

Research Article

Evaluation of Acceptability and Sensory Quality of Cocoa- or Cashew-Based Ready-to-Use Foods for Moderately Acutely Malnourished Children

Audrey Herbert Yépié^{1,*}, Nina Laurette Ahuéfa¹, Jean-Jacques Diagou¹, Anin Louise Anin-Atchibri¹, Odile Sassor Aké-Tano²

¹Department of Food Sciences and Technology, Laboratory of Nutrition and Food Safety, University of Nangui Abrogoua, Abidjan, Côte d'Ivoire

²Department of Nutrition, National Institute of Public Health, Abidjan, Côte d'Ivoire

Abstract

The fight against child malnutrition in Côte d'Ivoire requires solutions that are both appropriate and sustainable. Given the limited use of imported Ready-to-Use Foods, the integration of local ingredients such as cocoa and cashew emerges as a promising alternative. However, the sensory acceptability of these products remains a key challenge to ensure their adoption and effectiveness. The objective of this study was to evaluate the acceptability of two local formulae, based on cashew (CAF) and cocoa (COF), compared to the reference product, Plumpy'Sup[®]. To this end, a randomized controlled trial was conducted with 54 mother-child pairs. The study analyzed children's food consumption and the sensory preferences expressed by mothers, measured on a 1-to-5 scale. The results showed that the majority of the children were girls (57%), either well-nourished (67%) or moderately acutely malnourished (33%). Their mothers primarily practiced mixed breastfeeding (72-83%) and belonged to medium-sized households (4.34 to 5.1 people) with daily expenditures ranging from 2300 to 2600 FCFA per household, or 509.80 to 543.48 FCFA per individual (less than 1 USD per individual). Although Plumpy'Sup[®] received the highest sensory scores from mothers, children consumed more of the cashew-based formula (CAF), followed by the cocoa-based formula (COF), and then Plumpy'Sup[®]. These findings underscore the need to develop local, balanced, and accessible nutritional solutions tailored to the socio-economic realities of the country.

Keywords

Child Malnutrition, Sensory Acceptability, Ready-to-Use Foods, Cocoa, Cashew

1. Introduction

Child malnutrition remains a major public health issue in Côte d'Ivoire, affecting approximately 30% of children under five as chronic malnutrition, with nearly 6% suffering from severe acute malnutrition [1]. While Ready-to-Use Foods

(RUFs) have proven effective in addressing moderate acute malnutrition in children [2, 3], their widespread adoption is hindered by economic and logistical challenges, particularly in peri-urban and rural areas.

*Corresponding author: sensei.herbert@gmail.com (Audrey Herbert Yépié)

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This highlights the importance of developing accessible and locally adapted solutions. Among local ingredients, cocoa and cashew stand out due to their unique nutritional properties. Cocoa is a rich source of antioxidants, lipids, and minerals such as magnesium and iron, which are essential for children's growth and development [4]. Cashew, on the other hand, is renowned for its high-quality protein content, unsaturated fatty acids, and vitamins [5]. These characteristics make these ingredients particularly suitable for formulating RUFs that meet the specific nutritional needs of malnourished children.

However, beyond nutritional aspects, it is crucial to assess the sensory acceptability of these formulations to ensure their adoption by children. Food preferences, influenced by taste, texture, and aroma, play a central role in the success of RUFs, as they determine consistent consumption and nutritional efficacy [6].

This study aims to explore the level of acceptability and sensory quality of RUFs based on cocoa or cashew, while considering their potential as a sustainable and local alternative in the fight against child malnutrition.

2. Materials and Methods

The methodology used in this study was inspired by the approach described by [6].

2.1. Study Design

The study consisted of a grouped, randomized, and controlled food acceptability trial, with a reference food serving as the control. It was an open trial, as the three foods being tested were visibly different.

2.2. Foods Compared

The local formulae based on cashew (CAF) and cocoa (COF) [7], were compared to the reference product, Plumpy'Sup®.

2.3. Study Site and Population

The study was conducted over a two-month period, from September to October 2019, within the Nutrition Department of the National Institute of Public Health (in French Institut National de Santé Publique (INSP)). The study population consisted of mother-child pairs.

2.3.1. Inclusion Criteria

Subjects meeting the following criteria were invited to participate in the study:

Normal or moderately malnourished children (Z-score weight/height > -3) who appeared to be in good health during the three days preceding the tests were eligible. This ensured that the subjects had no appetite loss related to malnutrition or any illness.

