https://www.najfnr.com

ORIGINAL ARTICLE

Effect of a millet-based fortified complementary food on the anthropometric and biochemical indices of anemic infants (6-24 months)

Anim Ekpo Ujong [1*], **Olumide Oluwatoyosi Fashakin** [2], and **Roselyn Delase Davour** [3]

1. Department of Food Science and Technology, Rivers State University, Port Harcourt, Nkpolu, Oroworuwkwo, [illegible] E-mail: animityekpo@gmail.com
2. Department of Food Science and Technology, Chiang Mai University, Thailand. E-mail: Olumideoluwa[illegible]osi_f@c[illegible]
3. Noguchi Memorial Institute for Medical Research, Accra Ghana. E-mail: roselyndavour18@gmail.com

ABSTRACT

Background: Adequate nutrition during infancy is fundamental to ensuring children's growth, health, and development of to their full potential. However, several national reports have indicated poor nutritional status and high prevalence of anemia among children living in low-income areas where millet-based porridge is a predominant complementary food. **Aims:** The study aimed to examine the effect of a millet-based fortified complementary food on the anthropometric and biochemical indices of anemic infants (6-24 months). **Patients and Methods:** One hundred and twenty children aged 6 – 24 months were enrolled in this study. On six separate groups, each comprising ~~of~~ 20 children, they consumed Cerelac® (control diet), millet / OFSP (test diet 1), millet / OFSP / carrot (test diet II), millet / OFSP/carrot / oyster (test diet III), millet / OFSP / carrot / periwinkle (test diet IV), and millet / OFSP / carrot / periwinkle / oyster (test diet V), respectively. The children were fed with 50 g/day of the diets over a period of 36 weeks during which anthropometric and biochemical assessments were performed before and after test product ingestion. **Results:** Children fed on the test diets had an increase in anthropometric parameters. Test diet V had the highest percent effect on biochemical and anthropometric parameters at the end of the study. The percentage effect of test diet V (109.45 %; p = 0.020) on the hemoglobin of the infants was significantly (p < 0.05) higher than other test diets. **Conclusion:** Millet-based complementary diet fortified with carrots, OFSP, periwinkle and oyster display positive effects on the nutritional status of infants. Thus, it should be considered as an appropriate alternative when planning nutrition programs to ameliorate the nutritional status of children in areas where millet-based porridge is a predominant complementary food.

Keywords. Malnutrition, complementary food, nutritional status, infants, millet.

ARTICLE INFORMATION

* **Corresponding author:** animityekpo@gmail.com

Received: July 05, 2022
Revised: December 22, 2022
Accepted: December 24, 2022
Published: December 31, 2022

Article edited by:
- Pr. Meghit Boumediene Khaled

Article reviewed by:
- Dr. Meriem Bencharif
- Dr. Slimane Mehdad

Cite this article as: Ujong, E. A., Fashakin, O. O., & Davour, R. D. (2022). Effect of a millet-based fortified complementary food on the anthropometric and biochemical indices of anemic infants (6-24 months). *The North African Journal of Food and Nutrition Research, 6* (14): 198-206. https://doi.org/10.51745/najfnr.6.14.198-206

1 Introduction

The health of infants is crucial during their first year, and the nutritional requirements cannot be met with only breast feeding. In other words, complementary feeding is required. Complementary feeding is the process by which solid foods and diet components are gradually introduced into an infant's diet alongside breast milk. Complementary feeding is a process that starts at the age of six months when only breast milk is adequate to meet the nutritional needs of the infant. Hence, other foods are needed to complement breast milk [1]. These foods include legumes (soybeans and cowpeas, etc.), tubers, and cereals (wheat, maize, and rice, etc.), and they can be formulated by using either one or a combination of more than one plant product, e.g., cereals and legumes [2].

Malnutrition is a major nutritional issue among infants in developing African countries. Malnutrition can result in morbidity and mortality, stunted growth and mental sickness, and an increased risk of diseases such as diabetes mellitus and other cardiovascular diseases such as heart failure [3]. The principal cause of malnutrition in infants is the low nutritional value of foods such as protein, vitamins, and minerals in traditional complementary foods. Furthermore, inappropriate complementary feeding practices and overeating of protein-rich complementary foods are at the root of malnutrition in infants. Undernourishment is prevalent in Africa and Asia and affects millions of people [4]. In Africa, poverty and food shortages are on the rise, leading to undernourishment among 70 million children. Thus, the affected population feeds mainly on cereal foods such as maize, wheat, rice, sorghum, and millet that are low in protein [5]. Generally, malnutrition is frequent among the underprivileged populations who do not have access to a good diet and sufficient protein-rich foods. Protein-energy malnutrition is a public health issue in the developing countries of the world, where children's nutrition remains stagnant and deleterious in low and middle-income families.

