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NUTRIENT OPTIMIZATION IN COMPLEMENTARY FOOD FLOUR USING ORANGE-FLESHED SWEET POTATO, CRICKET FLOUR, FINGER MILLET AND COWPEA LEAVES

Guilamba CJ[1]*, Watako AO[1] and SO Konyole[2]

Cátia Júlio Guilamba

*Corresponding author email: catiajulio006@gmail.com
ORCID: https://orcid.org/0009-0002-9058-5657

[1]Department of Plant, Animals and Food Sciences, Jaramogi Oginga Odinga University of Science and Technology, P.O Box 210-40601, Bondo, Kenya

[2]Department of Nutritional Sciences, Masinde Muliro University of Science and Technology, P.O. Box 190-50100, Kakamega, Kenya

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ABSTRACT

Global child health is greatly affected by deficiency of essential nutrients especially among the low-income countries in Africa. Developing affordable strategies is crucial for addressing these deficiencies and enhancing food security. This research sought to address this critical gap for infants from 6 to 12 months by exploring the potential of complementary food produced using a root vegetable, specifically orange-fleshed sweet potato (*Ipomoea batatas*), traditional green vegetables, cowpea leaves (*Vigna unguculata* L. Walp), cereal finger millet (*Eleusine coracana*) and house cricket (*Acheta domesticus*) for enhancing the macronutrient and micronutrient consumption and improving food security. Formulations were optimized using NUTRISURVEY software through linear programming, where three different complementary foods, CF1 containing 45% finger millet, 25% orange fleshed sweet potato (OFSP), 20% house cricket, 5% cowpea leaves, 4% coconut oil and 1% sugar, CF2 including 40% OFSP, 25% finger millet, 25% house cricket, 5% cowpea leaves, 4% coconut oil and 1% sugar, lastly CF3 made of 43% finger millet, 30% house cricket, 20% OFSP, 3% cowpea leaves, 3% coconut oil, and 1% sugar, were developed following the recommended dietary allowance for this target group. Nutrient content analysis was conducted using proximate and mineral analysis, and safety analysis through microbiology analysis. One-way analysis of variance (ANOVA) was used to test the significant differences among treatments while mean differences between treatments at $p<0.05$ were separated using post-hoc Tukey Honestly Significant Difference (HSD). The results indicated that all the developed complementary foods fulfilled the recommended dietary allowance (RDA) for the nutrients, except CF1 that did not fulfil the required limit for fat content (9.1g/100g), as it fulfilled up to 94.5% of the requirement, however, it had significantly higher carbohydrates content (62g/100g) and calcium (406mg/100g). The CF3 exhibited significantly higher levels of protein (20.3g/100g), energy (417Kcal/100g), and iron (17.7mg/100g) compared to CF1 and CF2. The CF1 contained 17.2g/100g of protein, 401Kcal/100g of energy, and 15.7mg/100g of iron, while CF2 had 20.1g/100g of protein, 416Kcal/100g of energy, and 17mg/100g of iron. The concentration of retinol equivalent fulfilled the recommended dietary allowance for CF2 (599µg/100g) and CF3 (646µg/100g), however CF1(217µg/100g) did not meet the RDA for this nutrient. Additionally, all the tested safety parameters were within the established limit for the acceptability of powdered foods, making orange fleshed sweet potato, cowpea leaves, finger millet and house cricket optimal ingredients for infant food purpose. The study validated that orange fleshed sweet potato, finger millet, cowpea leaves, and house cricket form a nutritionally balanced combination suitable for complementary food for infants aged 6 to 12 months. Moreover, these ingredients do not compromise the microbial quality of the food. Therefore, their inclusion is recommended in the formulation of complementary foods for this age group.

Key words: Malnutrition, infants 6-12 months, complementary food, RDA, local resources

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INTRODUCTION

Complementary feeding refers to the practice of introducing additional foods to children from 6 months old when breast milk alone no longer meets their nutritional needs [1, 2]. This approach aims to offer significant nutritional benefits while enhancing breastfeeding, ensuring that the foods are both acceptable and affordable for consumers [1, 2]. In many developing countries in Africa, complementary foods primarily depend on staple cereals such as maize, rice, millet and wheat. However, these foods often lack sufficient protein and essential vitamins, which can contribute to malnutrition and hinder proper growth in children [3]. Specifically, iron and vitamin A deficiencies, are in the list of the top fifteen (15) reasons of the universal health status concern, resulting in mortality of more than one million children per year [4]. One strategy for addressing food insecurity among poor people is by providing access to diverse, nutritious and sustainable diets [5]. House cricket (*Acheta domesticus*) from orthoptera species, is one of the common insects farmed worldwide [6]. House crickets are rich in protein (65% dry matter), exceeding beef (50%) and eggs (52%) [6, 8] . They provide essential amino acids like leucine and lysine [7] along with minerals, vitamins and healthy fats, including omega-3 and omega-6 [8]. Crickets also contain about 8.75 mg of easily absorbed heme iron and 5.4 mg of vitamin B12 per 100 g of dry matter [7]. Aligned to insects, other components with the capacity to provide nutrients required for the human diet are vegetables, as they are rich in proteins and vitamins. Cowpea (*Vigna unguculata* L. Walp) is an indigenous African vegetable used for food and feed, with potential to improve food and nutrition security in sub-Saharan Africa [9]. Cowpea leaves are rich in protein, vitamins (provitamin A, folate, thiamin, riboflavin, vitamin C), and minerals (calcium, phosphorus, iron), making them a valuable dietary supplement [10].

