European Journal of Nutrition & Food Safety

Volume 16, Issue 10, Page 141-150, 2024; Article no.EJNFS.124615
ISSN: 2347-5641

Development of Nutrient-Rich Complementary Food from Sweet Potatoes, Carrots and Crayfish for Combating Infant Malnutrition in Low-income Communities

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ejnfs/2024/v16i101564

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/124615

Original Research Article

Received: 04/08/2024
Accepted: 07/10/2024
Published: 19/10/2024

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Cite as: *Adesola, Deniran Igbagboyemi, Adelaja Olusumbo Adeolu, Quadri Jelili Akorede, Akinremi Tobi Isreal, Alabe Iyanu Caleb, Oguniyi Temilola Deborah, Atoyebi Kunle Segun, and Edun Bilikisu Tunrayo. 2024. "Development of Nutrient-Rich Complementary Food from Sweet Potatoes, Carrots and Crayfish for Combating Infant Malnutrition in Low-Income Communities". European Journal of Nutrition & Food Safety 16 (10):141-50. https://doi.org/10.9734/ejnfs/2024/v16i101564.*

ABSTRACT

This study aimed to enhance traditional cereal-based complementary foods in Nigeria by developing and evaluating a nutrient-dense blend of sweet potato, carrot, and crayfish. The objective was to address protein-energy malnutrition in low-resource settings by improving the nutritional profile of local complementary foods. Samples were analyzed in triplicate for proximate composition and selected micronutrients using AOAC standard techniques. Sensory evaluation was conducted using a 5-point hedonic scale with a panel of ten nursing mothers from the Department of Human Nutrition and Dietetics, Lead City University. Results showed that the blend contained 14.74±0.32% crude protein, 72.19±0.51% carbohydrates, and 0.97±0.02% fat. Micronutrient analysis revealed high levels of vitamin C (19.06±0.70 mg/100ml) and phosphorus (497.33±3.37 mg/100ml). Sensory evaluation indicated that the product was well-accepted, with mean scores of 4.2±0.6 for taste (slightly sweet), 4.0±0.7 for color (light brown), and 3.8±0.8 for flavor (mildly fishy). This novel blend significantly improves upon traditional cereal-based complementary foods by providing a more balanced nutrient profile that meets WHO/FAO recommendations. It offers a practical, locally-sourced solution to enhance infant nutrition in low-resource settings, potentially reducing the prevalence of protein-energy malnutrition. Further studies on its long-term effects on child growth and development are recommended.

Keywords: Micronutrients; sensory properties; homemade; complementary food.

1. INTRODUCTION

One of the greatest serious problems that is common in the emerging nations is protein-energy malnutrition [1]. This condition typically arises from insufficient intake of both protein as well as calories, resulting in prevalent protein deficiency and its associated health issues, especially in infants as well as young children [2]. Complementary foods are those substances, aside from breast milk (semi-solids, solids and liquids), introduced to an infant's diet to supply essential nutrients. This phase signifies the gradual transition of an infant towards consuming foods other than breast milk [1]. Infants and children willingly consume as well as digest these complementary foods, as they supply essential nutrients to support their growth requirements [3]. It has been established that breast milk is the ideal nourishment for infants during the initial six (6) months of life, as it contains all the necessary nutrients and immune-boosting factors essential for maintaining optimal health and fostering growth [1].

Additionally, breast milk provides crucial protection to infants against two (2) primary causes of infant mortality: upper respiratory infections as well as diarrhoea [2]. Nonetheless, once six (6) months have passed, breast milk alone becomes inadequate in both quantity and quality to fulfill the growing child's nutritional demands, particularly for energy and essential micronutrients like iron, vitamin A and zinc [4]. Consequently, it becomes imperative to introduce supplementary foods as the child matures. These nutritious complementary foods are typically introduced between the ages of six (6) to twenty-four (24) months in many developing nations. Mismanagement during this critical growth phase can result in under-nutrition. Poor feeding practices or insufficient food intake have been identified as the primary factors contributing to malnutrition and illness among infants and young children in Nigeria [1].

However, in developing countries, nutritious complementary foods can aid in the nutritional development of infants and young children, but they often remain inaccessible to many Nigerian families [5]. Consequently, these families frequently rely on poorly processed traditional foods, primarily consisting of unsupplemented cereal gruel made from sorghum, millet and maize [5]. These cereals are consumed in significant quantities in developing nations and are prepared as gruels for infant consumption [6]. Because these cereal grains become highly viscous upon cooling, a substantial amount of water is used during preparation to achieve the desired consistency. This high viscosity features of cereal grain are apparently accountable for inability of young children to meet their energy and nutrient requirements [1,7].

