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ACCEPTABILITY OF NUTRITIOUS CHILDREN'S FOODS DEVELOPED FOR MARKETS IN SIERRA LEONE

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ABSTRACT

Sierra Leone has one of the highest levels of malnutrition and child mortality worldwide due, in part, to the micronutrient deficiencies that result from a lack of diet diversity and food accessibility. To address these challenges, nutrient-dense, affordable snack foods are being developed for children in Sierra Leone. The products in development are similar to foods that are currently eaten in the region, such that they could easily be integrated into children's diets. The two lead products are a groundnut butter pudding for children six months to two years of age and a sweet potato based muffin for children two to five years of age. The objectives of this study are (1) to determine the dietary habits of children in Sierra Leone between six months and five years of age, and (2) to perform acceptability testing with the pudding and the muffins. In total, 428 mother-child pairs participated in the study, which was performed in 2019 in multiple locations in the vicinity of Makeni, Sierra Leone. The mothers reported that the most common snacks for children six months to two years of age were porridge and rice, while the most common snacks for two to five year olds were rice and biscuits. These findings confirmed that the pudding and muffins would be familiar and appealing to young children. Moreover, the test results demonstrated that both the pudding and the muffins were acceptable in terms of taste and texture. Based upon these findings, the best formulations were selected, then further modified to reach the target levels of each micronutrient (vitamin A, iron, and zinc) in a single serving size. The estimated cost of each product is 1500 leones (\$0.15 USD), making it affordable for Sierra Leoneans. Future steps are to collaborate with local entrepreneurs to sell these products in the markets where people normally shop. This study was approved by the District Medical Officer of Health in Sierra Leone and performed in collaboration with World Hope International, an NGO with a facility in Makeni, Sierra Leone.

Key words: acceptability testing, malnutrition, micronutrient deficiencies, nutrition, sensory testing, Sierra Leone

INTRODUCTION

Sierra Leone has one of the highest malnutrition rates in the world, resulting in a high level of child mortality; 46% of childhood deaths are caused by malnutrition [1]. Moreover, malnutrition has led to a stunting rate of approximately 31% [2], and causes delays in education, reduction in the level of education attained, and increased poverty later in life [3]. Micronutrient deficiencies are also prevalent in Sierra Leone. For example, 17.4% of children have vitamin A deficiency and 76.3% are anemic; approximately one-quarter of the anemia cases are a result of iron deficiency [4]. Additionally, only 85% of households consume iodized salt [5]. A major factor contributing to micronutrient deficiencies is a lack of access to diverse foods, making people vulnerable to malnutrition [6]. Additional causes of malnutrition include food insecurity, inadequate resources at the household and community levels, and lack of access to health services [7].

Prior studies have evaluated the impact of different treatment regimens on reducing malnutrition in children in Sierra Leone. In one study, it was demonstrated that an integrated protocol consisting of a Ready-to-Use Therapeutic Food (RUTF) in combination with on-site and homecare medical visits, as well as medical interventions (e.g. lipid nutrient supplements, oral rehydration), as needed, led to successful management of malnutrition [8]. Additionally, the use of two RUTF products, Plumpy'Nut® and a solid biscuit (BP100), were shown to be well-accepted and effective for treating children with severe malnutrition relative to a standard treatment of F75 followed by F100 [9]. More recently, an oat-based RUTF was shown to be slightly more effective in treating severe acute malnutrition than a standard RUTF containing milk powder, sugar, peanut paste, and vegetable oil, perhaps due to the absence of hydrogenated vegetable oil in the oat-based RUTF [10]. These studies demonstrate the effectiveness of RUTF products in treating acute malnutrition, but more self-sustaining approaches are needed to improve nutrition and diet in the long term. Diets in Sierra Leone tend to be overly dependent upon rice and cassava. Though other foods such as fruits, vegetables, groundnuts, fish, and beans are commonly eaten, consumption of these nutritious foods depends on their affordability and seasonality [11].