The World Health Organization (WHO) [36] highlights the need for affordable complementary foods, as many households cannot afford commercial options. To improve accessibility, WHO advocates for and supports the development of complementary foods using locally available resources to support vulnerable populations. The combination of orange-fleshed sweet potato and house cricket is proposed as a strategy to enhance the iron content and its bioavailability in complementary foods. Additionally, cowpea leaves have been shown to improve the bioavailability of β-carotene when consumed [11]. The integration of these ingredients may result in a synergistic effect, where cricket contributes to an increased protein and iron content, thereby enhancing iron availability for the body [6]. Meanwhile, cowpea leaves facilitate the bioavailability of β-carotene present in orange-fleshed sweet potato [11], potentially improving vitamin A absorption in children. Finger millet is a digestible carbohydrate, a characteristic which can provide significant energy to the formulated complementary food, meeting the established requirements for children aged 6-12 months. Additionally, these grains are preferred for making thick porridge, making them an important contributing factor to the desirable texture of the final product. This study thus aimed to develop nutrient-dense complementary food formulations using orange-fleshed sweet potato, cowpea leaves, finger millet and house cricket, to assess their nutritional and microbiological quality for infants aged 6–12 months.

MATERIALS AND METHODS

Study area

The study was conducted at the Food Science Laboratory of Jaramogi Oginga Odinga University of Science and Technology (JOOUST) in Siaya County, Kenya. Selection of this area was due to the local availability of the target ingredients (orange-fleshed sweet potato, cowpea leaves, finger millet and cricket) and their relevance to food and nutrition insecurity in the region.

Sampling design

Purposive sampling was used for sourcing the ingredients from local markets and individual farmers. Each ingredient was obtained from a single farmer with one batch collected for orange fleshed sweet potato, finger millet and house cricket. For cowpea leaves, two separate batches were harvested from the same farm. The three complementary foods developed were analysed in nutritional, mineral and microbiological parameters with each test conducted in triplicate using samples from the same batch. No randomization was applied in assigning treatment or during laboratory tests.

Experimental schematic diagram

Figure 1 presents a schematic diagram of the experimental process, illustrating the sequence from ingredient selection to nutritional and microbial evaluation. A completely randomized design (CRD) was employed, involving three treatments (CF1, CF2 and CF3), each analysed in triplicate.

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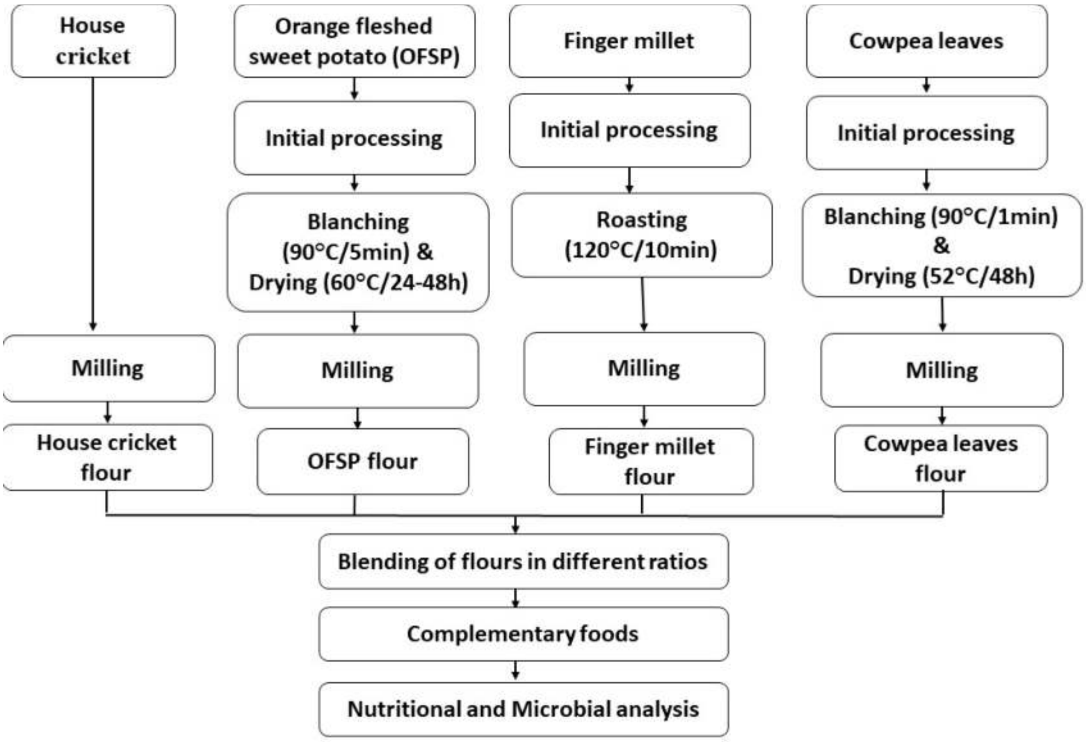