Millets are highly variable small-seeded grasses grown as cereal crops [6], and they contain about 7 – 12 % protein, 2 – 5 % fat, 65 – 75 % carbohydrates, and 15 – 20 % dietary fiber [7]. Among them, pearl millet has 12 – 16 % protein, which is considered a considerably high proportion of protein, as well as 4 – 6 % lipids. Millets can be boiled, baked, fermented, and processed into flour, which is then combined with other flours to make complementary foods [6]. However, being plant-based, it is limited in essential amino acids, has low energy and nutrient density, and a high content of antinutrients such as phytates and tannins [8]. The prominent use of millet has been attributed to the existence of high levels of child malnutrition among some communities [9]. A survey carried out by Isingoma et al. [10] showed higher percentages of stunted, underweight, and wasted children in millet-consuming communities in Uganda. Animal-source foods such as periwinkle and oyster, which are rich in protein, bioavailable minerals, and omega-3 fatty acids [11, 12], can be blended with millet-based complementary foods to improve the nutritional status of infants.

Complementary foods are considered to contain a high density of energy with adequate protein composition, required vitamins, and minerals while retaining their chemical and sensory properties. In Nigeria, complementary foods have been found to be inadequate in micronutrients such as iron, iodine, and vitamin A [14, 15]. Most of the traditional complementary foods are cereal-based and are not sufficient for infant growth and development, which may further lead to the problems of undernutrition and micronutrient malnutrition. Several studies and extensive research have been carried out on how to ameliorate the nutrient value of existing complementary foods by combining cereals, legumes, and other staples in order to leverage the efficiency of their proteins for weaning infants [2, 16]. However, very little is known about the effect of these formulations on the nutritional status of infants. There is very little evidence that formulated diets can improve infant growth and nutritional status in vivo. Therefore, the aim of this study was to investigate the effect of a millet-based fortified complementary food on the anthropometric and biochemical indices of anemic infants.

2 Patients and Methods

2.1 Collection of raw materials

Orange-flesh sweet potatoes (*Ipomoea batatas* L), millets (*Eleusine coracana*) and carrots (*Daurus carota* L) were purchased from Nsukka, Enugu State. Periwinkle (*Tympanatonus fuscatus*) and oysters (*Crassostrea madrasenis*) were bought from Creek Road Market in Port Harcourt Local Government Area, Rivers State, Nigeria.

2.2 Processing of raw materials

2.2.1 Preparation of orange-fleshed sweet potato flour

Orange-fleshed sweet potato was pulverized into fine powder according to the method of Kolawole and Ade-Omowaye [17]. Seventy kilograms (70 kg) of orange-fleshed sweet potatoes were peeled, washed, and sliced, then 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 oven (Gallen Kamp Co., Ltd., London, England) for 8 hrs. It was thereafter dry-milled in a laboratory mill (Thomas Willey mill model ED-5) into powder and sieved into flour using a (0.4 mm) sieve aperture. The flour sample was packed in ziplock bags and stored in a refrigerator at -4 °C for analysis and formulation of the complementary food.

2.2.2 Preparation of millet flour

Millet was processed into flour using the method of Iombor et al. [18]. 100 kg of maize gains were sorted, cleaned, soaked in clean water in a container, covered, and fermented at 37 °C for 24 hrs. After fermentation, the water was drained and the fermented grains were rinsed with 500 mL of water and oven dried at 80 °C for 3 hrs. The oven-dried grains were milled with a laboratory hammer mill (Thomas Willey mill model ED-5) and sieved into fine flour using a 30 mm sieve aperture. The flour sample was packed in ziplock bags and stored in a refrigerator at -4 °C for analysis and formulation of the complementary food.

2.2.3 Preparation of carrots flour

Thirty kilograms (30 kg) of carrots were washed, then scrapped to remove the epidermis and some sub-epidermal tissues, and then blanched at 80 °C for 6 mins, sliced, and dried at 30 °C for 3 hrs in a conventional oven. The dried carrots were then milled into flour using a Kenwood milling machine, model AT941A. The carrot powder was stored in airtight ziplock bags at a room temperature of 25 ºC away from light and humidity for analysis.