Two products have been developed by our research group: (1) a pudding containing sweet potatoes, bananas, and groundnuts, for children six months to two years of age and (2) a sweet potato muffin for children two to five years of age. Both products are sourced primarily from local ingredients and formulated to contain the micronutrients often missing in the diets of children in Sierra Leone. The products were developed with the aid of the model development and optimization tool AMPL (A Mathematical Programming Language), which was used to determine formulations that minimize cost, while meeting established constraints for ingredients and nutrient levels, as described in a previous study [12]. Ultimately, these products would be produced and sold in the local markets, where people typically purchase food for their household and would be priced such that they would be affordable.

The objectives of this study were (1) to determine the dietary habits of children in Sierra Leone between six months and five years of age, and (2) to perform acceptability testing with the pudding and the muffins. This study was executed in ten different locations in Makeni, Sierra Leone in 2019. The work was endorsed by the District Medical Officer of Health (DMOH) and the Director of Nutrition in Sierra Leone, and performed in collaboration with World Hope International (WHI), an NGO with a facility in Sierra Leone.

MATERIALS AND METHODS

Pudding preparation: The base formulation for one serving of pudding was 30g groundnut butter, 60g sweet potato, 30g banana, less than 1g of palm oil, 16mg ferrous fumarate (Bulk Supplements, Henderson, NV, USA). Three variations of the formulation were prepared and tested: (1) base formulation, (2) base formulation plus 12.5g sugar, and (3) base formulation minus 15g banana. The pudding was produced by roasting sweet potatoes for 45 to 65 minutes, until completely soft inside, followed by peeling and mashing with a mortar and pestle. The remaining ingredients were added, beginning with the groundnut butter, followed by bananas, palm oil, and ferrous fumarate. The pudding was mashed until the ingredients formed a homogeneous, smooth consistency, and stored in semi-closed plastic containers. The pudding was prepared at Bettah Bakery, a joint venture between the Wesleyan Church and WHI.

Muffin preparation: The base formulation for one serving of the muffin was 16g sweet potato, 14g banana, 14g cornmeal, 5g palm oil, 10mg vitamin C, 7mg ferrous fumarate, and 3mg zinc citrate (Bulk Supplements, Henderson, NV, USA). Six variations of the recipe were prepared and tested: (1) base formulation, (2) base formulation plus 2g sugar, (3) base formulation plus 4g sugar, (4) base formulation plus 2g banana, (5) base formulation with a dash of salt, and (6) base formulation plus 2g cornmeal. The muffins were prepared by first roasting sweet potatoes for 45 to 65 minutes, followed by peeling and mashing. The bananas were then mashed in a bowl until smooth and the remaining ingredients were weighed and mixed. The muffins were baked, distributed into one-quarter servings, and stored in a plastic container. Like the pudding, the muffins were produced at Bettah Bakery.

Participant demographics and recruitment: Interviews, as well as acceptability testing, were performed in ten different locations in or near Makeni, a city in the Bombali District of Sierra Leone, including: one church (Wesleyan Church of Makeni), one NGO (WHI), two health clinics (Kalangba Clinic, Kamabai Clinic), and six villages/regions (Graceland/Barracks Village, Makama Village, Masangbo Village, Rogbalan Area, Ropolon Village, and Sierra Leone Muslim Brotherhood Area). For the testing in the health clinics, the Community Health Worker in charge of clinic operations recruited participants in their communities. In the other locations, the research team worked with local translators to go door-to-door to recruit participants, with the permission of the community leader in that region. A total of 428 mother-child pairs participated in the study; 191 children were 6 months to 2 years of age and 237 children were two to five years old (Figure 1).