Figure 1: Schematic diagram of the experimental process

Source of ingredients and flours preparation

Orange-fleshed sweet potatoes were sourced from farmers in Siaya County, while 500g of crickets were purchased from a farmer in Kisumu, Kenya. Finger millet was obtained from an open-air market in Bondo, and cowpea leaves were cultivated at JOOUST Main Campus. Coconut oil 100% virgin, free from cholesterol and trans fat and fine granule size of sugar for enhancement of palatability and acceptance of the complementary foods were bought from a supermarket in Kisumu. All ingredients were carefully selected for high quality and taken to the JOOUST food science laboratory for processing. After delivering at the food laboratory, orange-fleshed sweet potatoes were cleaned, peeled using a kitchen knife, and soaked in a 2000 ppm ascorbic acid solution for 15 minutes to preserve the color based on findings reported by Azzahra [12]. They were then sliced to approximately 1.4 cm thickness, blanched at 90°C for 5minutes, and dried in a forced-air drying oven (Biobase, Model number BOV-V7OF) at 60°C for approximately 48 hours until a constant weight was reached [13]. Fresh cowpea leaves harvested at four weeks of maturity underwent a sorting process to remove wrinkled or damaged leaves, then washed to eliminate any foreign particles before blanching at 90°C for one minute [14]. The blanched leaves were oven-dried at 52°C for 48 hours, although nutrient degradation was not assessed, these conditions are regarded as safe for preserving nutrients in these leafy vegetables [15]. Finger millet grains were sorted to exclude foreign particles, then washed and allowed to drain excess water for 10 minutes, before undergoing roasting in an oven at 120°C for 10 minutes. This procedure is essential since it lowers the antinutrient factors such as phytates and tannins, which can inhibit the bioavailability of iron and other essential minerals [16]. All dried ingredients were milled into fine flour using a grinder (YUZHONG, model YZ-15-T-2000A). The composite flours were formulated as follow: CF1 contained 45% finger millet, 25% orange fleshed sweet potato (OFSP), 20% house cricket, 5% cowpea leaves, 4% coconut oil and 1% sugar; CF2 included 40% OFSP, 25% finger millet, 25% house cricket, 5% cowpea leaves, 4% coconut oil and 1% sugar, and CF3 consisted of 43% finger millet, 30% house cricket, 20% OFSP, 3% cowpea leaves, 3% coconut oil, and 1% sugar (Table 1), and stored in an airtight container at room temperature (25°C) protected from moisture and light for further use. Samples were used for analysis the day after formulation.

Formulation of the complementary foods

The process of formulation and optimization of the complementary foods was done utilizing NUTRISURVEY software to determine the proportions of ingredients needed to fulfil the recommended dietary allowance of energy (400Kcal/100g), carbohydrate (45g/100g), fat (10g/100g), protein (9.1g/100g), retinol equivalent (400µg/100g) and iron (9.3mg/100g) as specified in the Codex guidelines [22] for complementary food for infants 6 to 12 months old. Consequently, linear programming was applied to develop flour blends that could provide optimal levels of the key nutrients. Blends that achieved at least 90% of the recommended daily intake for the target nutrients were then chosen for further preparation into porridge. Therefore, three sample formulations were generated based on the selected flour blends combinations using the software. As shown in Table 1, complementary food 1 (CF1) had 45% of finger millet, 25% of orange fleshed sweet potato, 20% of house cricket, 5% of cowpea leaves, complementary food 2 (CF2) contained 40% of orange fleshed sweet potato, 25% of finger millet and house cricket equally, 5% of cowpea leaves and complementary food 3 (CF3) had 43% of finger millet, 30% of house cricket, 20% of orange fleshed sweet potato, 3% of cowpea leaves and coconut oil respectively. All complementary foods had 1% of sugar, CF1 and CF2 contained 4% of the coconut oil in their composition. Orange-fleshed sweet potato was added in the formulations as the main source of vitamin A and energy; finger millet added as a potential source of energy, as orange fleshed sweet potato cannot supply the required amount of energy for children 6-12 months old; cricket was added to supplement the protein and iron; cowpea leaves, as a source of protein and iron; coconut oil and sugar were incorporated to add the energy, and fats to enhance the flavour. Consequently, with this combination it was possible to come up with a complementary food which delivers balanced nutrients to infants 6 to 12 months old.