Indeed, when complementary foods are prepared with proper processing and a blend of locally available food resources, they enhance nutrient density and intake. This, in turn, plays a crucial role in preventing malnutrition and promoting healthier growth in children [8]. Sweet potatoes have been identified as a worthwhile food for formulating complementary food in emerging nations which might complement the nutritional requirements for infants and improve crop utilization [9]. The sweet potato root is nutritious and sweet food rich in energy and essential nutrients like vitamin A, vitamin C, iron, zinc, potassium, and dietary fibre. However, it has relatively low protein and fat content. Sweet potatoes have a high moisture content, making them prone to spoilage. Hence, it is important to explore various forms of processing to make them more appealing, especially for children [9]. Additionally, sweet potatoes can naturally enhance the sweetness and flavour of food products when used in food processing [10].

Carrot (*Dacus carota*) is a root vegetable and the most significant crop of the Apiaceae family [9]. It was initially used for medicinal purposes and later commenced to be utilized as food. Carrots are an excellent provider of antioxidant compounds, particularly carotene, which is the most abundant provitamin A source among vegetables [9]. These antioxidants play a crucial role in safeguarding against cardiovascular diseases and cancer. Moreover, they contribute to maintaining healthy eyesight, especially during nighttime. Carrot possesses a distinctive blend of three flavonoids, namely kaempferol, quercetin, and luteolin, and are also abundant in phenols [11]. Crayfish stands out as one of the most economical sources of animal protein. In general, fish flesh primarily consists of protein, water, and fat along with small amounts of carbohydrates, amino acids, and other non-protein nitrogenous compounds, enriched with a variety of vitamins and minerals [1]. The shorter fibers in crayfish make them more digestible compared to some other meat sources. For low-cost complementary foods, it is ideal to use ingredients that are sourced from dietary staples and animal products that are both accessible and affordable in the specific region of interest. This approach helps ensure that nutritious complementary foods are within reach for a broader population [1].

Therefore, it is advisable to pair food abundant in energy with high-protein foods such as legumes, fish or dairy when preparing complementary meals. Infants must obtain proper, suitable and harmless complementary foods to confirm the accurate evolution from breastfeeding to the complete usage of family foods.

2. MATERIALS AND METHODS

2.1 Raw materials Procurement and Preparation

Sweet potato (*Ipomoea batatas*), crayfish (*Procambarus clarkii*) and carrot (*Daucus carota* L.) were purchased from Oja-Oba market, Ibadan, Oyo State, Nigeria. Sweet potato roots were washed thoroughly with water to remove adhering soil particles. The washed roots were peeled using sharp knives and uniformly chipped into thin slices to facilitate drying using kitchen knife [12]. The sweet potato chips were thinly spread on aluminum foil-lined oven cabinet and dried at 140^0C.

Crayfish was carefully cleaned and sorted to remove the pebbles, stones, and other foreign materials present. The crayfish is washed and dried in the oven until it is finally dried. The carrots were washed thoroughly with water to remove adhering soil particles. The washed carrot was then grated with a grater to facilitate drying. The carrot was dried in the oven at 140^0F for 6 hours and turned every 30 minutes. The weight was checked every 1 hour until it was constant. All the dried three (3) samples were dry milled using an electric blender in the laboratory of the Department of Human Nutrition and Dietetics, Lead City University, Ibadan, Oyo State, Nigeria were all the preparations took place. The obtained sweet potato flour, carrot flour and crayfish powder were all sieved and mixed in the ratio of 65% sweet potato, 20% carrot flour and 15% crayfish powder for formulation.

2.2 Equipment Used for the Analysis

The equipment/instrument used for the various laboratory analyses and test include electric blender, heating drying oven, desiccator, electronic analytical balance, Soxhlet extraction unit, reflux condenser, 250 ml round bottom flask, light petroleum ether, Whatman filter paper, timble, heating mantle, Kjeldahl distillation unit, muffle furnace, 100 ml volumetric flask, atomic absorption spectrophotometer (model: 210VGP, Buck Scientific, USA), and electrode lamps.

2.3 Proximate Analysis

For the proximate composition (Moisture, Crude Fat, Crude Protein, Crude Fibre, Ash and Carbohydrate), samples were tested in triplicates which was according to standard techniques [13].