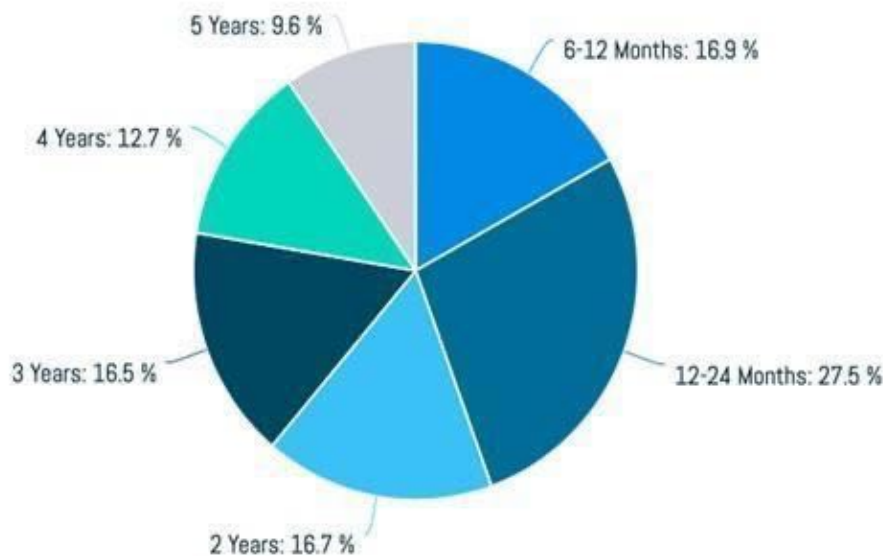


Figure 1: Age distribution of child participants

Test protocol: The investigators' questions were translated from English into Krio and Temne by translators, who conversed with the participants in their local language. The investigators asked the mothers questions about their child's activity levels and their appetite to assess the child's general health, since mothers might not know their child's current height or weight. Activity level was reported on a scale of 1 (often tired) to 5 (energetic); appetite was also reported on a scale of 1 (eats very little at each meal) to 5 (eats a lot). The mothers were also asked questions about what snack foods the children typically eat, and whether they have used Bennimix® and Plumpy'nut®, which are supplemental foods currently on the market. The motivation for these questions was to understand how the pudding and the muffins could be introduced into the marketplace, and be integrated into children's diets, especially since supplemental foods are already available.

Based upon the age of the child participant, each mother-child pair tasted one sample of the pudding (children 6 months to 2 years) or one sample of the muffin (2 to 5 years). Each mother-child pair tasted one of the product formulations, based upon the test location. The formulation tested in each location is shown in Table 2 and Table 3. Participants did not know which of the product formulations they sampled. Nor did they know that multiple formulations were being tested. Because young children have limited verbal skills and often cannot indicate taste preferences, observing behaviors, such as facial expressions, is a suitable evaluation technique for taste and sensory testing [13]. Additionally, behaviors such as spitting out food or storing food in the cheeks are indicative of a texture problem or the child's inability to chew the food [14]. Therefore, for this study, the children's acceptability of the products was evaluated by noting if the child participants spit out their sample or if they finished it. Also, when the mothers tasted the product, they rated their own score for the texture on a scale of 1 (bad) to 5 (excellent). To gain feedback on how the product formulations should be modified, the mothers were also asked if they would purchase the product, how many

times per day they would feed the product to their child, and how the product could be improved.

Protocol approval: The study was reviewed and approved by Lehigh University's Institutional Review Board (IRBNet ID 1451126-2) and by the DMOH in Sierra Leone.

RESULTS AND DISCUSSION

Children's activity levels and eating habits: For all age groups, the mothers reported an average activity level of at least 4.0 on a scale of 1 to 5 (Table 1), as previously described. Additionally, numerous mothers reported that their children are "active" or "strong". Mothers of children in all age groups reported, on average, that their children eat three times per day (Table 1). Based upon these results, it was concluded that the children participating in this study were in good general health. The most common snacks for children 6 months to 2 years were porridge and rice (Figure 2), while the most common snacks for 2 to 5 year olds were rice and biscuits (Figure 3). Porridge, rice, or biscuits contain minimal amounts of nutrients, demonstrating the need for more nutritious snack foods. However, the similarity of the pudding and muffins with current snack foods suggest that the foods being developed can be easily integrated into children's diets. Most of the mothers interviewed have fed Plumpy'Nut® and/or Bennimix® to their children. Prior usage was 29% for Plumpy'Nut® only, 14% for Bennimix® only, and 34% for both products. Reasons reported for not using these products included high cost and the perception that the products make their children ill.

