circumference; WAZ: weight-for-age z-score.

[a]Of the 92 children that completed the study, a small number had incomplete data or responded “don't know” for some variables. P values were computed by comparing sites. For continuous variables (reported as mean and SD), comparison between food types was made using one-way analysis of variance. For categorical variables, (reported as n and %) comparison was made using chi-squared test.

consumption was not normally distributed, it was recoded as low or high acceptability (less than or more than 50%, respectively) for the mixed-effects logistic regression. The secondary outcomes were caregivers' assessment of their child's preference for each food, caregivers' ranking of each food, and mean kilocalorie intake. Caregivers were asked to assess their child's preferences for different foods on a scale of 1 (*disliked a lot*) to 5 (*liked a lot*). Preferences were then recoded as low (1,2) or high (3-5), for the mixed effects logistic regression. Caregivers were asked to rank the foods according to their own preference from 1 (*liked most*) to 4 (*liked least*). Caregiver rankings were then recoded as a high (1,2) or low (3,4) for the mixed effects logistic regression. Because a measure of consumption in grammes or percentage of serving does not take into account the nutrient density of the different foods, we also calculated kilocalorie intake.

2.7 | Covariates

Data was collected on the following covariates, which were screened for inclusion in the analytical models: sex and age of the child; previous use of supplements and supplementary foods such as CSB++ or MNP; breastfeeding status (still breastfeeding or not); age at which complementary feeding was started (before or after 6 months); anthropometric measures at baseline, ie, weight-for-age z-score, height-for-age z-score, WHZ, and mid-upper arm circumference; the child's illness; and the child's last breastfeeding/eating (less or more than an hour before the consumption test).

2.7.1 | Statistical analysis

All data were double-entered in Excel and analysed in the statistical software STATA version 13.1. Outcome variables were recoded to categorical, binary variables to deal with non-normality and/or for easier interpretation. Mean and median consumption (grammes, percentage of serving, and kilocalories) were analysed. For all outcomes, initial univariate screening of covariates was conducted at $p \leq 0.2$ level using simple logistic regression, and collinearity assumptions were checked, in order to determine which covariates to include in the model. A complete mixed effects logistic regression was then fitted to the data. Manual, thematic analysis was used to analyse the FGDs.

2.7.2 | Ethical approval and trial registration

Ethical clearance was received from the University of Queensland Medical Research Ethics Committee (2014001070) and from Cambodia's National Ethics Committee for Health Research (03/8 NECHR). Written informed consent was obtained from all the caregivers before recruitment. The trial was registered at ClinicalTrials.Gov (identifier: LNS-CAMBINFANTS; NCT02257437).

3 | RESULTS

3.1 | Baseline characteristics

Of 105 children presenting, 95 were recruited. One child was excluded and referred for treatment because of severe acute malnutrition (WHZ < −3). Nine children were excluded because they were less than 9 months or more than 2 years of age. Ninety-two children completed the study. The caregivers of the three children who dropped out said they were too busy to attend daily for 2 weeks, despite having been informed of the study duration at recruitment. The baseline characteristics are presented in Table 2. There were slightly more female than male children, and the average age was 15.4 months. There were no significant differences in the anthropometric measures or feeding indicators across the four sites.

3.2 | Children's consumption of foods

Consumption was non-normally distributed, therefore only median consumption is shown in Table 3. Grammes consumed are provided for information but cannot be compared, as serving sizes differed. Children had the highest median consumption of *borbor* fortified with MNP at 50.4% (IQR = 24.2–84.5) and the lowest of the CSB++ at 21.3% (IQR = 7.8–67.4). The difference in the proportion of test foods consumed was statistically significant ($p = 0.003$). Kilocalorie intake showed a slightly different picture, with median kilocalorie intake lowest for CSB++ and *borbor* fortified with MNP at 14.9 kcals (IQR = 5.4–47.2) and 18.2 kcals (IQR = 8.7–30.4), respectively. Kilocalorie intake was highest for the RUSF with *borbor* or as a snack at 56.9 kcals (IQR = 21.5–117.5) and 48.1 kcals (IQR = 26.8–79.6), respectively. The difference in the kilocalories consumed for each test food was statistically significant ($p < 0.001$).