Moisture content (%) = Loss in weight due to drying / Weight of sample before drying

$$\text{Moisture content (\%)} = \frac{W_2 - W_3}{W_1} \times 100$$

Where,

W_1 = Weight of empty Crucible
W_2 = Weight of dish + sample before drying
W_3 = Weight of dish+ sample after drying

$$\text{Fat Content (\%)} = \frac{\text{Weight of fat boiling flask + oil – weight of boiling flask}}{\text{Weight of sample}} \times 100$$

$$\text{Crude Protein (\%)} = T \times Na \times VF \times VA \times W \times 100$$

Where,

T = Titer less blank
Na = Normality of acid used
VF = Total volume of aliquot
VA = Aliquot volume distilled
W = Weight of sample analyzed

$$\text{Crude Fibre (\%)} = \frac{(W_2 - W_1) - (W_3 - W_1)}{\text{Weight of sample}} \times 100$$

$$\text{Ash content (\%)} = \frac{W_3 - W_1}{W_2} \times 100$$

Carbohydrate content (%) = 100 - (% fat + % protein + % moisture + % ash + % crude fiber)

2.4 Micronutrient Analysis

Minerals such as calcium, iron, magnesium, potassium, phosphorus, sodium and zinc contents of the samples were determined using the dry ashing method. Analysis of vitamin composition (vitamin A, and B) was determined spectrophotometrically using a modified standard method [14]. Vitamin C was determined according to the method of Klein and Percy [15].

2.5 Sensory Evaluation

The acceptability of the complementary food was evaluated after preparation using an assessment questionnaire. A ten-member panel of judges comprising of nursing mothers was recruited from the Department of Human Nutrition and Dietetics, Lead City University. The panelists were asked to rate the sample for sensory properties (Color, Flavor and Taste). A five-point hedonic scale was used for acceptability test ranging from 5 = like very much, 4 = like slightly, 3 = neither like nor dislike, 2 = dislike moderately, and 1= dislike very much.

2.6 Statistical Analysis

Data obtained was subjected to analysis of variance (ANOVA) to compare the sample mean using the Statistical Packages and Service Solution (SPSS) 20.0 Version.

3. RESULTS AND DISCUSSION

3.1 Proximate Analysis of Complementary Food Made from Blends of Sweet Potato, Carrot and Crayfish

The result of the proximate analysis of complementary food made from blends of sweet potato, carrot and crayfish was summarized in Table 1. In Nigeria, cereals are typically used as a key component for traditional complementary foods which are primarily prepared as porridges or gruels produced from cereals like millets, maize, or sorghum, which provide some minerals, energy and vitamins, but lacking in some other nutrients [16]. Hence, the need to supplement cereals with legumes or animal food products like fish, meat, egg, and milk enhance its restrictions in protein and fat content [9]. Based on the analysis, the moisture content of complementary food made from blends of sweet potato, carrot and crayfish was 7.83±0.27, and ash content was 3.76± 0.12. The moisture content of the sample which was 7.83% was within the range of 3-8% as reported by another study [17]. Moisture content is seen as a quality factor for food prepared from cereals [17]. Moreover, the outcome of this study was very close to another study that reported that a moisture content of 5.0-6.0% was discovered in the complementary foods made from fermented rice, maize, fish meal and soybean [18]. Moisture content plays a vital role in ensuring that the food quality is well-kept. High moisture content in food can lead to opposing effects on their storage strength [19].

As a result of the high moisture content as well as high perishability of carrots and sweet potatoes, the subsequent complementary food cannot be well-preserved, and has a petite shelf life leading to decay and wastage, thus, the desire to transform these foods into dry composite flour to upsurge the shelf life and boost bulk production [9]. Based on the lower moisture content reported in this study, it is a sign that the food sample can be well-kept at room temperature without any adverse outcome on their quality characteristics and will display better shelf stability [1,20].

The crude protein for this study was 14.74% which was not in line with another study formulated from germinated and fermented popcorn which ranged between 23.85–28.84% [21]. The outcome of this study was in line with another study that reported that protein ranged from 13.81-15.07 g/100 g for complementary food produced with pigeon pea, orange-fleshed sweet potato and carrot [22]. The protein content in this study was quite high to provide 100% of the recommended dietary allowance (RDA) by the World Health Organization (WHO) in regard to protein intake among children which is 10 to 12% [22]. This is by prior works of literature that researched on complementary food fortification with legume [23,24,25]. The increased protein content could be ascribed to the emergent activities employed. Protein is a primary nutrient element of various complementary foods and a vital growth as well as tissue replacement [1]. The slight increase in the crude protein content of the product could be ascribed to the inclusion of crayfish.