2.2.4 Preparation of periwinkle and oyster meat flour

Periwinkle and oyster meat were converted into fine powder following the method used by Ufot et al. [11]. Thirty kilograms (30 kg) of periwinkle and oysters were washed with tap water to remove dirt and debris. It was then placed in a stainless pot of boiling water and allowed to cook for 5 minutes at 100 ºC, then drained using an aluminum sieve and cooled to a room temperature of about 25 ºC. The meat was manually removed from the shell using a stainless pin or n[illegible]dle, washed in tap water, drained, and oven-dried at 55 º[illegible] overni[illegible]t. The dried meats were pulverized to flour using [illegible]wood milling machine model AT941A. After pulverizing, [illegible]lour was stored in airtight ziplock bags at [illegible] temperature of 25ºC away from light and humidity.

2.3 Formulation of comp[illegible]ite flour from millet-orange fleshed sweet potato-carrot periwinkle and oyster meat

The protein content of the food materials was determined using the Kjeldahl method as described by AOAC (2012). The composites were formulated based on the recommended formulation of complementary food for infants (6–12 months) according to FAO/WHO [19]. A formulation containing all the processed flours was formed in ratios as shown in Table 1.

2.4 Experimental design, study participants and feeding intervention

2.4.1 Experimental design

This randomized controlled study involved 120 subjects divided equally into six groups based on their age, sex, weight, and height. A total of 20 children (10 boys and 10 girls) were assigned to the control group who received Cerelac®. Twenty (20) children (10 boys and 10 girls) were assigned as study gr[illegible] received millet and orange-fleshed sweet potat[illegible]s. Twenty [illegible]) groups (10 boys and 10 girls) were assigne[illegible]tudy II w[illegible] received millet / orange-fleshed sweet po[illegible]toes [illegible] T[illegible]enty (20) children (10 boys and 10 girls) [illegible]ere al[illegible] assig[illegible]d as study III who were fed with millet [illegible]fleshed sweet potatoes / carrot / oyster. Twenty (20) children (10 boys and 10 girls) were also assigned as study IV who was fed with millet / orange-fleshed sweet potatoes / carrot / periwinkle. Group V was composed of 20 children (10 boys and 10 girls) who were fed millet, orange-fleshed sweet potatoes, carrots, oysters, and periwinkle.

Table 1: Quantity of protein to be provided by each food item and the q[illegible]ity of food [illegible]em required to supply the required protein (15 g)

Sample	Ratio	Millet (g)	OFSP (g)	Carrot (g)	Oyster (g)	Periwinkle (g)	Total (g)
M	Cerelac®	-	-	-	-	-	14
MO	70:30	10.50 (150.1)	4.50 (144.3)	[illegible]	-	-	15 (294.4)
MOC	57:32:11	8.55 (122.1)	4.80 ([illegible])	[illegible] (183.3)	-	-	15 (459.2)
MOCOM	65:20:5:10	9.75 (139.3)	3.00 (96.[illegible])	0.75 (83.3)	1.50 (2.3)	-	15 (321.1)
MOCPM	49:29:7:15	7.35 (105.0)	[illegible] (139.4)	1.05 (116.7)	-	2.25 (3.2)	15 (364.3)
MOCOMPM	70:13:3:7:7	10.50 (150.1)	1.9[illegible] ([illegible])	0.45 (50.0)	1.05 (1.62)	1.05 (1.5)	15 (265.8)

Data are presented as amount of food protein in grams. **Abbreviations:** [illegible]elac® (Control diet); MO= millet/orange-fleshed sweet potato 70:30 (Test diet 1); MOC = millet/orange-fleshed sweet potato/carrot 57:32:11:0:0 (Test diet [illegible]; MOCOM[illegible]/orange-fleshed sweet potato/carrot/oyster meat flour 65:20:5:10 (Test diet 3); MOCPM = millet/orange-fleshed sweet potato/carrot/periwinkle meat flou[illegible]9:29:7:15 (Test di[illegible]); MOCOMPM = millet/orange-fleshed sweet potato/carrot/oyster/periwinkle meat flour 70:13:3:7:7 (Test diet 5)

2.4.2 Experimental participants

One hundred and twenty children (120), aged 6 – 24 months), were recruited for the study. The health of the children was considered by checking the children's vital signs by a healthcare professional, and any child displaying a sign of weakness was not included in the study. The children were screened for congenital and infectious diseases such as measles, whooping cough, and inability to swallow complementary foods. The inclusion criteria included screened and confirmed healthy children who would have been screened by a healthcare professional and were free from any health disorder and could eat well.

