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Anthropometric and Biochemical Indices of Infants fed Complementary Foods developed from Millets, Orange-Fleshed Sweet Potatoes, Carrot, Periwinkle and Oyster Meat Flour Blends

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Abstract

Purpose: This study examined the anthropometric and biochemical indices of infants fed complementary foods developed from millets (M), orange-fleshed sweet potatoes (OFSP), carrot (CF), periwinkle meat (PMF) and oyster meat flour (OMF) blends.

Materials and Methods: Six different blends of flour were formulated using the recommended guideline for the formulation of complementary food for infants 6 – 12 months. The blends were as follows 89: 11 M/C; 70:30 M/OFSP; 57:32:11 M/OFSP/C; 65:20:5:10 M/OFSP/C/OMF; 49:29:7:15 M/OFSP/C/PMF and 70:13:3: 7:7 M/OFSP/C/PMF/OMF while Cerelac was used as the control diet. Thirty-five children aged 6-12 months enrolled in this study. Seven groups comprising of 5 children each consumed cerelac (control diet), millet/carrot (Test diet I) millet/OFSP (test diet II), millet/OFSP/carrot (test diet III), millet/OFSP/carrot/oyster (test diet IV), millet/OFSP/carrot/periwinkle (test diet V), and millet/OFSP/carrot/periwinkle/oyster (test diet VI), respectively.

Findings: The children were fed with 50 g/day of the diets over a 6 months period during which anthropometric (weight, length, mid-upper arm circumference, head circumference, and chest circumference) and biochemical assessments (iodine level, hemoglobin level, calcium level, and vitamin A level) were carried out before and after test product ingestion. All children fed on the test diets had an increase in anthropometric parameters. Test diet VI had the highest percentage effect on biochemical and anthropometric parameters at the end of the study. The effect of test diet VI on the hemoglobin levels of the infants was significantly ($p<0.01$) higher than other test diets.

Implication to Theory, Practice and Policy: Dietary interventions incorporating carrots, OFSP, periwinkle, and oyster exhibited favorable impacts on the nutritional well-being of infants. Consequently, it ought to be regarded as a superior choice when devising nutrition initiatives aimed at enhancing the nutritional condition of children residing in regions where millet-based porridge prevails as the primary complementary food.

Keywords: *Millet; Orange-fleshed sweet potatoes; Carrot; Periwinkle; Oyster; Anthropometric*

1.0 INTRODUCTION

Complementary feeding is a gradual process of introducing solid foods to an infant's diet alongside breast milk. Complementary foods are anticipated to be high in energy density with adequate protein composition, required vitamins and minerals to meet the nutrient needs of the infant. Poor dietary quality and feeding practices, more often, a combination of the two, are the major challenges during complementary feeding [1]. Malnutrition is on the increase in some parts of the world mostly in developing countries, Nigeria inclusive. Poverty and lack of nutritional knowledge are linked to inadequate complementary feeding, resulting in inadequate nutrient intake [2]. The major problems affecting most children, particularly infants are lack of adequate protein and micronutrients intake in terms of quality and quantity from complementary foods [3]. Traditional complementary foods in most cases are made from mono cereal gruel such as millet, guinea corn, maize, sorghum which are deficient in essential amino acids, particularly lysine. A combination of cereal, tuber, vegetables and sea foods in formulating complementary food may help to make up for the deficiency in essential amino acids and micronutrients in mono cereal traditional complementary foods.

Millets are diverse small-seeded grasses cultivated as cereal crops, and they contain approximately 7 – 12 % protein, 2 – 5 % fat, 65 – 75 % carbohydrates, and 15 – 20 % dietary fiber [4]. Among these, pearl millet possesses 12 – 16 % protein, which is deemed a significantly high proportion of protein, alongside 4 – 6 % lipids. Millets can be boiled, baked, fermented, and processed into flour, which is subsequently mixed with other flours to create supplementary foods. However, due to their plant-based nature, they have limitations in essential amino acids, exhibit low energy and nutrient density, and contain elevated levels of antinutrients like phytates and tannins [5]. The widespread utilization of millet has been linked to the prevalence of high levels of child malnutrition in certain communities. A study conducted by Isingoma *et al*. [6] demonstrated higher percentages of stunted, underweight, and wasted children in millet-consuming communities in Uganda. This highlights the pressing need for research into improving the nutritional quality of millet-based complementary foods, particularly in developing countries grappling with prevalent malnutrition.

Orange-fleshed sweet potato is a low-cost crop, which is part of staple foods in sub-Saharan Africa [7]. The tubers are rich in starch, sugars, minerals and vitamin A in the form of β-carotene. Thus, low-income families with limited access to expensive vitamin A-rich animal foods such as egg, milk, meat, oily fishes amongst others can meet the daily requirement of vitamin A along with some other essential nutrients through increased consumption of Orange-fleshed sweet potato [8]. The tuber can also be used in composite with cereals and carrot in complementary food formulation. Carrot (*Daucus carota* L.) is a root vegetable with carotenoids, flavonoids, polyacetylenes, vitamins, and minerals, all of which possess numerous nutritional and health benefits. Carrots help in the maintenance of ocular health, strengthens the immune system, lowers the risk of cancer by preventing age-associated health problems, including gastric and prostate cancer as well as inflammation and coronary heart disease [9].

Periwinkles are invertebrates belonging to the phylum Mollusca and class Gastropoda [10]. Periwinkles are dominantly found in brackish waters of the riverine areas of Nigeria, where they are highly prolific. Periwinkle is a potential source of good-quality proteins. It contains most of the essential amino acids in adequate amount for human nutrition [11]. The high protein and low level of the crude fibre contents in the meat powder of periwinkle will make them appropriate for use in complementary foods. Oyster is a shellfish that have relatively large amounts of mineral constituents [12]. The edible oyster, *Crassostrea madrasensis*, is a bivalve mollusk (family Ostreidae) found in the riverine areas of Nigeria and other coastal regions of the world. The consumption of bivalve mollusks also provides an inexpensive source of protein with a high biological value, essential minerals, and vitamins [13]. Bivalve mollusks are one of the most valued sea foods as they constitute a rich source of fatty acids, amino acids, and minerals, which are essential for providing an adequate diet [14].