TABLE 3 Consumption in terms of median grammes, percentage, and kilocalories consumed per serving

Food consumed (serving size, kcals/serving)	Grammes consumed median (IQR)	% serving consumed median (IQR)	Kilocalories consumed median (IQR)
Borbor with MNP (100 g, 41 kcals/serving)	50.4 (24.2–84.5)	50.4 (24.2–84.5)	18.2 (8.7–30.4)
RUSF with *borbor* (100 g, 184 kcals/serving)	30.9 (11.7–63.9)	30.9 (11.7–63.9)	56.9 (21.5–117.5)
CSB++ (100 g, 70 kcals/serving)	21.3 (7.8–67.4)	21.3 (7.8–67.4)	14.9 (5.4–47.2)
RUSF snack (42 g, 160 kcals/serving)	12.6 (7.0–20.9)	30.1 (16.7–49.2)	48.1 (26.8–79.6)
P values		0.003*	<0.001**

Note. CSB++: corn–soy blend plus plus; MNP: micronutrient powder; RUSF: ready-to-use supplementary food. *P* values computed using Kruskal–Wallis test. No *p* value shown for grammes consumed because test foods were different serving sizes. Asterisks highlight significant *p* values.

*$p < 0.01$. **$p < 0.001$.

The odds of children consuming more than 50% of the test foods are presented in Table 4. The unadjusted odds of children consuming more than 50% of *borbor* fortified with MNP were higher than the odds of them consuming more than 50% of RUSF snack, RUSF with *borbor* or CSB++ (OR = 6.79; 95% CI = 2.80–16.47; p < 0.001; OR = 3.91; 95% CI = 1.71–8.96; p = 0.001; OR = 3.59; 95% CI = 1.58–8.16; p = 0.002, respectively). The odds of children consuming more than 50% of RUSF snack compared with the odds of them consuming more than 50% of CSB++, and the odds of children consuming more than 50% of RUSF with *borbor* in comparison with the odds of them consuming more than 50% of RUSF snack or CSB++ were not statistically significant.

The results for the adjusted model were very similar, with the odds of children consuming more than 50% of *borbor* fortified with MNP being higher than the odds of them consuming more than 50% of any of the other foods. The only predictor variable that was statistically significant was sex. Girls had much lower odds than boys of eating 50% or more of any food (OR = 0.27; 95% CI = 0.09–0.85; p = 0.25). None of the other covariates that were adjusted for in the model made a statistically significant difference to the odds of eating 50% or more of any food.

3.3 | Caregiver assessment of child preference for foods

Table 4 shows that the unadjusted odds that caregivers reported that their children had a high preference for *borbor* fortified with MNP was almost three times the odds of them reporting that their children had a high preference for RUSF with *borbor* or CSB++ (OR = 2.99; 95% CI = 1.42–6.28; p = 0.004; and OR = 2.92; 95% CI = 1.40–6.08; p = 0.004, respectively). The odds that caregivers reported that their children had a high preference for the RUSF snack were twice the odds of them reporting a high preference for RUSF with *borbor* or CSB++ (OR = 2.19; 95% CI = 1.07–4.48; p = 0.033; and OR = 2.13; 95% CI = 1.05–4.34; p = 0.037, respectively). The results for the adjusted model were fairly similar, although the odds of caregivers reporting that their children had a high preference for the RUSF snack compared with the odds of reporting a high preference for CSB++ were not quite statistically significant. None of the covariates made a statistically significant difference to the odds of caregivers reporting that their children had a high preference for any of the foods. As seen in Table 5, there were significant differences in hedonic ratings of the test foods (p = 0.003). Most caregivers felt that children liked *borbor*

TABLE 4 Odds ratios of children's consumption, caregiver assessment of child preference, and caregiver rankings of foods