- 1) To facilitate child feeding, mothers responsible for a single child were eligible.
- 2) Only mothers of children with no medical complications or illnesses were eligible to avoid appetite loss associated with health issues.
- 3) Only children whose mothers signed or provided their fingerprint on the informed consent document were eligible.

2.3.2. Exclusion Criteria

Subjects with the following characteristics were excluded:

- 1) Children with known food intolerances.
- 2) Parents and/or children who were ill during the trial.

2.4. Sample Size

The protocol of this study defines acceptability as the average consumption of at least 50% of the test food served. Thus, the sample size was calculated based on the primary outcome criterion, which is the consumption of more than 50% of the served test food [8]. The following equation was used for sample size estimation. It is based on a study design comparing two (2) groups [9, 10].

$$N = (Z_{\alpha} + Z_{\beta})^2 \times \left(\frac{SD}{\delta}\right)^2 \quad (1)$$

With:

N: Sample size

Z_{α} : Z-score for a significance level $\alpha = 0.05$

Z_{β} : Z-score for a test power $\beta = 90\%$

SD: Observed variation

δ : Delta or effect to be detected at the end of the study

Based on recent acceptability studies [10], a variation (SD) of 30% was assumed to detect a consumption difference (δ) of 20%. To ensure a precision of 0.05, a power of 0.8, and a probability $p < 0.05$, the required sample size was 44 children, or 53 children if we assume a 20% dropout rate.

2.5. Randomization

A total of 70 children were identified for randomization. Of these, 54 were selected and assigned to three study groups (Group 1: Plumpy'Sup®, Group 2: COF, Group 3: CAF) using simple random sampling based on computer-generated random numbers (Figure 1).

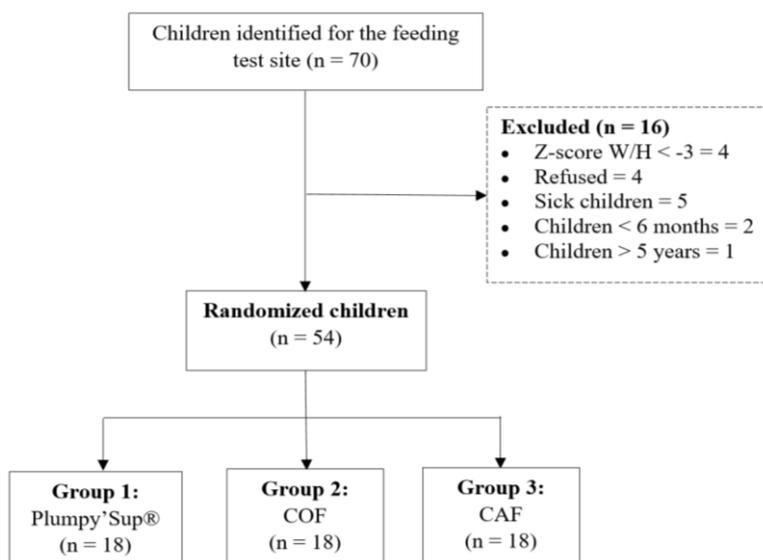


Figure 1. Acceptability Trial Flow Diagram.

2.6. Interventions

2.6.1. Baseline Data and Anthropometric Measures

Potential participants (mother-child pairs) were assessed for eligibility at the test site through the collection of baseline data, including demographic, anthropometric, dietary, and morbidity data. Anthropometric measurements included weight, recorded using a scale with 0.1 kg precision, age obtained from vaccination cards, and height, measured using a stadiometer with 0.1 cm precision.

2.6.2. Children's Consumption

Mothers were instructed, if possible, not to feed their children during the hour preceding the test. During the test, the foods were served in brown plastic cups labeled with the child's code. Each cup contained 15 ± 1 g of the test formulae (COF and CAF) or the reference product (*Plumpy'Sup*[®]). Water was served in white plastic cups. The cups, spoon, tissue, food, and water were weighed using a scale with 0.1 g precision. Mothers were instructed to feed their children for 10 to 15 minutes or until the child refused to eat further [11]. Once the child finished eating, the cups containing food or water leftovers, the spoon, and the tissue used to clean the child's mouth or collect saliva and residues were weighed. The difference between the initial and final weights was recorded as the amount of food or water consumed (in grams).

2.6.3. Mothers' Consumption

After the children completed the acceptability test, mothers were asked to evaluate the three foods. Their responses were recorded on a data collection form by marking a position on facial expression images used to measure preferences, with scores ranging from 1 to 5 (1 = dislike strongly, 2 = dislike

slightly, 3 = neutral, 4 = like slightly, 5 = like strongly).