The move from a complete milk diet to a variety of foods is necessary to satisfy the nutritional needs of infants especially as they are in their susceptible phase of life. Poor nutrition and less than optimum feeding practices during this critical period will increase the risk of faltering growth and nutritional deficiencies [15]. One of the challenges to the prevalent infant malnutrition in Nigeria is inadequate complementary food both in quantity and quality due to over reliance on cereals for complementary feeding [16]. Orange-fleshed sweet potato, millets, carrots, periwinkles and oysters are readily available foods in Nigeria with promising nutritional attributes. Animal-derived foods such as periwinkle and oyster, rich in protein, readily absorbable minerals, and omega-3 fatty acids, can be incorporated into millet-based supplementary foods to enhance the nutritional well-being of infants. This study was therefore aimed at investigating the anthropometric and biochemical indices of infants fed complementary foods developed from millets, orange-fleshed sweet potatoes, carrot, periwinkle meat and oyster meat flour blends.

Statement of the Problem

Infant wellbeing, growth, and long-term development hinge on optimal nutrition and feeding practices. Malnutrition and growth retardation, prevalent in certain regions in Nigeria, can be prevented through proper feeding. Poorly fed infants face increased infection risks and mortality. In Nigeria, prevalent infant malnutrition results from inadequate complementary foods, notably cereal reliance. This contributes significantly to child mortality. While infant formula offers nutritional diets, it is financially inaccessible to some Nigerians. Enhancing existing complementary foods with local staples like orange-fleshed sweet potatoes, millets, carrots, oysters and periwinkles is a viable approach. These locally available foods hold promise in improving infant nutrition by addressing macro and micronutrient deficiencies.

2.0 MATERIALS AND METHODS

Collection of Samples

The major food materials used in the study were orange-flesh sweet potatoes, millets, carrots, periwinkle and oysters. The orange-fleshed sweet potatoes (*Ipomoea batatas* L), millets (*Eleusine coracana*) and carrots (*Daurus carota* L) were purchased from Nsukka market in Enugu State. Periwinkle (*Tympanatonus fuscatus*) and oysters (*Crassostrea madrasenis*) were bought from Creek Road Market in Port Harcourt Local Government Area of Rivers state.

Identification of Samples

Identification of plant materials was done by a plant taxonomist in the Department of Plant Science and Biotechnology, University of Nigeria, Nsukka, Enugu State Nigeria. The shellfish samples were identified by an Animal Scientist in the Department of Animal Science, University of Nigeria, Nsukka. A handful of each of the plant materials and shellfish samples was wrapped in white polyethylene bags and carried to the departments.

Sample Preparation

Preparation of Orange-Fleshed Sweet Potato Flour

Orange-fleshed sweet potato was processed into flour according to the method of Oguizu et al. [17]. Seventy kilogram (70 kg) of orange-flesh sweet potatoes was peeled, washed and sliced with a kitchen knife. It was immediately immersed in a water bath of 1% sodium metabisulfite for 10 min to prevent enzymatic browning. The Orange-fleshed sweet potatoes were drained and oven dried at 55°C in a conventional air oven (Gallen kamp Co. Ltd London England) for 8 hrs. It was thereafter be dry-milled in a laboratory mill (Thomas Willey mill model ED-5) into powder and sieved into flour using (0.4 mm) sieve aperture. The flour sample was packed in Ziplock bags and stored in a refrigerator at -4^{o}C for analysis and formulation of complementary food.

Preparation of Millet Flour

Millet was processed into flour using the method of Iombor et al. [18]. Hundred kilograms (100 kg) of millet grains was sorted and cleaned and thereafter soaked in clean tap water in a covered container. The soaked grains were allowed to ferment at room temperature (37^{o}C) for 24 h. After fermentation, the water was drained and the grains were rinsed with 500 ml of water and oven dried at 60^{o}C for 3 h. The oven dried grains were milled in a laboratory hammer mill (Thomas Willey mill model ED-5) and sieved into fine flour using 30 mm sieve aperture. The flour sample was packed in Ziplock bags and stored in a refrigerator at -4^{o}C for analysis and formulation of complementary food.

Preparation of Carrot Flour

Thirty kilograms (30 kg) of carrots was washed, scrapped to remove the epidermis and some sub-epidermal tissues and then blanched at 80°C for 6 minutes, sliced and dried at 30^{o}C for 3 hours in a conventional air oven. The dried carrots were then milled into flour using a Kenwood milling machine model AT941A. The resulting flour was stored in air tight Ziplock bags at room temperature of 25^{o}C protected from light and humidity for further use.

Preparation of Periwinkle Meat Flour

Periwinkle meat flour was produced according to the method of Ufot et al. [19]. Thirty kilogram (30 kg) of periwinkle was thoroughly washed with potable tap water to remove mud and other debris. It was then put in a stainless pot of boiling water and allowed to cook for 5 min at 100^{o}C, then drained using an aluminum sieve and allowed to cool to ambient temperature of about 25^{o}C. The edible portion (meat) was manually removed from the shell with the aid of a sterilized stainless pin or needle. The shells were discarded and the meats washed in potable tap water, drained, dried at 55^{o}C overnight in a conventional air oven. The dried meats were milled to flour using a Kenwood milling machine model AT941A. The resulting flour was stored in air tight Ziplock bags at room temperature of 25^{o}C protected from light and humidity for further use.