Food processing

The mixture of composite flours (orange fleshed sweet potato, finger millet, cricket, cowpea leaves, sugar and coconut oil) was toasted in an oven at 100°C for 45 minutes, mixing every 5 minutes to ensure uniform toasting of the flours. This procedure improves shelf life of the flours by reducing the moisture content and microbial load, thereby enhancing product safety. Additionally, it improves the flavor and aroma, contributing to the acceptability of the complementary food flours [2, 3]. Then, the flours were properly blended in a food mixer (HYPERMAERT LTD model CS-B7) at a speed of 2 Rpm for 10 minutes. These flours can be reconstituted into porridge by adding water or milk and boiling for 5 minutes, as recommended by the Codex Alimentarius [35].

Determination of the nutritional composition of the complementary food

Nutritional analyses were performed following the methods outlined by the Association of Official Analytical Chemists (AOAC) [17]. Moisture content was determined through the oven-drying method at 105°C for five hours (AOAC 930.15). The crude protein content was analyzed using the Kjeldahl method, where the nitrogen content was measured and multiplied by a conversion factor of 6.25. Fat content was assessed using the Soxhlet extraction technique, while crude fiber was determined through a sequential process involving acid digestion using 150mL of 1.25% (w\v) of sulphuric acid (H_2SO_4), filtration, and alkaline digestion 150 mL of 1.25% of sodium hydroxide (NaOH), per sample. Ash content was determined by incinerating the samples in a muffle furnace at 600°C for two hours. Carbohydrate was calculated as the difference between 100 and the sum of the percentages of moisture, protein, fat, ash and crude fibre. The minerals content analysis were conducted following standard procedures. Zinc (Zn), Iron (Fe), and Calcium (Ca) were quantified using an Atomic Absorption Spectrophotometer (AAS) and Potassium (K), Sodium (Na), Magnesium (Mg) and Phosphorus (P) were analysed using flame photometry.

Quantification of β-carotene level

The concentration of β-carotene was measured using the standard procedure outlined by Irakisa [18]. A 5 mg sample was mixed with 10 mL of acetone and placed in a 100 mL volumetric flask, then filtered. The residue was re-extracted with another 10 mL of acetone. The combined 25 mL extract was evaporated using a Rotary Evaporator, then dissolved in 1 mL of petroleum ether and purified through a chromatographic column. The cromatographic column (silica gel 60, length 10 cm,

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diameter 1 cm) was eluted with 25 mL of petroleum ether, and 2 mL of the eluate was analyzed for absorbance at 440 nm using a spectrophotometer (CE 4400 UV-Vis Double Beam Scanning Spectrophotometer). A calibration curve was constructed using standard β-carotene solutions. Retinol equivalent was calculated using the conversion factor: 12 µg of beta-carotene equals 1 µg of retinol [19].

Estimation of β-carotene concentration was performed using the standard curve, as below:

$$mg\ of\ \beta - \text{carotene}/100g = \frac{\mu g\ of\ \beta - \text{carotene}/100\text{g}\ read\ from\ standard\ curve * dillution\ factor * 100}{Volume\ of\ the\ sample\ (mL) * 100}$$

Microbial analysis

Microbial analyses were conducted the day after formulation of the food flours following standard methods described by the Association of Official Analytical Chemists [17] under aerobic incubation atmosphere using Biobase BJPX-H160 incubator. Total coliform count (TCC) was determined by serially diluting the sample up to 10^{-5}, pouring MacConkey Agar over it, and incubating at 37°C for 24 hours. Enumeration of *Staphylococcus aureus* followed [20] with modifications, using Baird Parker Agar with Egg Yolk Tellurite Emulsion. *Salmonella* and *Shigella* were assessed via the pour plate method on Deoxycholate Citrate Agar, while yeasts and molds were analyzed using Potato Dextrose Agar, following the procedure described by da Rosa [21]. Incubation was at 28°C for 48 hours for fungi and 37°C for 24 hours for bacterias. Colony counts were expressed as CFU/g, calculated by multiplying the number of colonies by the dilution factor and dividing by the plated volume. Each parameter was analysed in triplicate after serial dilution up to 10^{-5}.

Data analysis

Microsoft Excel was utilized to document the data for this study. The Shapiro-Wilk test was employed to assess the normality of the data, while the Levine's test was used to examine the homogeneity of variance. Analysis of variance (ANOVA) was conducted to see if there were any statistically significant variations in the means of the nutrient composition and microbial load of the various complementary foods (CF1, CF2, CF3). The Tukey's Honestly Significant Difference (HSD) test with the significance level set at 95% ($p < 0.05$) was performed to determine which individual formulation was different from the other. All analyses were carried out utilizing the R-programming language software version 4.2.1 (R Core Team) using the packages stats, agricolae and multcomp.