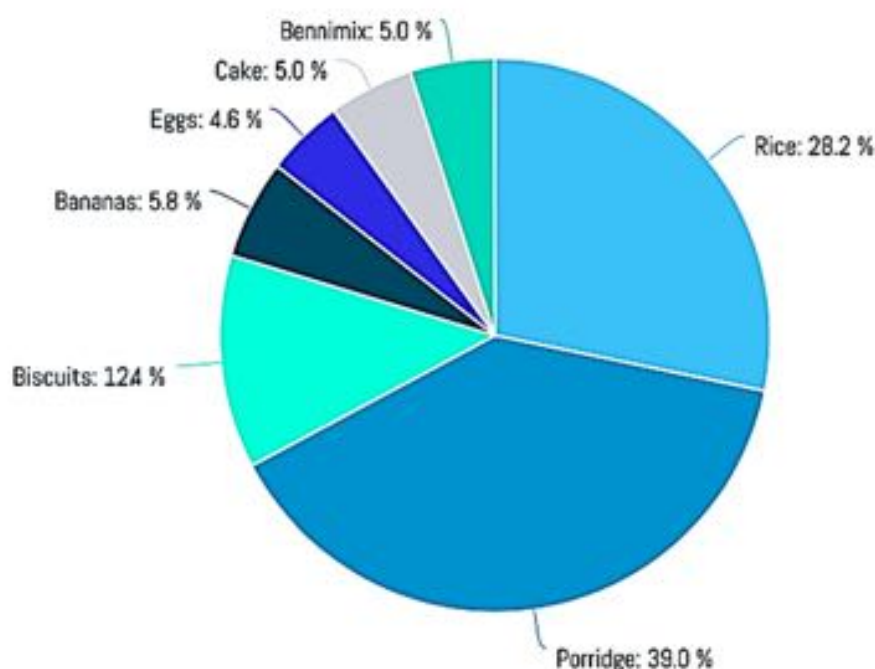


Figure 2: Common snack foods among children in Sierra Leone ages 6-24 months (n=191)

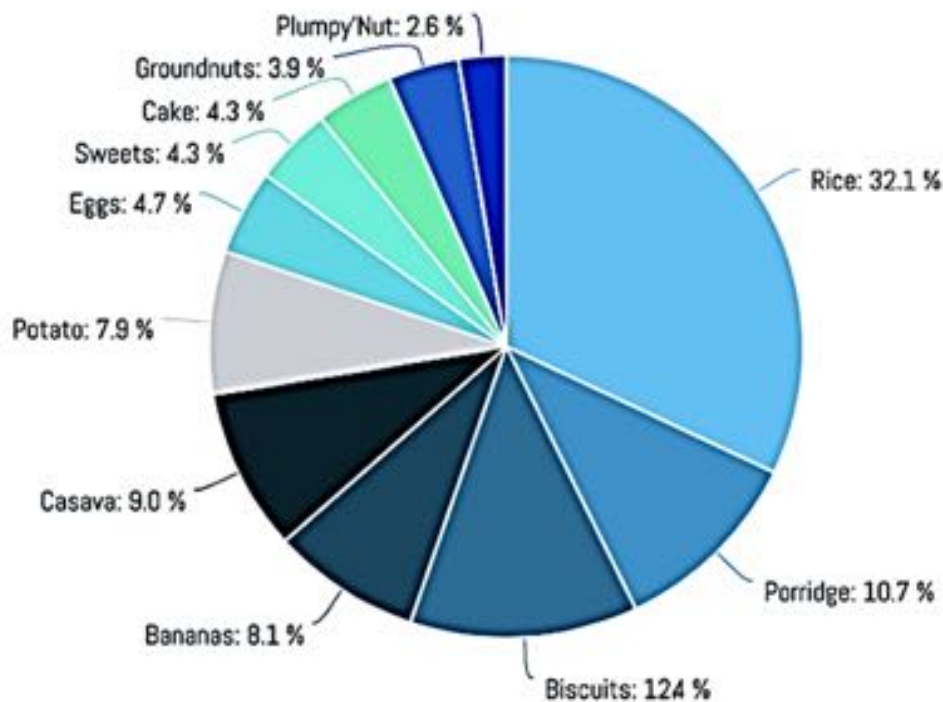


Figure 3: Common snack foods among children in Sierra Leone ages 2-5 years (n=237)

Acceptability of pudding For all three formulations, the majority of children finished the sample (58.8% to 68.4%) and did not spit it out (65.0% to 78.0%) (Table 2). It should be noted that many of the children were breastfeeding immediately before taste testing the pudding and were not hungry enough to finish the sample. Additionally, for all three formulations, texture scores reported by the mothers were between 4.5 and 4.8 (Table 2), but the differences between the base recipe and each variation were not statistically significant ($p \geq 0.06$). These results are comparable to those from a study in which female caregivers in the Pujehun District of Sierra Leone sampled a corn-soy blend porridge [15]. Over 95% of the mothers interviewed indicated that they would purchase the pudding. The mothers also reported that they would feed the product to the children three times per day, on average.