Preparation of Oyster Meat Flour

Oyster meat flour was produced according to the method of Ufot et al. [19]. Thirty kilograms (30 kg) of oyster was thoroughly washed with potable tap water to remove mud and other debris. It was then put in a stainless pot of boiling water and allowed to cook for 5 min at 100^{o}C, then drained using an aluminum sieve and allowed to cool to ambient temperature of about 25^{o}C. The edible portion (meat) was manually removed from the shell with the aid of a cleaned kitchen knife. The shells were discarded and the meats washed in potable tap water, drained, dried at 55^{o}C overnight in a conventional air oven. The dried meats were milled to flour using a Kenwood milling machine model AT941A. The resulting flour was stored in air tight Ziplock bags at room temperature of 25°C protected from light and humidity for further use.

Formulation of Composite Flour from Millet, Orange-Flesh Sweet Potato, Carrot, Periwinkle and Oyster Meat

The protein content of each food was determined by micro Kjeldahl procedure [20]. This was used for the formulation of the composite flours. Combination of millet with carrot, orange-fleshed sweet potato, oyster and periwinkle was done using the recommended guideline for the formulation of complementary food for infants 6 – 12 months [2]. It states that on dry weight basis, composite flour for complementary food should contain a minimum of 4 kcal/g carbohydrate, while the energy from protein should not be less than 6% of the total energy from the product and typically should not exceed 15% and dietary fibre content should be reduced to a level not exceeding 5 g per 100g [2]. The composites were formulated from the processed flours on protein basis, using the following ratios:

1. Cerelac 100% (Control diet)
2. Millet/carrot 89:11 (Test diet 1)
3. Millet/orange-flesh sweet potato 70:30 (Test diet 2)
4. Millet/orange-flesh sweet potato/carrot 57:32:11: 0:0 (Test diet 3)
5. Millet/orange-flesh sweet potato/carrot/oyster meat flour 65:20:5:10 (Test diet 4)
6. Millet/orange-flesh sweet potato/carrot/periwinkle meat flour 49:29:7:15 (Test diet 5)
7. Millet/orange-flesh sweet potato/carrot/oyster/periwinkle meat flour 70:13:3: 7:7 (Test diet 6)

The formulated composites were separately packaged in airtight plastic containers, labeled and preserved in a refrigerator (-4°C) until needed for analyses.

Table 1: Quantity of Protein Provided by Each Food Item and the Quantity of Food Item Required to Supply the Required Protein (15 G)

Sample	Ratio	Millet (G)	Carrot (G)	Orange-Flesh Sweet Potato (G)	Oyster (G)	Periwinkle (G)	Total (G)
M	Cerelac	-	-	-	-	-	14
MC	89:11	13.35(190.8)	1.65(183.3)	-	-	-	15(374.1)
MO	70:30	10.50(150.1)	-	4.50(144.3)	-	-	15(294.4)
MOC	57:32:11	8.55(122.1)	1.65(183.3)	4.80(153.8)	-	-	15(459.2)
MOCOM	65:20:5:10	9.75(139.3)	0.75(83.3)	3.00(96.2)	1.50(2.3)	-	15(321.1)
MOCPM	49:29:7:15	7.35(105.0)	1.05(116.7)	4.35(139.4)	-	2.25(3.2)	15(364.3)
MOCOMPM	70:13:3: 7:7	10.50(150.1)	0.45(50.0)	1.95(62.5)	1.05(1.62)	1.05(1.5)	15(265.8)

Keys:

M= Cerelac

MC= Millet/Carrot

MO= Millet/orange-flesh sweet potato

MOC= Millet/orange-flesh sweet potato/carrot

MOCOM= Millet/orange-flesh sweet potato/carrot/oyster meat

MOCPM= Millet/orange-flesh sweet potato/carrot/periwinkle meat

MOCOMPM= Millet/orange-flesh sweet potato/carrot/oyster meat/periwinkle meat

The composition was based on 15 g protein bases per day requirement for children 6-24 months [2]. Table 3.1 shows the quantity of protein provided by each food item and the quantity of food item that will supply the stated quantity of protein. Test diet 1 is 70:30 which means that 70% of millet flour provided 10.50% protein and 30% orange-fleshed sweet potato provided 4.50% protein. The quantity of food item that supplied the quantity is the figure i.e., 10.50% required 150.1 g of processed millet flour while the protein requirement of infants (6-12 months) is 15 g per day [2]. The quantity of food item that will supply the quantity of the protein is in the bracket. Test diet 1 has 294.4g quantity of the composite to supply 15g/day vice versa.

Ethical Clearance

Ethical approval number (228) was obtained from the Ethics and Research Committee of the Rivers State University Teaching Hospital, Port Harcourt. The human study was conducted at Grace Pearl orghanage, Igbo-Etche, Rivers according to the Nigerian National Code for Health Research Ethics and Committee (NHREC).

Consent Form

The consent of the care taker of the orphanage home at Grace Pearl orghanage, Igbo-Etche, Rivers State was sort, three weeks before the commencement of the study. The essence of the visit was to get permission from the caretaker of the home and to see the children that were involved in the study.

Selection Criteria

The subjects (children of 6-12 months) that were involved in the study were selected from the orphanage home. The health of the children was considered by checking the children's vital signs by a health personnel and any child that showed a sign of anemia such as weakness and sickle cell was not included in the study. The children were screened for infections like measles, whooping cough and inability to swallow complementary food. The inclusion criteria included screened and confirmed healthy children (6-12 months) and was free from any health disorder and could eat well. The age, weight and height of the children were also considered as the bases for the grouping and selection [21]. A total of thirty-five (35) children were involved in the study.

Experimental Design and Grouping

The randomized controlled study involved 35 children divided into seven groups based on their age, weight, and height. A total of 5 children were assigned to the control group who received cerelac, a commercial complementary food while the other six groups were fed the test diets.

Administration of Food

The thirty (30) children were fed for six (6) months on the test diets. Five research assistants were trained to assist the researcher during the sensory evaluation and feeding trials. The research assistants were selected from the final year students of the Department of Home Science and Management, Rivers State University, Port Harcourt, Rivers State. The diets were prepared as gruels using the recipe for the preparation of the gruels and fed to the children as breakfast. The children were fed with their other normal daily meals of lunch and dinner. The researcher prepared the test diets and feed the children from 7.30 am to 9.30am with the help of the research assistants. The quantity consumed at each meal was recorded and the leftover also recorded.