2.4.3 Feeding intervention

The administration of test food (diets supplemented with orange-fleshed sweet potatoes, carrots, periwinkle, and oysters) lasted for thirty-six weeks. The experimental group was instructed to consume 50 g of the test diets every day as breakfast for thirty-six weeks. Each serving of the test diet (50 g) was stirred into 250 mL of boiling water and stirred with a wooden spoon until a smooth consistency was obtained. About three (3) grams of sugar were added. The porridges were distributed to the intervention group daily as breakfast.

2.5 Anthropometric measurements

Anthropometric measurements consisted of measuring body weight, height, and head and mid-upper arm circumference of the children were taken at baseline and at the end of the study using the method recommended by the WHO [20]. The percentage difference between the two values (baseline and endline) was calculated by dividing the absolute value of the difference between the two values by the average of the values and multiplying by 100. A British weighing scale was used for weight measurements. The subjects were placed nauseous on the scales, and their weights were recorded to the nearest 0.1 kg. The measurements were taken before and after feeding the subjects. The subjects' height and length were assessed using a microtome height meter (20-205 cm; Seca 21 Standiometer). All the measurements were taken with an accuracy of 0.01 cm. The length of the subjects was collected with the aid of an infantometer (range 0-110 Chasmors Ltd, London, Uk) to the nearest 0.5 cm.

The heads of the children were measured with a narrow, non-stretchable Chinese measuring tape (superior tailoring rule). The tape was placed across the forehead just above the supraorbital ridges. It was passed around the head at the same level on both sides of the occiput and was fixed well to obtain the maximum circumference to the nearest 0.1 cm. The mid-upper arm circumference of the subjects was measured from the left upper arm. This was done between the tip of the shoulder and the tip of the elbow using measuring tape (the superior tailoring rule). The mid-upper arm circumference was obtained to the nearest 0.1 cm.

2.6 Biochemical analysis of blood samples

Biochemical analysis of the children was taken at baseline and at the end of the study. Similarly, the percentage difference between the two values (baseline and endline) was calculated by dividing the absolute value of the difference between the two values by the average of the values and multiplying by 100. The blood sample of each infant was collected into two (2) different sample bottles. One bottle contained 2 l of blood and the other contained anti-coagulant K-EDTA (potassium Ethylene Diamine Tetracetic acid) to prevent interface with hemoglobin (HB) estimation. The blood samples were taken to the laboratory for analysis within 2 hours of collecting them to avoid spoilage. Hemoglobin content was determined using the UV-VIS Spectrophotometer, while serum calcium concentration was determined using a colorimeter as described by Dacie & Lewis [23].

2.7 Ethical considerations

Ethical approval was obtained from the Ethics and Research Committee of the Rivers State University Teaching Hospital, Port Harcourt. The study was carried out following the ethics as stipulated by the Nigerian National Code for Health Research Ethics and Committee (NHREC). The informed consent of the caretaker of the motherless baby's home at Good Shepherd Foundation, Woji Road, Port Harcourt, was sorted three weeks before the commencement of the study.

2.8 Statistical analysis

Data obtained from this study was analyzed using statistical software, SPSS Version 21 (Statistical Package for Social Sciences Version 17). Continuous variables were expressed as means and standard deviation. Association between the baseline and endline were evaluated using Chi (X2) square statistics. Test results were considered as significant if p-value was < 0.05.

3 Results

3.1 Anthropometric status of infants after feeding the formulated complementary foods

Table 2 shows the anthropometric status of infants after feeding the complementary foods. Length of the infants at the baseline ranged from 55.06 – 68.95 cm while it ranged from 59.23 – 72.06 cm at the end line. Infants who consumed MOC had the highest length (72.06 cm) at the endline and this was significantly ($p < 0.05$) different from all other groups. However, MOCOP produced the highest percentage effect (7.30 %) on the length of the infants. The percentage effects of MO, MOC, MOCO and MOCP on the length of the infants were similar (4.32 %; p = 0.025, 4.41 %; p = 0.004, 4.67 %; p = 0.015, and 4.41 %; p = 0.021, respectively).