2.6.4. Outcome Measures

The primary outcome measure was to assess children's acceptability by determining the quantity of food consumed per child for a single type of food offered, based on the group to which they were assigned. In the absence of established guidelines for the acceptability of food supplements, the protocol defined acceptability as the average consumption of at least 50% of the food offered. This is consistent with similar acceptability studies [11-13].

The secondary outcome was to evaluate parents' preferences for each food. Parents were instructed to assess the sensory quality of the three test foods. The following sensory attributes were evaluated: color, smell, taste (sweetness), texture (smoothness), and overall appreciation, using a rating scale ranging from 1 (dislike strongly) to 5 (like strongly).

2.7. Statistical Analyses

All data were entered into Excel and analyzed using R software version 3.5.2. Data describing the characteristics of recruited mother-child pairs were recorded as mean \pm standard deviation or percentages. Anthropometric indices were calculated using WHO 2006 references and expressed as Z-scores for weight-for-height (W/H), weight-for-age (W/A), and height-for-age (H/A).

For the acceptability test, the percentage (%) of food or water consumed and the mean \pm standard deviation of their quantities were calculated. For comparisons among the three groups, a one-way ANOVA was conducted, followed by Bonferroni post hoc tests when significant differences were observed. Data for the hedonic evaluation were presented as mean \pm standard deviation.

2.8. Ethical Considerations

This study was approved by the National Institute of Public Health. Informed consent was obtained from mothers, ensuring confidentiality and anonymity. Participants were free to withdraw at any time, guaranteeing voluntary participation.

3. Results

3.1. Characteristics of the Study Population

The study included 54 mothers and their children aged 6 to 59 months. The majority of the children were girls (57%), with an average age ranging from 12.76 ± 2.1 months to 13.1 ± 1.8 months, depending on the groups. The average weight ranged from 7.4 ± 1.2 kg to 7.8 ± 0.7 kg, and the height ranged from 66.9 ± 4.4 cm to 67.5 ± 3.2 cm.

Table 1. Characteristics of Children Participating in the Acceptability Study.

Characteristics	Group 1 (n = 18) Plumpy'Sup®	Group 2 (n = 18) COF	Group 3 (n = 18) CAF
Sex			
Girls, % (n)	61 (11)	56 (10)	56 (10)
Boys, % (n)	39 (7)	44 (8)	44 (8)
Anthropometric Measurements			
Age, months (M ± SD)	13.1 ± 1.8	12.8 ± 2.3	12.76 ± 2.1
Weight, kg (M ± SD)	7.6 ± 0.6	7.8 ± 0.7	7.4 ± 1.2
Height, cm (M ± SD)	67.2 ± 3.5	67.5 ± 3.2	66.9 ± 4.4
Nutritional Indices			
W/H	MAM, Z-score < -2, % (n)	33 (6)	33 (6)
	N, Z-score > -2, % (n)	67 (12)	67 (12)
H/A	MCM, Z-score < -2, % (n)	11 (2)	11 (2)
	N, Z-score > -2, % (n)	89 (16)	89 (16)
W/A	MU, Z-score < -2, % (n)	44 (8)	44 (8)
	N, Z-score > -2, % (n)	56 (10)	56 (10)

Table 2. Characteristics of Mothers and Their Households During the Acceptability Study.

Characteristics	Group 1 (n = 18) Plumpy'Sup®	Group 2 (n = 18) COF	Group 3 (n = 18) CAF
Breastfeeding Until 6 Months			
Exclusive breastfeeding, % (n)	17 (3)	22 (4)	11 (2)
Artificial feeding, % (n)	0 (0)	6 (1)	11 (2)
Mixed feeding, % (n)	83 (15)	72 (13)	78 (14)
Complementary Foods			
< 6 months, % (n)	56 (10)	44 (8)	39 (7)
> 6 months, % (n)	44 (8)	56 (10)	61 (11)
Household Size (M ± SD)	4.34 ± 1.3	5.1 ± 1.8	4.6 ± 2.0
Daily Household Expenditure in FCFA	2300 ± 256	2600 ± 300	2500 ± 205
Expenditure per Individual in FCFA (USD)	529.95 (0.83)	509.80 (0.80)	543.48 (0.85)

Each group included 33% of children suffering from moderate acute malnutrition. Five cases of stunted growth were recorded (11% in Groups 1 and 2, and 6% in Group 3), and 23 children had moderate weight deficits, distributed across the three groups (Table 1).