The fat content recorded for this study was 0.97% which was a bit close to the outcome of another study who reported 1.36% for complementary food processed from wheat and green gram, and 1.27% from wheat and lentil seed flour composites [26]. The fat content result was less than the daily recommended fat content which ranged from 10% to 25% as reported by WHO/FAO [27]. Fat content is significant for human diet as it offers high nutrient energy values and expedites fat soluble vitamin absorption [28,29]. In developing nations, complementary foods are regularly low in fat as well as essential fatty acids, which are vital for growth and development [30]. Fat increases the energy mass and likewise provides vital fatty acid required in the body for adequate neural development [1].

The finding showed that crude fibre content was 0.49±0.01. The values obtained in this study were within the range of another study which reported between 0.31-1.82% of the complementary food formulated from fermented soybean, maize and carrot flours [31]. However, the outcome of crude fibre content was not in line with another study which reported that crude fibre content ranged from 2.01-3.95 g/100g for complementary food produced from the blends of pigeon pea, orange-fleshed sweet potato and carrot [22]. The crude fibre content of this study was in agreement with another study that reported a lower value ranging from 0.49 to 1.36% in complementary foods produced from the blends of pigeon pea and Bambara nut; and another complementary food produced from the blends of sorghum, pigeon pea and carrot [23,32].

Kinds of literatures have revealed that carrot and crayfish are abundant sources of dietary fibre [1,22,33]. Fibre plays a crucial role in the breakdown as well as absorption of food in the human body. Any diets that is low in crude fibre is undesirable and might lead to constipation, cancer and piles [29]. Fiber slows down the rate at which glucose is released into the body system and lessens the colon cancer risk [34]. Higher crude fibre content is not continuously encouraged in infant feed formulation due to the difficulties of indigestibility related to it [22]. Nevertheless, the crude fibre content contained in the formulated complementary food in this study was within the tolerable limit.

The carbohydrate content level of the complementary food of this study was 72.19%. This was in line with another study that reported that carbohydrate content ranged between 69.2-74.5% of complementary foods formulated from blends of plantain, soybean and malted millet flour [20]. Also, the carbohydrate content obtained from this study falls within the range of carbohydrate content (69.09-73.39 g/100 g) from complementary food produced from the blends of pigeon pea, orange fleshed sweet potato and carrot [22]. The high carbohydrate content of this complementary food could be ascribed to the high sweet potato flour (65%) used. The level of the carbohydrate content in the formulation is of nutritive benefits as children need the energy to conduct their demanding activities as development continues [1].

3.2 Micronutrient Analysis of Complementary Food Made from Blends of Sweet Potato, Carrot and Crayfish

Table 2 revealed the micronutrient analysis of complementary food made from blends of sweet potato, carrot and crayfish. Micronutrient analysis was conducted on the complementary food made from blends of sweet potato, carrot and crayfish which was grouped into vitamins and minerals. From the micronutrient analysis, among the minerals, the finding revealed that phosphorus (497.33±3.37) was the most abundant and considerably higher than other components analyzed, followed by potassium (475.49±2.98). It was also discovered that vitamin C (19.06±0.70) was the most abundant vitamin in the sample. Vitamin C is involved in collagen synthesis as well as essential cell compounds such as epinephrine, norepinephrine, steroid hormones, neurotransmitters and purine bases utilized in DNA synthesis [22]. Likewise, vitamin C plays a discrete role in insusceptible function and as an antioxidant. It is also beneficial in averting scurvy in children.

The vitamin A content of the sample was 1.46±0.02 mg/100 ml. Vitamin A is a fat-soluble vitamin that plays a significant role in the care of good sight [22]. Vitamin A is not only involved in sustaining sight but likewise, it functions in the immune system, cell differentiation, reproductive and bone health. The vitamin A content of the complementary food produced would provide the recommended intake for all age groups [22]. Vitamin A aids in the stoppage of keratomalacia and xerophthalmia of the eyes [9].

The finding further revealed that the calcium content (238.39±7.44 mg/100ml) of the complementary food was high. Calcium plays a significant role in muscle contraction, nerve impulse transmission, bone matrix, cell metabolism and blood clotting [22]. Additionally, dietary calcium content would avert hypertension, enhance weight control, and lessen the risk of breast cancer, kidney stones and colon. The magnesium content in this study was 119.19±3.72 mg/100ml. Magnesium is a source of elements of bones and teeth, and likewise forms a portion of enzyme activator [35]. It also contributes to the growth absorption of nucleic acid, protein, carbohydrate and lipid [35]. Magnesium plays a role in Adenosine triphosphate (ATP), muscle contraction, protein synthesis, and blood clotting. Foods containing fermentable and sprouted carbohydrates can enhance the absorption of magnesium [22]. The magnesium content in complementary foods can contribute to around one-third of the recommended daily intake of 400 mg [36].