Acceptability of the muffin: For each of the six formulations, less than 5% of the children spit out the product and over three-quarters of the children finished their sample (Table 3). A few children did not finish their sample because they wanted to share it with a sibling or save it for later. For each formulation, the texture score reported by the mothers was between 4.6 and 5.0 (Table 3), but the differences between the base recipe and each variation were not statistically significant ($p \geq 0.2$). Over 95% of the mothers interviewed indicated that they would purchase the product. They also reported that they would feed the product to the children three times per day, on average. The acceptability of the muffin is favorable compared to a study evaluating acceptability of Plumpy'nut® in Bangladesh, in which only four in ten caregivers reported the product to be acceptable for their children [16]. The caregivers reported

problems with taste and texture of Plumpy'nut®, as well as side effects such as nausea and vomiting [16].

Formulation selection and modifications: The formulation chosen for the pudding and for the muffin, as well as the nutrition content, is shown in Table 4 and Table 5, respectively. White sweet potatoes were used in this study, based on the availability in the local markets at the time. However, orange-fleshed sweet potatoes (OFSP), which are rich in vitamin A, will be used in the future, since Sierra Leone is currently transitioning to the OFSP varieties [17]. Based on the acceptability results, the pudding with the reduced amount of banana (15 g per serving) was selected, keeping the amount of sweet potato, groundnut butter, and palm oil the same. Because mothers report that children might eat the product more than once per day, ferrous fumarate and zinc citrate were added to bring the iron and zinc levels to 50% of the recommended daily allowance (RDA) for children one to three years of age. For the muffins, the base formulation was selected, since the taste and sensory studies showed similar results for all the formulations tested. The quantity of sweet potato, banana, and palm oil will be the same, while the amount of cornmeal will be slightly reduced to lower the cost without compromising nutritional content. Again, based upon the mothers' responses, children might eat more than one muffin per day. Therefore, ferrous fumarate and zinc citrate were added to bring the iron and zinc levels to 50% of the RDA for children four to eight years of age. While the percent of the RDA would be higher for younger children, it was assumed that the younger children would eat roughly a half portion. Moreover, both products are affordable for most Sierra Leoneans. The estimated cost to produce one serving of pudding and one muffin is 600 SLL (\$0.062 USD) and 642 SLL (\$0.066 USD), respectively. The estimated sale price is 1500 leones (\$0.15 USD), which would generate meaningful income for the seller, while making the products affordable for most Sierra Leoneans.

For this study, both the pudding and the muffins were formulated with unrefined palm oil, which is rich in vitamin A. However, several of the mothers interviewed noted their preference for refined palm oil, which is produced by boiling the oil until it turns from red to clear. Despite this preference, the formulation will contain unrefined palm oil, since the boiling process lowers the vitamin A content. Moreover, the refining process produces toxic byproducts that can potentially cause adverse effects such as reproductive infertility, higher cholesterol level, and increased blood pressure [18]. Moreover, it was observed that pudding and the muffins spoiled quickly due to the warm, humid climate in Sierra Leone, as well as a lack of reliable electricity for refrigeration. Additionally, the bananas used in the pudding caused the product to brown within minutes. Therefore, to improve the shelf-life of both products, we plan to add sodium propionate, a common preservative in baked goods, to the muffins and ascorbic acid (vitamin C) or lemon juice, which are commonly used antioxidants, to the pudding [19].