Regarding the mothers, mixed breastfeeding was the dominant feeding method (72% to 83% depending on the groups), while exclusive breastfeeding until six months of age was reported for 22% of mothers in Group 2, 17% in Group 1, and 11% in Group 3. The introduction of complementary foods before six months was common (39% to 56% across groups). Families had an average size of 4.34 to 5.1 members,

with daily expenditures ranging from 2300 ± 256 FCFA to 2600 ± 300 FCFA, equivalent to approximately 510 to 530 FCFA (0.8 to 0.85 USD) per individual (Table 2).

3.2. Sensory Analyses and Acceptability Test of RUFs

Tables 3 and 4 present the comparative effects of organoleptic evaluations by mother-child pairs on the hedonic and acceptability characteristics of the two local formulae, cocoa-based (COF) and cashew-based (CAF), compared to the reference food (Plumpy'Sup®).

Table 3. Sensory Acceptability Analysis of Tested Foods by Mothers.

Parameters (M ± SD)	Plumpy'Sup® (n = 18) (1)	COF (n = 18) (2)	CAF (n = 18) (3)	p-value ¹	p-value ²		
					1 vs 2	2 vs 3	1 vs 3
Color	4.9 ± 0.2	4.8 ± 0.4	4.9 ± 0.3	ns	-	-	-
Aroma/Flavor	4.8 ± 0.4	4.5 ± 0.6	4.8 ± 0.3	0.042	0.041	0.04	ns
Taste (Sweetness)	4.9 ± 0.2	4.0 ± 0.4	4.2 ± 0.1	0.008	0.007	ns	0.005
Texture (Smoothness)	4.8 ± 0.3	4.5 ± 0.6	4.7 ± 0.2	0.015	0.017	ns	0.013
Overall Appreciation	4.9 ± 0.2	4.9 ± 0.2	4.9 ± 0.3	ns	-	-	-

Notes: Each value represents the percentage or mean ± standard deviation (M ± SD) for 18 participants per group. After a univariate analysis of variance (ANOVA), mean comparisons were performed using the Bonferroni test at a 5% threshold.

Table 4. Analysis of Food Consumption and Acceptability of Tested Foods by Children.

Parameters (M ± SD)	Plumpy'Sup® (n = 18) (1)	COF (n = 18) (2)	CAF (n = 18) (3)	p-value ¹	p-value ²		
					1 vs 2	2 vs 3	1 vs 3
Quantity of Food Offered (g)	15.1 ± 0.2	14.9 ± 0.4	15.2 ± 0.1	ns	-	-	-
Quantity of Food Consumed (g)	8.9 ± 4	8.8 ± 5	10.9 ± 2	0.017	ns	0.013	0.014
Food Consumed / Food Offered (%)	58.94 ± 20	59.06 ± 12.5	71.71 ± 20	0.018	ns	0.014	0.017
Energy from Food Consumed (kcal)	47.98 ± 21.6	46.13 ± 26.2	58.65 ± 10.8	ns	-	-	-
Quantity of Water Offered (g)	127 ± 2	125 ± 4	126 ± 3	ns	-	-	-
Quantity of Water Consumed (g)	49.3 ± 4	50.4 ± 2	48.9 ± 6	ns	-	-	-
Water Consumed / Water Offered (%)	38.82 ± 2	40.32 ± 0.5	38.81 ± 2	ns	-	-	-
Consumption Duration (min)	8.1 ± 2	7.9 ± 3	9.9 ± 1	0.020	ns	0.016	0.014
Consumption Rate (g/min)	1.10 ± 2	1.11 ± 1.6	1.10 ± 1	ns	-	-	-

Notes: Each value represents the percentage or mean ± standard deviation (M ± SD) for 18 children per group. After a univariate analysis of variance (ANOVA), mean comparisons were performed using the Bonferroni test at a 5% threshold.

The results reveal a significant influence of the three formulae on the mothers' level of appreciation at the 5% threshold. Except for the parameters related to color and overall appreciation, mothers expressed significant differences in their perception of the formulae. Plumpy'Sup® stood out with a more pronounced sweet taste and a smoother texture compared to COF and CAF. Furthermore, the mothers' satisfaction level was significantly higher for Plumpy'Sup® and CAF compared to COF (Table 3).

In terms of acceptability, children consumed significantly more CAF (10.9 ± 2 g) than Plumpy'Sup® (8.9 ± 4 g) and COF (8.8 ± 5 g). This corresponded to average consumption percentages of $71.71 \pm 20\%$ for CAF, $58.94 \pm 20\%$ for Plumpy'Sup®, and $59.06 \pm 12.5\%$ for COF. However, no significant differences were observed regarding the energy provided by the foods consumed or the amount of water consumed.