Biochemical Analysis of Blood Samples

Blood samples were collected from subjects by a medical laboratory technologist before and after a feeding trial. Each subject's blood was divided into two sample bottles, one with 2μl of blood and the other containing anti-coagulant K-EDTA. These samples were analyzed within 2 hours. Hemoglobin levels were determined following Dacie & Lewis [22], involving mixing 2μl of blood with Drabkins solution and measuring absorbance. Urinary iodine concentration was determined using the WHO-recommended Sandell–Kolt–koff method. Serum calcium was assessed following Dacie & Lewis [22] method. Serum vitamin A was analyzed according to Abdullahi et al. (2017), involving BHT addition, hexane extraction, and HPLC-based quantification using a calibration curve.

Anthropometric Measurements

Anthropometric measurements consisting of weight, height, length, head, chest and mid upper arm circumference of the children were taken before and after the feeding trials using the method of Cogil [24]. World Health Organization (WHO) cut off points for classifying malnutrition using anthropometrics measurement (MUAC of less than 11.5 cm in children between 6 months to 5 years indicates severe malnutrition, between 11.5 to 12.5 cms indicates moderate malnutrition and that above 12.5 cm indicates a normal child) [25] was used to classify the nutritional status of the infants.

Statistical Analysis

Data obtained from biochemical and anthropometric indices were subjected to statistical analysis using the software Statistical Package for Service Solution (SPSS Version 21). The biochemical and anthropometric parameters were compared using the paired samples t-test. All statistical tests were performed at 5% significant levels.

3.0 FINDINGS

The Effects of the Infant Complementary Foods on the Anthropometric Status of the Infants After Six Months Feeding Period

Mean Baseline and End-Line of Weight (Kg) of the Infants After 6 Months Period

Table 2 shows the effect of various complementary foods compared to the control on infant weight. The results reveal significant differences ($p<0.01$) in both the mean baseline and end-line weights of infants subjected to different food combinations. Notably, infants fed with cerelac experienced a substantial increase in weight, with a mean difference of 5.19 kg (from 6.50 kg to 11.69 kg), indicating a remarkable 79.84% increase in their weight. Similarly, the introduction of millet/carrot into their diets also led to significant weight gain, with a mean baseline weight of 5.48 kg and an end-line weight of 7.63 kg, resulting in a 39.23% increase and a mean difference of approximately 2.15 kg. Moreover, infants who consumed millet/orange-fleshed sweet potato showed a significant weight difference ($p<0.01$), with a mean baseline weight of 5.38 kg and an end-line weight of 7.72 kg, reflecting a 43.49% increase and a mean difference of 2.34 kg. Notably, formulations incorporating oyster and periwinkle yielded the most substantial effects on infant weight. These findings align with previous research by Nwosu et al. [26], highlighting that feeding children with complementary foods prepared from maize, soybean and moringa leaves powder increase some anthropometric measurements (weight and head circumference).

Table 2: Mean Baseline and End-Line of Weight (Kg) of the Infants After 6 Months Period

Groups	Baseline	End-Line	MD	Std Error	Df	T	%D
Cerelac	6.50±0.13	11.69±0.22	5.19	0.10	4	-45.16**	79.84
MC	5.48±0.14	7.63±0.07	2.15	0.10	4	-30.29**	39.23
MO	5.38±0.22	7.72±0.24	2.34	0.10	4	-16.34**	43.49
MOC	5.01±0.05	8.34±0.21	3.33	0.10	4	-34.23**	66.46
MOCO	5.09±0.10	8.73±0.20	3.64	0.10	4	-35.72**	71.51
MOCP	7.42±0.28	8.73±0.26	1.31	0.10	4	-7.66**	17.65
MOCOP	5.55±0.33	10.51±0.27	4.96	0.13	4	-26.40**	89.36

MD= mean difference; Std error= standard error; df= degree of freedom; t= t-test value; % D= % difference; **= (P<0.01); baseline= after induction; end-line= after intervention

MC= 89% Millet: 11% carrot;

MO= 70% Millet: 30% Orange-fleshed sweet potato

MOC= 57% Millet: 32% OFSP: 11% Carrot; MOCO= 65% Millet: 20% OFSP: 5% Carrot: 10% Oyster

MOCP= 49% Millet: 29% OFSP: 7% Carrot: 15% Periwinkle;

MOCOP= 70% Millet: 13% OFSP: 3% Carrot: 7% Oyster: 7% Periwinkle

Mean Baseline and End-Line of Length (Cm) of the Infants After 6 Months Period

Table 3 illustrates the impact of various infant complementary foods compared to a control group on infant length. There were significant differences (p<0.01) in baseline and end-line lengths. Cerelac-fed infants showed a 4.25 cm mean length increase (6.21%). Millet/carrot-fed infants had a 2.15 cm mean length increase (3.18%). Millet/orange-fleshed sweet potato-fed infants demonstrated a 3.03 cm mean length increase (4.63%). Infants receiving millet/orange-fleshed sweet potato/carrot exhibited a 3.10 cm mean length increase (5.12%). Millet/orange-fleshed sweet potato/carrot/oyster-fed infants had a 2.91 cm mean length increase (4.44%), while millet/orange-fleshed sweet potato/carrot/periwinkle-fed infants showed a 2.82 cm mean length increase (4.24%). The most significant growth (7.29%) occurred in infants fed millet/orange-fleshed sweet potato/carrot/oyster/periwinkle, even with a low baseline length. This suggests that enriching complementary foods with fruits and shellfish can effectively address malnutrition concerns in infants, aligning with previous research by Kiin-Kabari *et al*. [13].