Weight of the infants at the base line ranged from 5.01 kg in infants who consumed MOCO to 7.31 kg in infants who consumed MO. At the end line, infants who consumed the control diet (Cerelac®) had the highest weight (11.67 kg) and this was followed closely by infants who consumed MOCOP (10.66 kg) which produced the highest percentage effect (57.96 %; p = 0.016) on the weight of the infants. There was no significant ($p<0.05$) difference in the weight of infants who consumed MO, MOCO and MOCP at the end line.

Mid-upper circumference of the infants at the baseline ranged from 9.23 cm in infants who consumed Cerelac® to 10.82 cm in infants who consumed MOCO. At the endline, infants who consumed Cerelac® had the highest mid-upper circumference (14.87 cm) while infants who consumed MO had the lowest (12.49 cm). The percentage effect showed that Cerelac® had the highest percentage effect (46.80 %; p = 0.041) on the mid-upper circumference of the infants and this was followed closely by infants who consumed MOCOP. MOCP and MOC had similar percentage effect (25.74 %; p = 0.005 and 24.85 %; p = 0.019, respectively) on the mid-upper circumference of the infants.

0.033) and MOCP (5.81 %; p = 0.028) while MO produced the lowest percentage effect (0.90 %; p = 0.214) on the head circumference of the infants. The percentage effects of MOCO and Cerelac® on the head circumference of the infants were similar (2.83 %; p = 0.016 and 2.78 %; p = 0.044, respectively).

3.2 Biochemical parameters of infants fed with the formulated complementary foods

Table 3 presents the biochemical parameters of infants fed with the formulated complementary foods. The concentration of iodine of the infants at the baseline ranged from [illegible].27 mg/dl to [illegible].68 mg/dl with the highest value (0.27

Table 2: Anthropometric Indices of Infants fed with the formulated Complementary foods (n=120)

Measures	Samples	Baseline (mg/dl)	End line (mg/dl)	Percentage difference (%)	p-value
Length	Cerelac®	60.31±0.5[illegible]	63.7[illegible]0.46	5.47	0.019*
	MO	65.39±0.39	[illegible]8±0.08	4.32	0.025*
	MOC	68.95±0.38	72.06±0.03	4.41	0.004*
	MOCO	[illegible]	65.11±0.08	4.67	0.015*
	MOCP	66.[illegible]	69.51±0.25	4.41	0.021*
	MOCOP	55.06[illegible]	59.23±0.07	7.30	0.044*
Weight	Cerelac®	6.55±0.2[illegible]	11.67±0.23	56.20	0.029*
	MO	[illegible].31±0.16	8.63±0.17	16.56	0.144
	MOC	[illegible]	7.80±0.16	35.29	0.022*
	MOCO	[illegible]	8.37±0.21	50.22	0.042*
	MOCP	[illegible]07±0.12	8.65±0.48	52.19	0.013*
	MOCOP	[illegible]0.08	10.66±0.07	57.96	0.016*
Mid-upper circumference	Cerelac®	9.23±0.05	14.87±0.17	46.80	0.041*
	MO	10.57±0.03	12.49±0.11	16.65	0.001*
	MOC	10.43±0.03	13.39±0.08	24.85	0.019*
	MOCO	10.82±0.10	13.46±0.07	21.66	0.021*
	MOCP	10.46±0.06	13.55±0.06	25.74	0.005*
	MOCOP	9.53±0.25	14.06±0.11	38.41	0.028*
Head circumference	Cerelac®	44.31±0.08	46.45±0.25	4.72	0.044*
	MO	39.83±0.25	40.19±0.69	0.90	0.214
	MOC	43.23±0.11	44.13±0.07	2.06	0.341
	MOCO	42.79±0.18	44.02±0.08	2.83	0.016*
	MOCP	42.27±0.11	44.80±0.03	5.81	0.028*
	MOCOP	43.11±0.08	45.86±0.03	6.18	0.033*

Mean values are of duplicate determinations. Mean values within a column with different superscripts are significantly different at ($p < 0.05$). **Abbreviations:** MO = 70 % Millet: 30 % Orange-fleshed sweet potato; MOC = 57 % M: 32 % O: 11 % C; MOCO = 65 % M: 20 % O: 5 % C: 10 % Oyster; MOCP = 49 % M: 29 % O: 7 % C: 15 % Periwinkle; MOCOP = 70 % M: 13 % O: 3 % C: 7 % Oyster: 7 % Periwinkle.