	Children's consumption			Caregiver assessment of child preference			Caregiver rankings of foods		
Unadjusted	**OR**	**95% CI**	***P* value**	**OR**	**95% CI**	***P* value**	**OR**	**95% CI**	***P* value**
Borbor-MNP vs. RUSF snack	6.79	2.80–16.47	<0.001***	1.37	0.65-2.88	0.408	0.08[a]	0.04–0.19	<0.001***
Borbor-MNP vs. RUSF-*borbor*	3.91	1.71–8.96	0.001**	2.99	1.42-6.28	0.004**	1.25	0.70-2.23	0.458
Borbor-MNP vs. CSB++	3.59	1.58–8.16	0.002**	2.92	1.40-6.08	0.004**	3.37	1.76-6.46	<0.001***
RUSF snack vs. RUSF-*borbor*	0.58	0.25–1.35	0.202	2.19	1.07–4.48	0.033*	14.92	6.47-34.41	<0.001***
RUSF snack vs. CSB++	0.53	0.23–1.23	0.140	2.13	1.05–4.34	0.037*	40.34	16.67-97.61	<0.001***
RUSF-*borbor* vs. CSB++	0.92	0.41–2.07	0.835	0.98	0.49–1.94	0.942	2.70	1.41–5.20	0.003**
Adjusted									
Borbor-MNP vs. RUSF snack	7.12	2.84–17.84	<0.001***	1.63	0.75-3.53	0.218	0.08	0.04–0.19	<0.001***
Borbor-MNP vs. RUSF-*borbor*	4.27	1.82–10.00	0.001**	3.59	1.65-7.79	0.001**	1.18	0.65-2.13	0.591
Borbor-MNP vs. CSB++	3.40	1.47–7.87	0.004**	3.35	1.56-7.20	0.002**	3.54	1.82-6.88	<0.001***
RUSF snack vs. RUSF-*borbor*	0.60	0.25 1.42	0.245	2.21	1.06–4.60	0.035*	14.20	6.13 – 32.88	<0.001***
RUSF snack vs. CSB++	0.48	0.20–1.14	0.096	2.06	0.99–4.27	0.052	42.65	17.38–104.65	<0.001***
RUSF-*borbor* vs. CSB++	0.80	0.35–1.82	0.591	0.93	0.46–1.89	0.849	3.00	1.54–5.86	0.001**
Adjusted for									
Sex	0.27	0.09–0.85	0.025*	0.99	0.46-2.13	0.970	0.99	0.60–1.61	0.952
Age	1.02	0.90–1.15	0.785	0.96	0.88–1.05	0.377	0.99	0.94–1.05	0.822
Mid-upper arm circumference (MUAC)	0.58	0.31–1.08	0.085	0.88	0.60–1.29	0.523	1.01	0.79–1.29	0.914
Illness	1.50	0.57–3.94	0.413	0.90	0.41–2.01	0.803	0.75	0.39–1.43	0.384
Last eating/breastfeeding before test (<1 hr ago)	0.51	0.16–1.66	0.266	1.07	0.39–2.91	0.895	1.30	0.59–2.90	0.514
Site									
Site 2	0.51	0.10–2.56	0.416	0.87	0.30–2.54	0.804	1.04	0.51–2.11	0.910
Site 3	1.12	0.25–4.97	0.878	2.73	0.94–7.92	0.065	1.03	0.53–2.00	0.942
Site 4	1.11	0.25–5.00	0.892	2.37	0.79–7.08	0.122	1.05	0.52–2.10	0.893

Note. CSB++: corn–soy blend plus plus; MNP: micronutrient powder; RUSF: ready-to-use supplementary food.

[a]Expressed as RUSF snack versus *borbor*-MNP, OR = 11.97, 95% CI = 5.20–27.52, p < 0.001. Unadjusted and adjusted mixed-effects regression models were fit for the primary outcome (consumption) and the secondary outcomes (caregiver assessment of child preference and caregiver rankings of foods). Asterisks highlight significant p values.

*p < 0.05. **p < 0.01. ***p < 0.001.