Product implementation: Prior studies have shown that poor consumers often purchase much of their household food from businesses such as small and medium-sized enterprises, micro-entrepreneurs, and local vendors [20]. Therefore, small businesses can play an important role in promoting the consumption of healthy foods

[21]. Such markets are even essential for nutrition and diet diversity of smallholder farm owners who grow much of their own food [21]. Therefore, once the product formulations of the pudding and muffins are finalized, the next step is to work with local food producers and micro-entrepreneurs to sell and market the products. However, there are challenges associated with marketing nutrient-rich foods, such as making the products available and affordable for the people who need them [22]. Making a business viable and sustainable can also be difficult because those who would be selling the products often lack the access to finance needed to start their business [20]. Additionally, the products would need to be marketed, such that customers would understand the value of products aimed at improving diets and nutrition [21]. Despite the challenges, the effort can be beneficial. For example, a recent study suggested that small businesses may increase access for the poor to nutritious products [21]. For such enterprises to achieve success, however, there must be support from public agencies and NGOs in creating the market for these foods [23]. Such organizations, as well as public-private partnerships, can provide support in procurement and distribution to the small businesses lacking the resources to accomplish these activities [24]. Lastly, it is essential for the public sector to collaborate with these businesses to help promote healthy eating, since demand cannot be created by the businesses alone [20].

CONCLUSION

Sierra Leone suffers from a high rate of malnutrition due to a combination of factors, including poverty and a lack of diet diversity. While RUTFs are effective for treating acute malnutrition on a short-term basis, more self-sustaining approaches are needed to improve nutrition throughout the duration of childhood. Our approach is to develop affordable snack foods that are formulated primarily with local ingredients and supplemented with the micronutrients often lacking in children's diets, as well as appealing to children and available in the markets where people normally shop. The results of this study showed that the two foods that have been developed, the pudding and the muffin, are acceptable to mothers and to their young children, needing just minor adjustments to improve the taste, nutrient content, and shelf-life. These products could also be viable alternatives to existing therapeutic foods which are perceived as being high in cost and low in acceptability. Moreover, the pudding and the muffins are similar to foods that children already eat and, therefore, could easily be integrated into their diets. Based on the results of this study, the next step for this work is to bring these products to the local markets by continuing to work with WHI and to begin collaborating with entrepreneurs in Sierra Leone.

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Table 1: Children's activity level and eating habits, as reported by mothers.
Results are reported as average \pm standard deviation

	Pudding			Muffins			
	6-11 mon (n = 73)	12-23 mon (n = 95)	2 year (n = 23)	2 year (n = 72)	3 year (n = 69)	4 year (n = 53)	5 year (n = 40)
Activity level of child Scale of 1 (often tired) to 5 (energetic)	4.5 \pm 1.1	4.0 \pm 1.3	4.0 \pm 1.2	4.2 \pm 1.3	4.4 \pm 1.3	4.1 \pm 1.2	4.4 \pm 1.1
Frequency child eats (times/day)	2.7 \pm 1.0	2.8 \pm 1.0	3.0 \pm 0.8	3.2 \pm 1.2	2.9 \pm 0.8	3.1 \pm 1.0	3.3 \pm 1.1
Appetite of child Scale of 1 (eats little at each meal) to 5 (eats a lot at each meal)	4.0 \pm 1.5	3.7 \pm 1.7	3.9 \pm 1.5	4.2 \pm 1.4	4.0 \pm 1.5	3.8 \pm 1.6	3.7 \pm 1.5

Table 2: Acceptability of the pudding

	Base recipe 30g banana/serving	Base + sugar 12.5g sugar/serving	Base with reduced banana 15g banana/serving
Locations	<i>Church, WHI, Graceland Village, Slmb Area</i>	<i>Wesleyan Church, Kalangba Clinic, Rogbalan Area and Masongbo Area</i>	<i>Kalangba Clinic, Kamambai Clinic, and Rogbalan Area</i>
Number of mother/child pairs	63	65	63
Average age of child (months)	14 ± 6.1	13 ± 5.1	11 ± 4.4
Texture, as reported by mother	4.6 ± 0.7	4.5 ± 0.9 (p = 0.74)	4.8 ± 0.7 (p = 0.06)
How many times per day would you (the mother) feed your child this product?	2.8 ± 0.7	2.9 ± 0.7 (p = 0.30)	2.9 ± 0.5 (p = 0.53)
Did the child spit out the product?	NO – 75.0%	NO – 78.0% (p = 0.74)	NO – 65.0% (p = 0.41)
Did the child finish the sample?	YES – 63.6%	YES – 58.8% (p = 0.63)	YES – 68.4% (p = 0.65)
Would you (the mother) buy this product?	YES – 96.8%	YES – 95.4% (p = 0.67)	YES – 98.4% (p = 0.56)