Head circumference of the infants at the baseline ranged from 39.83 cm to 44.31 cm with the infants who consumed Cerelac® having significantly ($p < 0.05$) higher head circumference (44.31 cm). At the endline, infants who consumed Cerelac® also had significantly higher head circumference than other groups. However, the highest percentage effect was observed in MOCOP (6.18 %; p =

mg/dl) recorded in infants who consumed Cerelac® while infants who consumed MO had the lowest iodine concentration. At the endline, infants who consumed Cerelac® also had the highest iodine concentration (1.78 mg/dL) while infants who consumed MOC had the lowest iodine (0.27 mg/dL). The highest percentage effect (89.43 %; p = 0.041) was observed in infants who consumed Cerelac®

and this was followed closely by infants who consumed MOCOP (63.41 %; p = 0.008). MOC and MOCO produced similar percentage effects (20.41 %; p = 0.149 and 20.56 %; p = 0.277) on the iodine concentration of the infants.

Calcium concentration of the infants at the baseline ranged from 1.07 mg/dL in infants who consumed Cerelac® to 3.90 mg/dL in infants who consumed MO. At the endline, infants who consumed MO also had the highest calcium concentration (8.22 mg/dL) while infants who consumed Cerelac® had the lowest calcium (4.61 [illegible]g/d[illegible]owever, MOCP produced the significantly ([illegible] < 0.05[illegible]her percentage effect (137.95 %; p = 0[illegible]28) [illegible] the calcium concentration of the infants whi[illegible]O[illegible] had [illegible]he least percentage effect (71.29 %; p = 0.017).

Hemoglobin concentration of [illegible]fants at [illegible]e baseline ranged from 4.56 – 5.52 [illegible]g/dL [illegible] infants who consumed Cerelac® recodi[illegible] highest hemoglobin concentration while infants who con[illegible] MO had the least concentration (4.56 mg/dL). At the en[illegible]dline, infants who consumed MOCOP recorded the highest hemoglobin concentration (18.01 mg/dL) while infants who consumed MO had the least concentration (11.79 mg/dL). The percentage effect of the diets on the hemoglobin levels were higher in infants fed with MOCOP (109.45 %; p = 0.020) than other groups.

Table 3: Biochemical indices of infants fed with the formulated complementary foo[illegible]

Measures	Samples	Baseline (mg/dl)	End line (mg/dl)	Percentage d[illegible]ference (%[illegible]	p-value
Iodine	Cerelac®	0.68±0.01a	1.78±0.0[illegible]	8[illegible].43	0.041*
	MO	0.27±0.01e	0.31±0.[illegible]	[illegible]13.79	0.205
	MOC	0.22±0.01f	0.27[illegible].00f	20.41	0.149
	MOCO	0.48±0.01b	0.5[illegible]0.00d	20.56	0.277
	MOCP	0.34±0.01d	0[illegible]c	58.33	0.032*
	MOCOP	0.42±0.01c	[illegible]81±0.[illegible]	63.41	0.008*
Calcium	Cerelac®	1.07±0.41cd	[illegible]4.61±0.17e	124.65	0.009*
	MO	3.90±0.91a	8.22±0.11a	71.29	0.017*
	MOC	1.12±0.56c	4.24±0.18f[illegible]	116.42	0.024*
	MOCO	1.82±0.40b	7.34±0.19b[illegible]	120.52	0.011*
	MOCP	1.21±0.37c	6.59±0.2[illegible]	137.95	0.028*
	MOCOP	1.19±0.30c	[illegible]d	127.33	0.004*
Hemoglobin	Cerelac®	5.52±[illegible]	15.47±0.25c	94.81	0.003*
	MO	4.56±[illegible]	[illegible]9±0.03f	88.51	0.013*
	MOC	5.00±0.[illegible]	[illegible].53±0.69e	85.91	0.032*
	MOCO	4.62±0.20d	13.62±0.46d	98.67	0.026*
	MOCP	[illegible]±0.38b	16.72±0.03b	105.67	0.042*
	MOCOP	[illegible].47b	18.01±0.08a	109.45	0.020*

Mean values are of duplicate determinations. Mean values within a c[illegible]n wit[illegible]perscripts are significantly different at (p <0.05). **Abbreviations:** MO = 70 % Millet: 30 % Orange-fleshed sweet potato; MOC = 57 % M: 32 % O: 11 % [illegible] = 65 % M: 20 % O: 5 % C: 10 % Oyster; MOCP = 49 % M: 29 % O: 7 % C: 15 % Periwinkle; MOCOP = 70 % M: 13 % O: 3 % C: 7 % Oyster: 7 % Periwin[illegible].