TABLE 5 Caregiver assessment of child preference and caregiver rankings of test foods

Caregiver assessment of child preference for test foods	*Borbor*-MNP $n = 90$[a]	RUSF-*borbor* $n = 87$[a]	CSB++ $n = 91$[a]	RUSF snack $n = 90$[a]
(1) Disliked a lot, *n* (%)	15 (16.7%)	18 (20.7%)	24 (26.4%)	9 (10.0%)
(2) Disliked a little, *n* (%)	6 (6.7%)	21 (24.1%)	16 (17.6%)	19 (21.1%)
(3) Neither liked nor disliked, *n* (%)	14 (15.6%)	12 (13.8%)	13 (14.3%)	19 (21.1%)
(4) Liked a little, *n* (%)	28 (31.1%)	22 (25.3%)	16 (17.6%)	30 (33.3%)
(5) Liked a lot, *n* (%)	27 (30.0%)	14 (16.1%)	22 (24.2%)	13 (14.4%)
*p = 0.003**				
Odds of low (1 + 2) vs high (3 + 4 + 5) ranking	0.30	0.81	0.78	0.45
Caregiver ranking of test foods ($N = 92$[a])	***Borbor*-MNP**	**RUSF-*borbor***	**CSB++**	**RUSF snack**
(1) Like most, *n* (%)	12 (13.0%)	10 (10.9%)	6 (6.5%)	64 (69.6%)
(2) Like 2nd best, *n* (%)	31 (33.7%)	28 (30.4%)	13 (14.1%)	20 (21.7%)
(3) Like 3rd best, *n* (%)	25 (27.2%)	33 (35.9%)	31 (33.7%)	3 (3.3%)
(4) Like least, *n* (%)	24 (26.1%)	21 (22.8%)	42 (45.7%)	5 (5.4%)
*p < 0.001***				
Odds of high (1 + 2) vs. low (3 + 4) ranking	0.88	0.70	0.26	10.49

Note. CSB++: corn–soy blend plus plus; MNP: micronutrient powder; RUSF: ready-to-use supplementary food.

[a]Caregiver assessment of child preference for test foods was conducted every 3rd day. Therefore, n reflects attendance on the given day/s. Caregiver ranking was conducted on day 13, and N reflects attendance on that day. P-values computed using chi-squared. Asterisks highlight significant p-values: *$p < 0.01$. **$p < 0.001$.

fortified with MNP a lot or a little (61.1%) and disliked RUSF with *borbor and* CSB++ a lot or a little (44.8% and 44.0%, respectively). Almost half the caregivers (47.7%) said that their children like the RUSF snack a lot or a little.

3.4 | Caregiver ranking of foods

Table 4 shows that caregivers had far greater odds of giving the novel RUSF snack a high ranking compared to giving CSB++, RUSF with *borbor* (OR = 40.34; 95% CI = 16.67–97.61; $p < 0.001$; and OR = 14.92; 95% CI = 6.47–34.41; $p < 0.001$; respectively) or *borbor* fortified with MNP a high ranking (OR = 11.97; 95% CI = = 5.20–27.52; $p < 0.001$, which is the other way of expressing OR = 0.08, CI = 0.04–0.19, p < 0.001 for *borbor* fortified with MNP versus RUSF snack). Caregivers had slightly greater odds of giving *borbor* fortified with MNP or RUSF with *borbor* a high ranking compared with giving CSB++ a high ranking (OR = 3.37; 95% CI = 1.76–6.46; $p < 0.001$; OR = 2.70; 95% CI = 1.41–5.20; $p = 0.003$). The odds of caregivers giving *borbor* fortified with MNP and RUSF with *borbor* different rankings were not statistically significant. The odds that caregivers gave foods a high ranking were not significantly affected by any predictor variables. As seen in Table 5, there were significant differences in caregivers' rankings of the test foods ($p < 0.001$). The majority of caregivers (69.6%) liked the RUSF snack the most, and almost half (45.7%) liked CSB++ the least.

3.5 | Focus group discussions

The analysis of the FGDs confirms that caregivers liked the CSB++ least, and the RUSF snack best. Generally, caregivers agreed that the taste, smell, colour, and presentation of the snack were acceptable, although a number of caregivers mentioned that the snack had a fishy smell. They liked the wafer, saying that it is familiar, and that their children liked to hold the snack, which then encouraged them to eat more. A number of caregivers mentioned that their children's appetite seemed improved after eating the snack. Some caregivers mentioned that the wafer was thick and the filling got stuck to their children's palate. This led to the reformulation of the snack in a thinner wafer. Many caregivers said that they would consider feeding the snack to their children two or three times a day, citing improved and weight gain as incentives. Others felt their children would get bored with the snack if they ate it so frequently.