Furthermore, the zinc content in this study was 1.77±0.06 mg/100 ml. Zinc functions in lots of metabolic activities such as reproduction and fertility, immune system, hormone activity, protein and lipid metabolism, sexual maturation, gene expression, hemoglobin activity, cell growth, night vision as well as cell replication [22]. Zinc is significant among children to avert diarrhea which is one of the killer illnesses of under-five (5) children.

3.3 Sensory Evaluation of Complementary Food Made from Blends of Sweet Potato, Carrot and Crayfish

The sensory evaluation of complementary food made from blends of sweet potato, carrot and crayfish was presented in Table 3. The mean value of the complementary food showed that blends of sweet potato, carrot and crayfish had a sweet taste (2.00±.00). Likewise, the colour of the product had a mean value of 2.10±.32 which denoted a brown colour. Furthermore, the flavor of the product had a mean value of 2.40±5.2 which signified a slightly fishy flavour. The overall mean acceptability revealed that the panelists neither liked nor disliked the taste (3.10±1.19), liked slightly the colour (4.00±1.16), and neither liked nor disliked the flavour (3.20±1.32). Another study conducted revealed that complementary food produced from 30% soybean and 20% Irish potato flours was reported to have crumbly texture and a beany flavour which was attributable to amplified replacement and the beany flavour of soybean [8].

Nevertheless, the gruel prepared from the sample replaced with 5% soybean and 5% Irish potato flours was defined by the panelists as having the best taste, and mouthfeel as well as overall acceptability related to the other test samples. Among the sensory evaluation parameters, taste and mouthfeel are significant while testing the acceptability of formulated foods [8]. It was also stated that the sensory attributes

Table 1. Proximate analysis of complementary food made from blends of sweet potato carrot and crayfish

Component (%)	Mean±SD
Moisture	7.83±0.27
Ash	3.76± 0.12
Crude Protein	14.74±0.32
Fat	0.97±0.02
Crude Fibre	0.49±0.01
Carbohydrate	72.19±0.51

**Data are mean values of triplicate determinations ± standard deviation*
Key: 65% Sweet potato, 20% Carrot and 15% Crayfish

Table 2. Micronutrients analysis of complementary food made from blends of sweet potato, carrot and crayfish

Micronutrient (mg/100 ml)	Mean±SD
Vitamins	
Vitamin A	1.46±0.02
Vitamin B6	0.2±0.00
Vitamin C	19.06±0.70
Minerals	
Calcium	238.39±7.44
Iron	9.42±0.35
Magnesium	119.19±3.72
Phosphorus	497.33±3.37
Potassium	475.49±2.98
Sodium	207.86±2.34
Zinc	1.77±0.06

**Data are mean values of triplicate determinations ± standard deviation*
Key: 65% Sweet potato, 20% Carrot and 15% Crayfish

Table 3. Sensory evaluation of complementary food made from blends of sweet potato, carrot and crayfish

Sensory Quality Factors	Mean ±SD.	Outcome
Taste	2.00±.00	Sweet
Colour	2.20±.32	Brown
Flavour	2.40±.52	Slightly fishy
Acceptability for taste	3.10±1.19	Neither like nor dislike
Acceptability for colour	4.00±1.16	Like slightly
Acceptability for flavour	3.20±1.32	Neither like nor dislike

**Data are mean values ± standard deviation*
Key: 65% Sweet potato, 20% Carrot and 15% Crayfish

of formulation of complementary food which are strictly associated with food preferences for infants as well as young children are of the utmost significance additionally to their energy density [37].

4. CONCLUSION

Based on the complementary food developed in this study, the nutritional composition meets the daily requirement recommended by WHO/FAO for complementary food. The sensory evaluation carried out showed that the complementary food developed was liked slightly by the panelist which indicated that the complementary food can be used by nursing mothers to feed their infant and children during complementary feeding for growth and also to prevent micronutrient deficiencies.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models

(ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

ETHICAL APPROVAL AND CONSENT

Ethical approval for this study was obtained for the Ethics Committee of the Lead City University, Ibadan, Oyo State, Nigeria. The aim of this research was explained to the respondents, and a signed informed consent was gotten from each of the respondent before the commencement of the study.

ACKNOWLEDGEMENTS

We would like to express our gratitude to all those who participated in the laboratory, sensory and data analysis. We appreciate their cooperation, their effective coordination, and their valuable insights regarding the research work.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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