RESULTS AND DISCUSSION

Nutrient composition of the ingredients

The proximate composition of the ingredients: house cricket (*Acheta domesticus),* orange fleshed sweet potato, cowpea leaves and finger millet used in the development of the complementary foods are presented in Table 2. The moisture content was in the range of 5.25% to 9.28%, with significant differences among the ingredients' flours where, cricket and orange fleshed sweet potato presented the lowest values of 5.25% and 6.14%, respectively, cowpea leaves (7.28%) and finger millet 9.28%, with higher moisture content. These values were significantly lower ($p<0.05$) than the standard limits (14% or less) for flour moisture [22]. Moisture content is a crucial parameter for flour products as it is associated with microbial growth and hydrolysis of fat, impacting the shelf-life of the food products [23]. Low moisture content of the ingredient flours suggests stability and extended shelf-life of the complementary foods. Cricket flour exhibited the highest protein content (55.7g/100g), fat content (21.4g/100g), falling within the range observed by Kipkoech [8], where fat content in this insect seemed to vary from 12.67 to 25g/100g. Orange fleshed sweet potato had the highest carbohydrate content (83.9g/100g) among the ingredient flours, followed by cowpea leaves which had (50.3g/100g) and the lowest amount was detected in the cricket (6.38g/100g). This is supported by the findings of Harahap [24] who reported that sweet potatoes contain 50-80% carbohydrates (dry weight), primarily as starch. This high starch content enhances the sweetness and viscosity of complementary food formulas [22]. Additionally, orange fleshed sweet potato is a rich source of β-carotene (provitamin A), calcium (Ca), and iron (Fe), making it a key ingredient in improving the nutritional value of the developed complementary foods [18] . Finger millet had the second highest carbohydrate content (76.6g) among the ingredient flours, aligning with previous findings that reported carbohydrate levels of finger millet ranging from 75 to 83.8g [25]. This highlights its role as a significant energy source in the complementary food formulations. Cowpea leaves had the second highest protein content (26.2g/100g), fat content (4.48g/100g) and the highest dietary fiber content (9.17g/100g). These values align with the findings of Owade [9], which reported the protein and fat content of blanched and oven-dried cowpea leaves to range between 4.0g/100g to 31.86g/100g and 4.33g/100g to 12.91g/100g, respectively, highlighting their potential role in improving both protein intake and dietary fiber consumption. However, the ash content presented in this study (5.47g/100g) is lower than the 11.15g/100g observed by Enyiukwu [26]. This variation may be attributed to differences in maturity and harvest stage, as for the present study leaves were harvested four weeks after planting, whereas in the other study, leaves were

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collected at eight weeks. Younger leaves may contain lower ash content than mature leaves due to differences in mineral accumulation over time [27].

Nutrient composition of the developed complementary foods
The proximate composition and energy values of the formulated complementary foods (CF) are presented in Table 3.

The moisture content of the developed complementary foods ranged from 2.97% to 4.15%, where CF1 had the highest value (4.15%) and CF3 the lowest (2.97%), falling within the recommended limits (<5%) set by Codex standards [35], indicating a potential microbial stability and prolonged shelf-life of the developed products. This can be attributed to the lower moisture content of the ingredient flours (Table 2). The findings are consistent with those reported by Marcel [22], which indicated a 4.90% rate for the formulated complementary food. Among the formulations, CF1 exhibited significantly lower energy value (401.40Kcal/100g) than CF2 and CF3, yet it contained the highest carbohydrate content (61g/100g) (Table 3). This can be related to the level of cricket added in the CF2 and CF3 which was higher than the amount added in CF1, as cricket has the potential to enhance the energy content of complementary food.

A significant higher level of fat (12.8g/100g) and protein (20.3g/100g) was detected in CF3 than CF1 and CF2 (Table 3). Studies have demonstrated that incorporating edible insects into cereal-based formulations significantly enhances both protein and fat content in food products [16]. In line with this, CF3 contained approximately more protein and fat, highlighting the contribution of cricket flour as a high-quality protein source.

All the developed complementary foods (CF1, CF2 and CF3) fulfilled the recommended dietary allowance level of energy (400Kcal/100g), carbohydrate (45g/100g) and protein (9.1g/100g). However, the fat content of CF1 met 94.2% of the stablished level 10g/100g in the Codex guidelines for infants aged 6 to 12 months. This difference may have been caused by the differences in the flour proportion thereby deviating it from the standard level, as it had the lowest amount of house cricket in its formulation (Table 1) and this ingredient had the highest fat content (Table 2) which highly influenced the fat content values of the developed complementary foods [16].

The carbohydrate content of the complementary foods differed significantly, with CF3 containing 10.63% less carbohydrate than CF1 and 5.24% less than CF2. The higher carbohydrate concentration in CF1 can be attributed to its greater proportion of finger millet and orange fleshed sweet potato, both are rich in carbohydrates.

Finger millet is primarily composed of carbohydrates [25], while orange fleshed sweet potato is also high in carbohydrates and is widely recognized as a staple food due to its substantial starch content [22]. The fiber content of all developed complementary foods was below 6%, with no significant differences, aligning with standard recommendations. Low fiber content is preferred in infant formulations to prevent bulkiness and flatulence, as infants have an underdeveloped digestive system [28]. Excess fiber may increase water absorption and reduce essential energy and nutrient intake, impacting growth in children under 12 months [22].