4 | DISCUSSION

4.1 | Consumption—Percentage of serving

Children in our trial consumed significantly more *borbor* fortified with MNP in comparison to other foods. This is probably because *borbor* is very familiar, and MNP is not thought to change the taste or smell. In comparison, they did not eat as much of the RUSF snack. This is understandable; even though each food was provided over 3 days to reduce food neophobia, it typically takes repeated exposures to increase acceptance of unfamiliar foods (Gibson & Cooke, 2017; Konyole et al., 2012).

Compared with similar trials, children in our trial consumed a smaller percentage of all food servings (Adu–Afarwuah et al., 2011; Ahmed et al., 2014; Konyole et al., 2012; Nga et al., 2013; Pachón et al., 2007; Phuka et al., 2011; Weber et al., 2017), although a Cambodian trial with fortified blended foods had similar rates of consumption (Skau et al., 2012). Low rates of consumption may be related to laissez-faire feeding styles (Wondafrash, Amsalu, & Woldie, 2012), which are observed in Cambodia, although no literature exists. It may also be related to the unfamiliar environment, as children are likely to eat more during home feeding (Konyole et al., 2012), and to the fact that caregivers did not model consumption of the foods during the test feeding (Blissett & Fogel, 2013; Dovey, Staples, Gibson, & Halford, 2008; Wardle & Cooke, 2008).

4.2 | Consumption—Energy intake

Few acceptability studies have considered energy consumed as an outcome (Ahmed et al., 2014; Dibari et al., 2013), possibly because in most studies, the foods or servings were isocaloric (Adu-Afarwuah et al., 2011; Dibari et al., 2013; Pachón et al., 2007; Weber et al., 2017). The larger portion size required for fortified blends to deliver calorific content has been noted (Iuel-Brockdorf et al., 2015; Nackers et al., 2010). Research on small-quantity LNSs is explicit that, given the small gastric volume of young children, smaller portions of more nutrient dense foods are preferable in order to avoid displacement of breastmilk and local foods that enhance dietary diversity, including animal-source foods, fruits, and vegetables (Arimond et al., 2015; Matsungo, Kruger, Smuts, & Faber, 2017).

Thus, if we take energy consumption into consideration, we note that even the smaller amounts of RUSF snack or RUSF with *borbor* that children consumed, provided about three times more energy than the CSB++ or *borbor* fortified with MNP consumed. This is not surprising, because *borbor* is low in energy and nutrient density, and even CSB++ is high in volume relative to energy and nutrient density. Therefore, even children consuming large amounts of *borbor* fortified with MNP or CSB++ will not consume the quantity of macronutrients (kilocalories, protein, or fat) as children consuming a food that is high in energy and nutrient density, such as our novel RUSF.

4.3 | Caregiver assessment of child preference for foods

It is useful to ascertain caregivers' perceptions of their child's food preference, as has been done in some other studies (Ali et al., 2013; Iuel-Brockdorf et al., 2015; Pachón et al., 2007). Although caregivers assessed that their children liked *borbor* fortified with MNP slightly more than the RUSF snack, they still thought that their children had a fairly high preference for the RUSF snack, especially in comparison with CSB++ and RUSF with *borbor*. However, it is also important to acknowledge that this outcome may not be conclusive, as caregivers may hesitate to express negative opinions (Bauserman et al., 2015; Iuel-Brockdorf et al., 2015).