Table 3: Mean Baseline and End-Line of Length (Cm) of the Infants After 6 Months Period

Groups	Baseline	End-Line	MD	Std Error	Df	T	%D
Cerelac	68.37±0.29	72.62±0.49	4.25	0.17	4	-16.62**	6.21
MC	67.40±0.34	69.55±0.38	2.15	0.16	4	-9.41**	3.18
MO	65.37±0.41	68.40±0.40	3.03	0.18	4	-11.93**	4.63
MOC	60.49±0.30	63.59±0.28	3.10	0.13	4	-17.14**	5.12
MOCO	65.43±0.16	68.34±0.32	2.91	0.10	4	-18.17**	4.44
MOCP	66.41±0.44	69.23±0.26	2.82	0.15	4	-12.43**	4.24
MOCOP	55.14±0.22	59.16±0.16	4.02	0.08	4	-33.08**	7.29

MD= mean difference; Std error= standard error; df= degree of freedom; t= t-test value; % D= % difference; **= ($P<0.01$); baseline= after induction; end-line= after intervention

KEYS:

MC= 89% Millet: 11% carrot; MO= 70% Millet: 30% Orange-fleshed sweet potato

MOC= 57% Millet: 32% OFSP: 11% Carrot; MOCO= 65% Millet: 20% OFSP: 5% Carrot: 10% Oyster

MOCP= 49% Millet: 29% OFSP: 7% Carrot: 15% Periwinkle;

MOCOP= 70% Millet: 13% OFSP: 3% Carrot: 7% Oyster: 7% Periwinkle

Mean Baseline and End-Line of Mid-Upper Circumference (Cm) of the Infants After 6 Months Period

Table 4 illustrates the impact of infant complementary foods on mid-upper arm circumference, showing significant improvements ($p<0.01$) in all groups. Cerelac-fed infants experienced a substantial 56.01% increase (5.26 cm mean difference), while millet-based diets with various additions also led to notable increases ranging from 10.31% to 48.63%. The mid upper arm circumference (MUAC) at the baseline (9.39-10.95) were all below the WHO (12.5 cm) cut for infants from 6-12 months of (MUAC). However, the formulations had a significant effect ($p<0.01$) on the end line data. Mid upper arm-arm circumference has been identified by Mwangome et al. [27] as a critical tool that enables the implementation of a community-based management of acute malnutrition. All the formulations meet up with the requirement for such mobility.

Table 4: Mean Baseline and End-Line of Mid-Upper Circumference (Cm) of the Infants After 6 Months Period

Groups	Baseline	End-line	MD	Std Error	Df	t	%D
Cerelac	9.39±0.14	14.65±0.35	5.26	0.10	4	-31.10**	56.01
MC	9.40±0.20	10.37±0.18	0.97	0.08	4	-8.13**	10.31
MO	10.52±0.23	12.34±0.22	1.82	0.10	4	-12.67**	17.30
MOC	10.46±0.18	13.18±0.42	2.72	0.12	4	-13.15**	26.00
MOCO	10.95±0.12	13.61±0.30	2.66	0.10	4	-18.32**	24.29
MOCP	10.59±0.16	13.66±0.29	3.07	0.09	4	-20.67**	28.98
MOCOP	9.54±0.22	14.18±0.24	4.64	0.10	4	-31.27**	48.63

MD= mean difference; Std error= standard error; df= degree of freedom; t= t-test value; % D= % difference; **= ($P<0.01$); baseline= after induction; end-line= after intervention

KEYS:

MC= 89% Millet: 11% carrot; MO= 70% Millet: 30% Orange-fleshed sweet potato

MOC= 57% Millet: 32% OFSP: 11% Carrot; MOCO= 65% Millet: 20% OFSP: 5% Carrot: 10% Oyster

MOCP= 49% Millet: 29% OFSP: 7% Carrot: 15% Periwinkle;

MOCOP= 70% Millet: 13% OFSP: 3% Carrot: 7% Oyster: 7% Periwinkle

Mean Baseline and End-Line of Head Circumference (Cm) of the Infants After 6 Months Period

Table 5 shows the effect of infant complementary foods on head circumference, revealing significant differences (p<0.01) across all groups. Cerelac-fed infants experienced a 5.51% increase (2.44 cm mean difference) over six months. Similarly, millet-based diets with various additions showed increases ranging from 2.12% to 4.88%, with corresponding mean differences. All infants achieved normal head circumferences, aligning with WHO standards. Cerelac demonstrated the highest percentage increase (5.51%) at the end line, followed by formulations containing oyster and periwinkle. This aligns with WHO guidelines for infants aged 12 months, who are expected to triple their birth weight and have head and chest measurements within a certain range, a milestone achieved by the control group and formulations containing oyster and periwinkle meat flour (3.46-4.88) according to WHO [28].

Table 5. Mean Baseline and End-Line of Head Circumference (Cm) of the Infants After 6 Months Period

Groups	Baseline	End-line	MD	Std Error	Df	t	%D
Cerelac	44.22±0.20	46.66±0.21	2.44	0.09	4	-19.07**	5.51
MC	40.68±0.29	41.57±0.29	0.89	0.13	4	-4.86**	2.18
MO	39.51±0.27	40.35±0.34	0.84	0.13	4	-4.31**	2.12
MOC	42.49±0.33	43.73±0.22	1.24	0.12	4	-7.02**	2.91
MOCO	43.05±0.13	44.54±0.31	1.49	0.09	4	-10.03**	3.46
MOCP	42.36±0.33	44.43±0.43	2.07	0.17	4	-8.57**	4.88
MOCOP	42.99±0.56	45.06±0.18	2.07	0.15	4	-7.78**	4.81

MD= mean difference; Std error= standard error; df= degree of freedom; t= t-test value; % D= % difference; **= (P<0.01); baseline= after induction; end-line= after intervention

KEYS:

MC= 89% Millet: 11% carrot; MO= 70% Millet: 30% Orange-fleshed sweet potato

MOC= 57% Millet: 32% OFSP: 11% Carrot; MOCO= 65% Millet: 20% OFSP: 5% Carrot: 10% Oyster