Regarding the duration of consumption, COF recorded the shortest duration (7.9 ± 3 minutes), followed by Plumpy'Sup® (8.1 ± 2 minutes) and CAF (9.9 ± 1 minute). Nevertheless, no significant differences were observed in the consumption rate (Table 4).

4. Discussion

This study aimed to evaluate the acceptability of food formulas through two approaches: a hedonic evaluation conducted with mothers and a food consumption test performed with children who were either nutritionally normal or moderately malnourished, aged 6 to 59 months.

The characteristics of the study population revealed a predominance of girls, consistent with [6]. However, similar studies, such as [14], reported a higher proportion of boys. Regarding anthropometric and nutritional parameters, approximately one-third of the children (18/54) exhibited moderate acute malnutrition. Moreover, the mothers predominantly practiced mixed breastfeeding and early dietary diversification, observed in nearly half the cases (25/54). These inadequate feeding practices may explain the poor nutritional status observed among the children, consistent with findings by [15, 16] in Madagascar, and [17] in Cameroon, which demonstrated a positive correlation between early diversification and acute malnutrition.

From a socio-economic perspective, the families of the participating mothers had low daily expenditures, ranging from 509.80 FCFA (Group 2) to 543.48 FCFA (Group 3). These amounts are below the poverty line of 737 FCFA per day but above the extreme poverty line set at 335 FCFA per day [18]. Globally, these families are in extreme poverty, defined as living on less than \$2.15 per day (approximately €64 per month).

In terms of sensory characteristics, mothers rated Plumpy'Sup® and CAF (cashew-based formula) as more acceptable than COF (cocoa-based formula) based on attributes such as color, flavor, sweetness, texture, and overall appreciation. These results align with the conclusions of [6]. The superior acceptability of Plumpy'Sup® could be attributed to its

texture and sweet taste, enhanced by specific technologies and the use of emulsifiers [19, 20]. Furthermore, the high sugar content of this formula, approximately 26 g/100 g, similar to Plumpy'Nut® or Soy RUSF [21], contributes to its pronounced sweetness. Conversely, the local formulas were limited to a sugar content of 10 to 15 g/100 g to avoid habituating children to sugar, thereby reducing the risk of chronic diseases in adulthood, as recommended by [22].

It is important to note that mothers' evaluations may not accurately reflect children's preferences. [6] demonstrated that mothers' tastes often differ from those of their children. While the primary criterion of this study was the average proportion of food consumed by children, it was deemed relevant to also assess mothers' preferences using a five-point hedonic scale to compare the overall acceptability for the mother-child pair.

Regarding children's consumption, the results indicate significantly higher acceptability for CAF ($71.71 \pm 20\%$) compared to COF ($59.06 \pm 12.5\%$) and Plumpy'Sup® ($58.94 \pm 20\%$). These findings suggest that children prefer local formulas, with a marked preference for CAF (cashew-based), followed by COF (cocoa-based) and Plumpy'Sup®. Thus, results based on mothers' hedonic evaluations should be interpreted cautiously, as similar studies conducted in Mexico and Ghana [23] confirmed that mothers' preferences do not always align with those of their children.

5. Conclusion

In summary, while mothers preferred the sensory qualities of Plumpy'Sup®, children showed better acceptability and higher consumption of the local formulas, particularly the cashew-based formula (CAF). These results highlight the importance of developing local, balanced nutritional solutions tailored to children's needs, while considering socio-economic realities.

Abbreviations

n	Number of Individuals
M	Mean
SD	Standard Deviation
N	Normal
MAM	Moderate Acute Malnutrition
MCM	Moderate Chronic Malnutrition
MU	Moderate Underweight
FCFA	Franc of the French Colonies of Africa
USD	United States Dollar
1 USD	636.5 FCFA
COF	Cocoa-based Local Formula
CAF	Cashew-based Local Formula
ns	Not Significant
1	ANOVA
2	Post-hoc

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Author Contributions

Audrey Herbert Yépié: Conceptualization, Methodology, Supervision, Validation, Writing – original draft, Resources

Nina Laurette Ahuéfa: Data curation, Investigation, Writing – review and editing

Jean-Jacques Diagou: Data curation, Investigation, Writing – review and editing

Anin Louise Anin-Atchibri: Project administration, Methodology, Supervision, Validation

Odile Sassor AkéTano: Methodology, Supervision, Validation

All authors contributed significantly to the preparation of this article, read, and approved the final version of the manuscript

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Data Availability Statement

The data are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

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