4 Discussion

The assessment of the anthropometry of the infants indicated that infants that were fed millet, OFSP, carrots, oysters, or periwinkle had longer statures, even when they had low baseline statures at the onset of the feeding. The increase in length after feeding might be attributed to the addition of OFSP, periwinkle, and oyster. Ivon and Eyo [12] asserted that shellfish such as periwinkle and oysters are valuable, cheap, and good sources of protein. When shellfish (protein) and millet (carbohydrate) were combined, the length of infants increased. With the addition of carrots, they all had better growth patterns in infants. Thus, enriched complementary foods can be used to address malnutrition issues.

The formulations had an increasing effect on the weight of the infants. Chipili et al. [24] had already reported a better growth pattern in children fed a maize-based diet with the addition of fish powder to the infant's usual powder. The inclusion of carrots, orange-fleshed sweet potatoes, periwinkle, and oysters in infant food formulation could help to reduce malnutrition among vulnerable groups. The formulations also had a significant (p > 0.05) effect on the endline data. Upper mid-arm circumference has been identified by Mwangome et al. [25] as a critical tool that enables the implementation of community-based management of acute malnutrition. The result showed that Cerelac® and MOCOP produced a significantly (p < 0.05) higher percentage effect on the mid-upper circumference of the infants. Hence, MOCOP could be used for the management of acute malnutrition. Head circumference measurement reflects head growth and is a useful tool for tracking and monitoring child growth and development [26]. The result from the present study showed that MOCP and MOCOP produced a significantly ($p < 0.05$) higher percentage effect on the head circumference of the infants. According to the WHO [27], infants as young as 12 months are supposed to triple their birth age, with their head and chest being equal within this age range. This was achieved at the end of the feeding for the control sample and the formulations MOCOP, MOCO, and MOCP.

In the present study, none of the formulations reached the WHO iodine level of 70 ug/dL daily. This might be because the children were fed the formulations once a day. If they are fed the normal three or four times daily, this requirement might be met. FAO/WHO [28] explained that iodine is important in infants for the synthesis of thyroid hormones necessary for growth, development, and the avoidance of mental retardation. The infants in this study had a low hemoglobin level at baseline (4.56 – 5.52 g/dL). Severe anemia was defined as hemoglobin levels of 5.0 g/dL in children [29]. This indicated that the infants in this study had severe anemia at the base line. A high prevalence of anemia has been reported among Nigerian children. Ughasoro et al. [30] reported a prevalence of 4[illegible] in south-east Nigeria, with the highest prevalence among children 12-month-old, whereas Mainasara et al. [31] reported a prevalence of 34.8 % among children in Sokoto, north-western Nigeria. Hemoglobin concentration (Hb) is used clinically to determine the presence of anemia. Anemia is a global problem with a major debilitative effect, especially in children in sub-Saharan Africa [32]. The current study further showed that MOCOP produced a significantly ($p < 0.05$) higher percentage effect (119.43 [illegible]) on the hemoglobin concentration of the infants. This suggests that periwinkle and oyster supplementation improved the infants' hemoglobin levels. The effect of millet, OFSP, carrot, oyster, and periwinkle on the hemoglobin levels of infants was significantly ($p < 0.05$) higher, probably because all the fortifications were used in the formulations. The result therefore showed that the formulated complementary foods have the potential to prevent anemia in infants and young children. According to Linderkamp et al. [33], an infant's hemoglobin level at birth ranges from 14.9 to 23.7 g/dL in term babies and 19.1 – 22.1 g/dL in preterm infants. Supplementing maize-based complementary foods with periwinkle and oyster may produce an acceptable result as a protein in red blood cells that transports oxygen to the body's organs and tissues.