Mineral content of the complementary foods

The level of minerals in the developed complementary foods are presented in Table 4. The CF3 had the highest iron content (17.7 mg/100g) than CF1 (15.7 mg/100g) and CF2 (17 mg/100g). Similarly, CF3 had the highest zinc content (33.3 mg/100g), significantly exceeding CF2 (8.3 mg/100g) and CF1 (6.9 mg/100g). Despite these differences, all three complementary foods fulfilled the recommended dietary allowance for these minerals.

This is likely due to the inclusion of cricket flour, a rich source of essential minerals like iron, zinc and manganese [8], which supports micronutrient intake and helps address deficiencies. Iron, essential for hemoglobin production, is particularly crucial in infants' diets, as its deficiency can affect growth during the weaning phase [28].

The CF2 presented the highest phosphorus content (38mg/100g), however lower than the standard recommendation, followed closely by CF1 (36mg/100g), while CF3 had the lowest phosphorus concentration (32.7mg/100g) differing significantly from CF1 and CF2. Among the formulated complementary foods, CF3 had the highest sodium concentration (228mg/100g) compared to CF1 and CF2 which presented 93.3 mg/100g and 184mg/100g, respectively. Similar to these findings, previous research has reported high sodium levels ranging from 147.20 to 269.70mg/100g in the developed complementary foods [22]. These variations likely result from differences in ingredient composition and processing. In this study, sodium content mainly comes from orange-fleshed sweet potato, a known source of sodium (~30 mg/100 g) [22]. However, the highest level (228 mg/100 g) was found in CF3, despite its lower proportion in the formulation (Table 1). Magnesium ranged from 15.7mg/100g to 17.7mg/100g, with CF2 having the highest level, though still below the RDA. In contrast, Ndife [29] reported higher magnesium levels (88.62–178.05 mg/100 g) in a maize, soybean and orange-fleshed sweet potato snack, likely due to magnesium-rich ingredients not used in this study. Complementary food 1 had significantly more calcium than CF2 and CF3, with CF2 having the lowest. This may be due to calcium-rich ingredients like finger millet and cowpea leaves, which

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contain up to 1615.2 mg/100 g [30] and 162–358 mg/100 g, respectively [31]. In contrast, Laryea [28] reported lower calcium concentration of 23.91 mg/100g in orange fleshed sweet potato-based complementary foods. This difference is probably caused by their use of lower-calcium ingredients like soybean, amaranth grains, and pumpkin seeds, compared to the higher-calcium ingredients in this study. Potassium ranged from 513 mg/100g to 615 mg/100g, where CF3 showed a significant increase 615 mg/100g while CF1 had a significant lower concentration (513 mg/100g) of this mineral (Table 4).

Retinol equivalent concentration in the developed complementary food

Figure 2 illustrates the retinol equivalent concentration for the complementary foods. A significant difference ($p<0.05$) was observed among the three complementary foods. The CF3 exhibited the highest retinol equivalent concentration (646µg/100g), followed by CF2 (599µg/100g) and the lower concentration was observed in the CF1 with 217µg/100g.