MOCP= 49% Millet: 29% OFSP: 7% Carrot: 15% Periwinkle;

MOCOP= 70% Millet: 13% OFSP: 3% Carrot: 7% Oyster: 7% Periwinkle

Mean Baseline and End-Line of Chest Circumference (Cm) of the Infants After 6 Months Period

Table 6 illustrates the impact of infant complementary foods, including a control group, on chest circumference, revealing significant improvements (p<0.01) across all groups. Cerelac-fed infants exhibited a 5.69% increase (2.45 cm mean difference) over six months. Millet/carrot-fed infants displayed a significant but modest 0.72% increase (0.30 cm mean difference) in chest circumference. Infants consuming millet/orange-fleshed sweet potato experienced a slight 0.81% increase (0.34 cm mean difference). Moreover, infants receiving millet/orange-fleshed sweet potato/carrot exhibited a more noticeable 5.34% increase (2.22 cm mean difference) in chest circumference. Infants fed millet/orange-fleshed sweet potato/carrot/oyster displayed a 4.46% increase (1.78 cm mean difference), while those consuming millet/orange-fleshed sweet potato/carrot/periwinkle showed a 3.29% increase (1.36 cm mean difference). The most substantial increase, about 6.32%, was observed in infants fed millet/orange-fleshed sweet potato/carrot/oyster/periwinkle, likely due to the inclusion of periwinkle and oyster in their diet.

These seafood sources are known for their nutritional value and potential to address hidden hunger, providing essential nutrients like iron, zinc, and vitamin B12, which are crucial for growth and development. Chest circumference serves as a vital anthropometric measurement to assess body composition, growth, and development. The findings are consistent with previous research by Kiin-Kabari et al. [13], which highlighted the nutritional benefits of oyster and periwinkle in addressing hidden hunger. Oyster and periwinkle are rich in omega-3 fatty acids, essential for brain development, and offer high-quality protein, amino acids, vitamins, and minerals essential for optimal growth. Overall, these results underscore the importance of dietary diversity and the inclusion of nutrient-rich foods like oyster and periwinkle in infant complementary feeding to promote healthy growth and development.

Table 6: Mean Baseline and End-Line of Chest Circumference (Cm) of the Infants After 6 Months Period

Groups	Baseline	End-line	MD	Std Error	Df	T	%D
Cerelac	43.00±0.24	45.45±0.33	2.45	0.13	4	-13.45**	5.69
MC	41.24±0.28	41.54±0.24	0.30	0.12	4	-1.83**	0.72
MO	41.91±0.23	42.25±0.10	0.34	0.05	4	-3.05**	0.81
MOC	41.51±0.36	43.73±0.31	2.22	0.15	4	-10.44**	5.34
MOCO	39.89±0.07	41.67±0.16	1.78	0.05	4	-22.85**	4.46
MOCP	41.27±0.18	42.63±0.19	1.36	0.08	4	-11.60**	3.29
MOCOP	42.21±0.34	44.88±0.63	2.67	0.21	4	-8.36**	6.32

MD= mean difference; Std error= standard error; df= degree of freedom; t= t-test value; % D= % difference; **= (P<0.01); baseline= after induction; end-line= after intervention

KEYS:

MC= 89% Millet: 11% carrot; MO= 70% Millet: 30% Orange-fleshed sweet potato

MOC= 57% Millet: 32% OFSP: 11% Carrot; MOCO= 65% Millet: 20% OFSP: 5% Carrot: 10% Oyster

MOCP= 49% Millet: 29% OFSP: 7% Carrot: 15% Periwinkle;

MOCOP= 70% Millet: 13% OFSP: 3% Carrot: 7% Oyster: 7% Periwinkle

Effects of the Infant Complementary Foods and the Control on the Biochemical Parameters of the Children

Mean Baseline and End-Line Serum Iodine (Mg/Dl) of the Infants After 6 Months Period

Table 7 shows the effect of infant complementary foods, including a control group, on serum iodine levels. The result shows a significant increase in iodine levels (p<0.01) across all groups. Cerelac-fed infants had a substantial 162.31% increase, reaching a mean of 1.12 mg/dl (0.69 mg/dl to 1.81 mg/dl) over six months. Similarly, infants fed millet/carrot exhibited a significant

34.04% increase, with a mean change of approximately 0.16 mg/dl (0.47 mg/dl to 0.63 mg/dl). Infants consuming millet/orange-fleshed sweet potato demonstrated a 72.72% increase, with a mean change of 0.16 mg/dl (0.22 mg/dl to 0.38 mg/dl). Moreover, those receiving millet/orange-fleshed sweet potato/carrot displayed a 63.15% increase, with a mean change of 0.12 mg/dl (0.19 mg/dl to 0.31 mg/dl). Infants fed millet/orange-fleshed sweet potato/carrot/oyster experienced a 31.25% increase, with a mean change of 0.15 mg/dl (0.48 mg/dl to 0.63 mg/dl).

Similarly, those consuming millet/orange-fleshed sweet potato/carrot/periwinkle showed an 80.55% increase, with a mean change of 0.29 mg/dl (0.36 mg/dl to 0.65 mg/dl). Furthermore, infants fed millet/orange-fleshed sweet potato/carrot/oyster/periwinkle exhibited a 72.34% increase, with a mean change of approximately 0.34 mg/dl (0.47 mg/dl to 0.81 mg/dl). However, none of the formulations reached the WHO's recommended daily iodine levels of 70 µg/dl, likely due to the infants being fed only once a day. Increasing feeding frequency is essential to meet these requirements. Adequate iodine intake is vital, as emphasized by FAO and WHO, for thyroid hormone synthesis, growth, development, and preventing iodine deficiency disorders [29].