The p-values are reported relative to the base recipe

Table 3: Acceptability of the muffins

	Base recipe	Base + 2g sugar	Base + 4g sugar	Base + 2g banana	Base with a dash of salt	Base + 2g cornmeal
Location	<i>Wesleyan Church, WHI, Graceland Area</i>	<i>Rogbalan Area</i>	<i>Kalangba Clinic and Wesleyan Church</i>	<i>Ropolon Area</i>	<i>Masongbo Area</i>	<i>Makama Area</i>
Number of mother/child pairs	37	40	40	38	41	41
Average age of child (years)	3.1 ± 0.9	3.6 ± 1.1	2.9 ± 1.0	3.6 ± 1.1	3.3 ± 1.1	3.2 ± 1.0
Texture, as reported by mother	4.8 ± 0.8	4.8 ± 0.4 (p = 0.42)	4.6 ± 0.9 (p = 0.17)	4.7 ± 0.5 (p = 0.18)	5.0 ± 0.3 (p = 0.39)	4.8 ± 0.6 (p = 0.64)
How many times per day would you (the mother) feed your child this product?	2.7 ± 0.7	3.2 ± 1.6 (p = 0.12)	3.1 ± 0.9 (p = 0.04)	2.8 ± 0.5 (p = 0.56)	2.9 ± 0.8 (p = 0.42)	2.9 ± 0.7 (p = 0.22)
Did the child spit out the product?	NO – 97.2%	NO – 97.5% (p = 0.29)	NO – 100.0% (p = 0.34)	NO – 100.0% (p = 0.38)	NO – 100.0% (p = 0.41)	NO – 94.9% (p = 0.97)
Did the child finish the sample?	YES – 86.7%	YES – 80.0% (p = 0.47)	YES – 77.8% (p = 0.71)	YES – 86.2% (p = 0.96)	YES – 96.9% (p = 0.14)	YES – 87.2% (p = 0.95)
Would you (the mother) buy this product?	YES – 97.3%	YES – 100.0% (p = 0.29)	YES – 97.5% (p = 0.96)	YES – 100.0% (p = 0.31)	YES – 100.0% (p = 0.29)	YES – 100.0% (p = 0.00)

The p-values are reported relative to the base recipe

Table 4: Pudding formulation and micronutrient levels on a per serving basis [25, 26]

Ingredient	Vitamin A (mcg RAE*)	Iron (mg)	Zinc (mg)
60 g roasted orange-fleshed sweet potatoes	226	0.60	0.21
15 g mashed banana	0.60	0.05	0.03
30 g groundnut butter	0.60	0.99	1.01
1 g palm oil	57.2	0.00	0.00
5.67 mg ferrous fumarate	0.00	1.86	0.00
0.73 mg zinc citrate	0.00	0.00	0.25
Total	285	3.50	1.50
Daily recommended value (7-12 months)	56.9%	31.8%	50.0%
Daily recommended value (1-3 years)	94.9%	50.0%	50.0%

*RAE: Retinol Activity Equivalent

Table 5: Muffin formulation and micronutrient levels on a per serving basis [25, 26]

Ingredient	Vitamin A (mcg RAE*)	Iron (mg)	Zinc (mg)
16 g roasted orange-fleshed sweet potato	60.3	0.16	0.06
8 g cornmeal	2.24	0.24	0.14
14 g mashed banana	0.56	0.04	0.02
5 g palm oil	286	0.00	0.00
13.9 mg ferrous fumarate	0.00	4.56	0.00
6.68 mg zinc citrate	0.00	0.00	2.28
Total	349	5.00	2.50
Percent daily rec. values (1-3 years)**	116%	71.4%	83.3%
Percent daily rec. values (4-8 years)**	87.3%	50.0%	50.0%

*RAE: Retinol Activity Equivalent

**It was assumed that children 1-3 years of age would only eat ½ a full sized muffin while children 4-8 years of age would consume the entire muffin

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