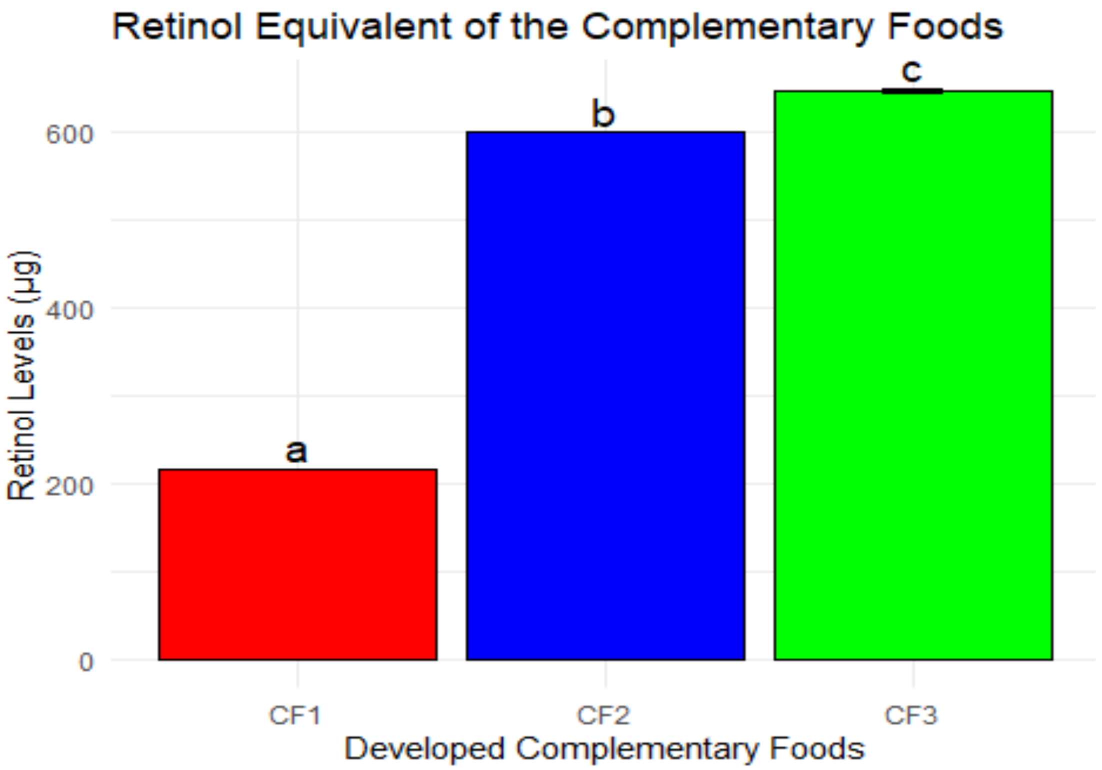

Figure 2: Mean ± standard error. Bars with different letters in the same graph differ significantly ($p<0.05$)

Complementary food 1 did not meet the standard recommendation (400µg/100g) for retinol equivalents, reaching 54.25%. Variations in retinol may result from differences in orange-fleshed sweet potato content, a key source of provitamin A carotenoids [32,33]. Rich in β-carotene, it helps boost micronutrient density alongside house cricket. Daily consumption of orange-fleshed sweet potato improved vitamin A status in children in rural Mozambique [33].

Microbial quality of the complementary foods

Table 5 presents the microbiological analysis results of the three developed complementary foods, focusing on food safety indicators [34]. Total coliform counts were negligible (<1 CFU/g) complying with safety guidelines that set a maximum of 3 CFU/g [36]. Similar findings were reported by Agbemafle [37] in a study conducted with orange fleshed sweet potato and Weanimix. The yeast and mold counts in the developed formulas were below the acceptable limit (3Log10 CFU/g). None of the samples showed growth of Salmonella or Shigella, consistent with Laryea [28]. These findings confirm the microbial safety and suitability of the complementary foods for infant consumption. *Staphylococcus aureus* ranged from 3.21 to 3.72 Log10 CFU/g, with no significant differences among the complementary foods. This bacterium is commonly found on human skin and in the environment, with contamination typically occurring through physical contact, surfaces or respiratory droplets [38, 39]. Additionally, edible insects may carry *Staphylococcus aureus* in their gastrointestinal tract, influenced by their diet [40]. Concentrations above 10^5 CFU/g are needed for heat-stable enterotoxin production, and the levels in these formulas do not pose a toxin risk [34]. Proper cooking effectively eliminates bacteria, with thermal processing reducing microbial contamination and enhancing food safety.

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

The blend of orange-fleshed sweet potato, finger millet, cowpea leaves and cricket provides a nutritionally balanced complementary food for infants aged 6 to 12 months, rich in protein, iron, vitamin A, and other micronutrients. The inclusion of house cricket did not significantly affect the microbiological quality, with total coliforms, yeast, molds, Salmonella and Shigella below acceptable limits. While *Staphylococcus aureus* levels were slightly higher, they were insufficient to produce heat-stable enterotoxins. Further assessment is required to evaluate protein availability and conduct stability and safety tests to determine the shelf life of the complementary foods. Additionally, a Randomized Controlled Trial (RCT) should be performed to assess its impact on the nutritional status of infants aged 6-12 months.

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Ethical consideration

This study did not involve human or animal subjects. Ethical approval will be sought prior to any in vivo application or testing of the formulated products in infants.

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Table 1: Ingredient flour proportion per 100g of complementary food

	Quantities (g)		
Ingredients	**CF1**	**CF2**	**CF3**
Cowpea leaves	5	5	3
Orange fleshed sweet potato (OFSP)	25	40	20
House cricket	20	25	30
Finger millet	45	25	43
Coconut oil	4	4	3
Sugar	1	1	1

CF1=complementary food 1; CF2= complementary food 2; CF3=complementary food 3

Table 2: Nutritional composition of the ingredient flours used in complementary foods

	Nutritional composition					
Ingredient	**Moisture (%)**	**Ash (g/100g)**	**Fiber (g/100g)**	**Protein (g/100g)**	**Fat (g/100g)**	**Carbohydrate (g/100g)**
CP	7.89±0.11[a]	5.52±0.27[a]	9.17±0.16[a]	26.2±0.03[a]	4.48±0.02[a]	50.3±1.72[a]
FM	9.28±0.57[ab]	2.71±1.13[a]	3.33±0.16[b]	6.46±0.20[b]	1.56±0.02[b]	76.6±1.35[b]
HC	5.25±1.04[b]	4.64±1.63[a]	6.61±0.43[c]	55.7±0.03[c]	21.4±0.02[c]	6.38±0.93[c]
OFSP	6.14±0.33[b]	2.79±0.16[a]	2.82±0.84[c]	2.73±0.06[d]	1.62±0.02[c]	83.9±0.35[d]
p-value	0.007	0.205	<0.001	<0.001	<0.001	<0.001