4.4 | Caregiver ranking of foods

The attitude and practices of caregivers are paramount in determining whether children will ultimately accept a novel food (Konyole et al., 2012). In our study, ranking forced caregivers to make choices, which is more conclusive than preference scales, and may help to mitigate the socially acceptable responding encountered in other studies (Bauserman et al., 2015; Iuel-Brockdorf et al., 2015). Caregivers ranked our novel RUSF snack very highly. The unusually high odds ratio of the caregiver ranking the RUSF snack highly versus ranking CSB++ highly (OR = 40.34, CI = 16.67–97.61, $p < 0.001$) demonstrates how much more caregivers liked the RUSF snack than CSB++. We can therefore expect that they would give the RUSF snack to their children, and in doing so, that their children would come to accept the snack. Moreover, high consumption of fish, soy, and mungbeans in Cambodia, including during pregnancy and lactation, exposes newborns and young children to these flavours via amniotic fluid and breastmilk (Ventura & Worobey, 2013) and may thus predispose children to accepting those flavours in the novel RUSF.

It is also noteworthy for programming purposes that caregivers ranked CSB++ very low. This confirms the field observations that CSB++ had low acceptability (WFP, 2014b).

4.5 | Focus group discussions

The FGDs supported the quantitative findings. As in some other studies, caregivers emphasised the health benefit of the snack (Ashorn et al., 2015; Weber et al., 2017). Interestingly, as in another study, caregivers reported that after eating the RUSF, their children had more appetite for eating other foods offered, which pleased caregivers (Cohuet et al., 2012). As in other studies (Phuka et al., 2011; Segrè et al., 2015; Weber et al., 2017), caregivers stated that they would be willing to pay for the RUSF snack. Caregivers indicated that they would be willing to pay between 300 and 1,000 riel (US$0.07–0.25) for the RUSF, which is similar to what they currently pay for snacks (Pries et al., 2016; World Vision, 2015).

4.6 | Snack or porridge

Despite a Cambodian (indeed global) preference for soft, porridge-like foods for younger children, our study found that caregivers would be more likely to give their child the RUSF snack than to mix the RUSF with *borbor*. This may be because, when mixed with warm *borbor*, the fish smell of the RUSF became stronger. Also, it was noted that even the younger children had no difficulty holding the snack themselves to suck on it, if not bite and chew it. Some caregivers broke the snack into smaller pieces to help the younger children eat it. Given this finding, future caregivers will be encouraged to use the RUSF as a snack, although it will be noted that the RUSF can be mixed with *borbor* or other foods, especially for younger children, as is suggested with some other LNSs (Arimond et al., 2015). This also concurs with evidence that consumption of snacks is very common amongst infants and young children in Phnom Penh even in the lowest wealth tercile (Pries et al., 2017; Pries et al., 2016; WFP, 2014b; World Vision, 2015).

4.7 | Strengths and limitations of this study

This trial contributes to the literature comparing supplementary foods using animal-source foods other than milk and foods acceptable to a South East Asian population. Having said that, the study was limited to peri-urban Phnom Penh and may not be representative of rural areas or of neighbouring countries.

The large sample size and high retention combined with the cross-over design and cluster randomisation, along with the use of ranking, make this study robust. Nevertheless, despite attempting to avoid bias toward any of the foods, unintentional interviewer and respondent bias may have favoured the novel RUSF in caregiver assessments.

5 | CONCLUSIONS

This trial contributes much-needed data on the acceptability of a novel RUSF to Cambodian caregivers and children. Moreover, it sheds light on the acceptability of supplementary foods with an animal-source food other than milk. Although children ate less of the RUSF snack than of the other, more familiar foods, the RUSF (whether eaten as a snack or with *borbor*) provided more energy than CSB++ or *borbor* fortified with MNP. Moreover, caregivers ranked the RUSF snack very highly, demonstrating that our locally produced RUSF, using fish instead of milk, is more acceptable to Cambodian caregivers than the commonly used MNP and CSB++. In view of these results, the research team felt confident to proceed to a 6-month trial to test the RUSF's effectiveness in preventing growth faltering. Given that testing over 3 days in an unfamiliar setting may not be an indication of how caregivers and children would accept the food over a longer period, we note that the subsequent 6-month effectiveness trial will also give additional information on long-term acceptability.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

CONTRIBUTIONS

BB developed the research protocol, trial design, and questionnaires, and refined these with FTW, SM, MG, DS, CC, and AL. AL and FTW secured funding. BB managed data collection with support from DS. BB conducted the statistical analysis with support from MG. BB wrote the manuscript and all authors subsequently commented on the manuscript and approved the final version.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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