Table 7: Mean Baseline and End-Line Serum Iodine (Mg/Dl) of the Infants After 6 Months Period

Groups	Baseline	End-line	MD	Std Error	Df	T	%D
Cerelac	0.69±0.03	1.81±0.06	1.12	0.02	4	-35.45**	162.31
MC	0.47±0.03	0.63±0.10	0.16	0.03	4	-3.30**	34.04
MO	0.22±0.03	0.38±0.05	0.16	0.02	4	-5.60**	72.72
MOC	0.19±0.06	0.31±0.03	0.12	0.02	4	-4.52**	63.15
MOCO	0.48±0.05	0.63±0.05	0.15	0.02	4	-4.79**	31.25
MOCP	0.36±0.03	0.65±0.03	0.29	0.01	4	-13.99**	80.55
MOCOP	0.47±0.06	0.81±0.06	0.34	0.03	4	-9.56**	72.34

MD= mean difference; Std error= standard error; df= degree of freedom; t= t-test value; % D= % difference; **= (P<0.01); baseline= after induction; end-line= after intervention

KEYS:

MC= 89% Millet: 11% carrot; MO= 70% Millet: 30% Orange-fleshed sweet potato

MOC= 57% Millet: 32% OFSP: 11% Carrot; MOCO= 65% Millet: 20% OFSP: 5% Carrot: 10% Oyster

MOCP= 49% Millet: 29% OFSP: 7% Carrot: 15% Periwinkle;

MOCOP= 70% Millet: 13% OFSP: 3% Carrot: 7% Oyster: 7% Periwinkle

Mean Baseline and End-Line of Hemoglobin (Mg/Dl) of the Infants After 6 Months Period

Table 9 shows the impact of different complementary foods on infant hemoglobin levels. Across various formulations, significant increases in hemoglobin levels were observed, ranging from 141.61% to 286.06%, with mean differences in the range of 7.35 to 15.19 mg/dl. Infants fed millet/orange-fleshed sweet potato/carrot/oyster exhibited a significant (p<0.01) 219.11% increase, with a mean difference of 11.35 mg/dl (baseline 5.18 mg/dl to end-line 16.53 mg/dl). Similarly, those fed millet/orange-fleshed sweet potato/carrot/periwinkle saw a 226.74% increase, with a mean difference of 11.70 mg/dl (baseline 5.16 mg/dl to end-line 16.86 mg/dl). Infants fed millet/orange-fleshed sweet potato/carrot/oyster/periwinkle had a remarkable

286.06% increase, with a mean difference of approximately 15.19 mg/dl (baseline 5.31 mg/dl to end-line 20.50 mg/dl).

At baseline, infants showed low hemoglobin levels (4.45 to 5.31 g/dL), indicating severe anemia. This aligns with high anemia prevalence among Nigerian children, as reported by Ughasoro et al. [30], especially in 12-month-olds. Hemoglobin concentration (Hb) serves as a key marker for anemia, a global health concern in sub-Saharan Africa, as per WHO [31] standards.

The study highlights that the millet/orange-fleshed sweet potatoes/carrot/oyster/periwinkle formulation had a significantly greater impact (117.71%) on infant hemoglobin levels compared to other formulations ($p < 0.05$). This suggests that including periwinkle and oyster in the formulation improved hemoglobin levels. The combined fortification of millet, orange-fleshed sweet potatoes, carrot, oyster, and periwinkle had a significantly higher effect on hemoglobin levels ($p < 0.01$), indicating a synergistic impact. These findings suggest that formulated complementary foods have potential in preventing infant anemia and offer a promising strategy to address low hemoglobin levels. Inclusion of periwinkle and oyster further enhances their effectiveness, underscoring the importance of fortification and complementary feeding practices in promoting infant and child health.

Table 8: Mean Baseline and End-Line of Hemoglobin (Mg/Dl) of the Infants After 6 Months Period

Groups	Baseline	End-line	MD	Std Error	Df	t	%D
Cerelac	5.43±0.25	15.34±0.21	9.91	0.10	4	-66.68**	182.50
MC	4.45±0.25	11.81±0.21	7.36	0.10	4	-50.18**	165.39
MO	5.19±0.19	12.54±0.23	7.35	0.09	4	-55.87**	141.61
MOC	4.80±0.28	13.24±0.32	8.44	0.13	4	-43.99**	175.83
MOCO	5.18±0.12	16.53±0.27	11.35	0.09	4	-85.15**	219.11
MOCP	5.16±0.12	16.86±0.30	11.70	0.07	4	-82.15**	226.74
MOCOP	5.31±0.25	20.50±0.28	15.19	0.11	4	-90.64**	286.06

MD= mean difference; Std error= standard error; df= degree of freedom; t= t-test value; % D= % difference; **= (P<0.01); baseline= after induction; end-line= after intervention

KEYS:

MC= 89% Millet: 11% carrot; MO= 70% Millet: 30% Orange-fleshed sweet potato

MOC= 57% Millet: 32% OFSP: 11% Carrot; MOCO= 65% Millet: 20% OFSP: 5% Carrot: 10% Oyster

MOCP= 49% Millet: 29% OFSP: 7% Carrot: 15% Periwinkle;

MOCOP= 70% Millet: 13% OFSP: 3% Carrot: 7% Oyster: 7% Periwinkle

Mean Baseline and End-Line of Calcium (Mg/Dl) of the Infants After 6 Months Period

Table 10 shows the impact of various complementary foods on infant calcium levels. Significant improvements ($p<0.01$) were observed in all groups, with percentage increases ranging from 81.81% to 555.65%. Feeding with millet/orange-fleshed sweet potato/carrot/oyster resulted in a 353.06% increase, with a mean difference of 5.19 mg/dl. Infants fed millet/orange-fleshed sweet potato/carrot/periwinkle exhibited a 536.88% increase, with a mean difference of 6.55 mg/dl. Furthermore, infants fed millet/orange-fleshed sweet potato/carrot/oyster/periwinkle experienced a 488.97% increase, with a mean difference of approximately 6.65 mg/dl.