Results are expressed as mean ± standard error, n=3. Values with equal superscripts in the same column are not significantly different (p>0.05). CP=cowpea leaves; FM=finger millet; HC=house cricket; OFSP=orange fleshed sweet potato

Table 3: Nutritional composition of the developed complementary foods

Nutrient	**CF1**	**CF2**	**CF3**	**p-value**	**RDA**	**Reference**
Moisture, %	4.15±0.44[a]	3.47±0.29[a]	2.97±0.28[a]	0.132	<5	Codex, 1991
Energy, Kcal/100g	401±1.75[a]	416±3.00[a]	417±1.91[b]	0.004	400	Codex,1991
Carbohydrate, g/100g	62±0.51[a]	58.8±0.77[b]	55.1±0.27[c]	<0.001	45	WHO, 1998
Protein, g/100g	17.2±0.02[a]	20.1±0.02[a]	20.3±0.18[b]	<0.001	9.1	WHO, 1998
Fat, g/100g	9.4±0.04[a]	11.1±0.02[b]	12.8±0.03[c]	<0.001	10	Codex, 1991
Fiber, g/100g	3.8±0.66[a]	3.9±0.57[a]	5.4±0.27[a]	0.130	5.0	Codex, 1991
Ash, g/100g	3.4±0.99[a]	2.4±0.50[a]	3.3±0.33[a]	0.570	-	

Results are expressed as mean ± standard error, n=3. Values with equal superscripts in the same column are not significantly different (p>0.05)
CF1:5g cowpea leaves + 25g orange fleshed sweet potato + 20g cricket + 45g finger millet + 4g coconut oil + 1g sugar
CF2:5g cowpea leaves + 40g orange fleshed sweet potato + 25g cricket + 25g finger millet + 4g coconut oil + 1g sugar
CF3:3g cowpea leaves + 20g orange fleshed sweet potato + 30g cricket + 43g finger millet + 3g coconut oil + 1g sugar
RDA=Recommended Dietary Allowance

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Table 4: Mineral composition of the developed complementary foods

Mineral content (mg/100g)	CF1	CF2	CF3	p-value	RDA	Reference
Phosphorus	36±0.57[a]	38±0.57[a]	32.7±0.88[b]	0.004	275	WFP, 2018
Sodium	93.3±0.88[a]	184±0.57[b]	228±0.88[c]	<0.001	0.37	WFP, 2018
Potassium	513±1.45[a]	521±11.3[b]	615±2.19[b]	<0.001	-	-
Magnesium	15.7±0.33[a]	17.7±0.88[a]	17.3±0.88[a]	0.208	54-75	WFP, 2018
Calcium	406±2.60[a]	125±0.33[b]	315±4.84[c]	<0.001	260-400	WFP, 2018
Iron	15.7±0.66[b]	17±1.15[b]	17.7±0.88[a]	0.360	9.3	FAO/WHO, 2004
Zinc	6.9±0.20[a]	8.3±0.33[b]	33.3±3.33[b]	<0.001	4.6	FAO/WHO, 2002

Results are expressed as mean ± standard error, n=3. Values with equal superscripts in the same column are not significantly different (p>0.05)
CF1:5g cowpea leaves + 25g orange fleshed sweet potato + 20g cricket + 45g finger millet + 4g coconut oil + 1g sugar
CF2:5g cowpea leaves + 40g orange fleshed sweet potato + 25g cricket + 25g finger millet + 4g coconut oil + 1g sugar
CF3:3g cowpea leaves + 20g orange fleshed sweet potato + 30g cricket + 43g finger millet + 3g coconut oil + 1g sugar
RDA=Recommended dietary allowance

Table 5: Microbial quality of the developed complementary foods

Sample	Microbiology parameters (Log10 CFU/g)			
	Total coliforms	**Salmonella and Shigella**	**Staphylococcus aureus**	**Yeasts and Molds**
CF1	0.0000104±0.000[a]	Absent	3.64±0.620[a]	2.17±1.900[a]
CF2	0.0000143±0.000[a]	Absent	3.21±0.645[a]	0.84±1.460[a]
CF3	0.0000300±0.000[a]	Absent	3.72±0.374[a]	1.73±2.990[a]
Acceptable limit (Codex, 2008)	3 Log10	Absent	$<10^5$	3Log10

Results are expressed as mean ± standard error, n=3. Values with equal superscripts in the same column are not significantly different (p>0.05)
CF1:5g cowpea leaves + 25g orange fleshed sweet potato + 20g cricket + 45g finger millet + 4g coconut oil + 1g sugar
CF2:5g cowpea leaves + 40g orange fleshed sweet potato + 25g cricket + 25g finger millet + 4g coconut oil + 1g sugar
CF3:3g cowpea leaves + 20g orange fleshed sweet potato + 30g cricket + 43g finger millet + 3g coconut oil+ 1g sugar

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