These findings indicate a calcium deficiency before and after feeding, especially in millet/orange-fleshed sweet potatoes/carrot/periwinkle (145.72%). The recommended safe calcium level is 8.8 µg/dl [32]. Calcium is crucial for bone and teeth development, and low levels can impact growth and lead to conditions like osteoporosis. Meeting calcium requirements may require increasing the frequency of infant meals beyond once a day, preferably to the normal three or four feedings per day.

Table 9: Mean Baseline and End-Line of Calcium (Mg/Dl) of the Infants After 6 Months Period

Groups	Baseline	End-line	MD	Std error	Df	t	%D
Cerelac	1.15±0.12	8.69±0.21	7.54	0.07	4	-70.28**	555.65
MC	4.07±0.22	7.40±0.28	3.33	0.11	4	-21.52**	81.81
MO	1.44±0.21	5.28±0.31	3.84	0.11	4	-22.88**	266.66
MOC	1.56±0.33	6.35±0.32	4.79	0.13	4	-23.20**	307.05
MOCO	1.47±0.26	6.66±0.25	5.19	0.11	4	-32.33**	353.06
MOCP	1.22±0.15	7.77±0.19	6.55	0.07	4	-59.15**	536.88
MOCOP	1.36±0.10	8.01±0.31	6.65	0.08	4	-45.09**	488.97

MD= mean difference; Std error= standard error; df= degree of freedom; t= t-test value; % D= % difference; **= (P<0.01); baseline= after induction; end-line= after intervention;

MC= 89% Millet: 11% carrot; MO= 70% Millet: 30% Orange-fleshed sweet potato

MOC= 57% Millet: 32% OFSP: 11% Carrot; MOCO= 65% Millet: 20% OFSP: 5% Carrot: 10% Oyster

MOCP= 49% Millet: 29% OFSP: 7% Carrot: 15% Periwinkle;

MOCOP= 70% Millet: 13% OFSP: 3% Carrot: 7% Oyster: 7% Periwinkle

Mean Baseline and End-Line of Vitamin a (Mg/Dl) of the Infants After 6 Months Period of the Infant

Table 11 shows the effect of infant complementary foods on vitamin A levels. Across different formulations, significant changes in vitamin A levels were observed, with increases ranging from 20.30% to 91.92%. Vitamin A levels indicated no deficiency risk among infants. Millet/carrot had the highest effect at 62.99%, followed by millet/orange-fleshed sweet potatoes/carrot with a 39.95% effect. The WHO [33] recommends a daily vitamin A requirement of 450 µg, which could be met with the infants' normal three or four daily feedings. Vitamin A supports vision and immune functions and helps prevent preventable blindness due to prolonged deficiency.

Table 10: Mean Baseline and End-Line of Vitamin a (Mg/Dl) of the Infants After 6 Months Period

Groups	Baseline	End-line	MD	Std Error	Df	T	%D
Cerelac	234.85±2.05	282.53±0.51	47.68	0.51	4	-50.60**	20.30
MC	109.37±0.69	209.91±0.72	100.54	0.31	4	-224.72**	91.92
MO	169.88±0.44	244.33±0.71	74.45	0.25	4	-199.77**	43.82
MOC	148.53±0.57	221.30±0.76	72.77	0.29	4	-171.56**	48.99
MOCO	179.70±0.58	258.71±0.56	79.01	0.26	4	-219.90**	43.96
MOCP	200.73±0.72	281.75±0.36	81.01	0.23	4	-224.73**	40.36
MOCOP	197.87±0.60	275.64±0.61	77.77	0.27	4	-203.26**	39.30

MD= mean difference; Std error= standard error; df= degree of freedom; t= t-test value; % D= % difference; **= ($P<0.01$); baseline= after induction; end-line= after intervention

KEYS:

MC= 89% Millet: 11% carrot; MO= 70% Millet: 30% Orange-fleshed sweet potato

MOC= 57% Millet: 32% OFSP: 11% Carrot; MOCO= 65% Millet: 20% OFSP: 5% Carrot: 10% Oyster

MOCP= 49% Millet: 29% OFSP: 7% Carrot: 15% Periwinkle;

MOCOP= 70% Millet: 13% OFSP: 3% Carrot: 7% Oyster: 7% Periwinkle

4.0 CONCLUSION AND RECOMMENDATIONS

Conclusion

The formulations, enriched with millet, orange-fleshed sweet potato, carrot, oyster, and periwinkle, aimed to address the nutritional needs of this vulnerable age group. The findings reveal significant improvements in various anthropometric indicators, including weight, length, mid-upper arm circumference, head circumference, and chest circumference across all experimental groups. Notably, the formulation containing millet, orange-fleshed sweet potato, carrot, oyster, and periwinkle demonstrated the most substantial impact on these anthropometric parameters, indicating the potential of this combination in promoting healthy growth and development. Furthermore, the study assessed the biochemical parameters, specifically serum iodine levels, and hemoglobin concentrations.

While all groups showed significant increases in serum iodine levels, none reached the WHO's recommended daily iodine levels of 70 µg/dl. This suggests the need for further exploration of feeding frequencies to meet these requirements. Importantly, the study revealed severe anemia among infants at baseline, emphasizing the gravity of nutritional challenges in this population. The formulations, particularly the one containing oyster and periwinkle, exhibited remarkable increases in hemoglobin levels, addressing the initial anemic conditions. The observed outcomes underscore the importance of dietary diversity and the inclusion of nutrient-rich foods, especially oyster and periwinkle, in infant complementary feeding practices. The study contributes valuable insights into formulating complementary foods that not only meet nutritional requirements but also effectively address anemia, a prevalent concern in this age group. These findings hold implications for public health interventions aimed at reducing malnutrition and anemia among infants in resource-constrained settings.

Recommendation

The fortification of millet based complementary foods with periwinkle and oyster meat flour is highly recommended in the formulation of complementary foods with adequate nutrients. However, the formulations should be used for the normal feeding three or four times daily to actualize the high protein profiles. Future research should focus on larger cohorts and explore additional factors influencing the efficacy of the complementary foods.

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