The resultant effect of the formulations on calcium levels indicated that there is a baseline calcium deficiency. After the feeding, the blood calcium level increased, especially for infants fed with millet, OFSP, carrots, or periwinkle (47.15 %). The WHO [22] established a calcium safety level of 8.8 ug/dl. Ruel et al. [34] observed a decrease in blood calcium in children, which they attributed to the low calcium content of their diets. Calcium aids in bone and tooth growth. Low calcium could result from poor growth and development of bones and teeth during the first 1000 days of an infant's life and could lead to a disease condition known as osteoporosis. If the infants are fed their normal three or four meals per day, this low calcium level may not be achieved in one meal per day.

5 Conclusion

The effect of millet-based diets supplemented with carrot, orange-fleshed sweet potato, oyster, and periwinkle on the nutritional status of infants was statistically significant. The assessment of the anthropometric status of the investigated infants indicated that infants fed with millet / OFSP / carrot / oyster / periwinkle had higher length, head circumference, iodine, body weight, calcium, and hemoglobin concentrations than other formulations. This suggests that periwinkle and oyster supplementation contained the required hemoglobin levels, implying that they could be more appropriate for the prevention of anemia and protein-energy malnutrition in infants in developed countries. However, to achieve maximum nutritional effect, the infants must be fed at least three times a day with the formulated complementary food.

Study Limitations

This study has two limitations. First, the study sample size is limited which may affect the generalizability of results. The other limitation is that the survey was conducted in an urban area which may not represent pastoralists living in the rural areas.

Acknowledgement: None.

Author Contribution AEU: Conceptualization, Methodology, undertook the literature research, analysis, and interpretation of data, Writing- Original draft preparation. OOF: Writing- Reviewing and Editing. All authors approved the final version before submission.

Funding (Source of support): This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflicts of Interest: The authors declare no conflicts of interest or personal ties that could appear to have influenced the work described in this study.

References

[1] Pearce, J., & Langley-Evans, S. C. (2013). The types of food introduced during complementary feeding and risk of childhood obesity: a systematic review. *International*

Journal of Obesity (2005), *37* (4), 477–485. https://doi.org/10.1038/ijo.2013.8

[2] Obinna-Echem, P. C., Barber, L. I., & Enyi, C. I. (2018). Proximate composition and sensory properties of complementary food formulated from malted pre-gelatinized maize, soybean and carrot flours. *Journal of Food Research*, *7* (2), 17. https://doi.org/10.5539/jfr.v7n2p17

[3] Michaelsen, K. F., Hoppe, C., Roos, N., Kaestel, P., Stougaard, M., Lauritzen, L., … Friis, H. (2009). Michaelsen, K. F., Hoppe, C., Roos, N., Kaestel, P., Stougaard, M., Lauritzen, L., Mølgaard, C., Girma, T., & Friis, H. (2009). Choice of foods and ingredients for moderately malnourished children 6 months to 5 years of age. *Food and Nutrition Bulletin*, *30* (3_suppl3), S343–S404. https://doi.org/10.1177/15648265090303s303

[4] *The future of food and agriculture: Trends and challenges*. (2017). Food and Agriculture Organization of the United Nations. https://www.fao.org/3/i6583e/i6583e.pdf

[5] Asfaw Tufa, M., & Food, Medicine and Health Care Administration and Control Authority of Ethiopia. (2016). Development and nutritional assessment of complementary foods from fermented cereals and soybean. *Food Science & Nutrition*, *2* (2), 1–8. https://doi.org/10.24966/fsn-1076/100014

[6] Amadou, I., Gbadamosi, S., Le, G. W. (2011). Millet-b[illegible]sed Traditional Processed Foods and Bevera[illegible] A Review. *Cereal Foods World*. *56*, [illegible]15-12[illegible] https://doi.org/10.1094/cfw-56-3-0115

[7] Amadoubr, I., & Le, M. (2013). Millets: [illegible]nal composition, some health benefits and processing [illegible] Review. *Emirates Journal of Food an[illegible] Agriculture, 25* (7), 501. https://doi.org/10.9755/e[illegible]25i7[illegible]12045

[8] Bachar, K., Mansour, E., Ben Khaled, A., Abi[illegible] Had[illegible]ad, M., Ben Yahya, L., El Jarra[illegible] & Ferc[illegible]i, A. (2013). Fiber content and m[illegible]neral [illegible]mpositio[illegible] of the finger millet of the oasis [illegible] *Journal of Agricultural Science*, [illegible] (2). https://doi.org/10.5539/jas.v5n2p219

[9] Nungo, R. A., Okoth, M. W., & Mbugua, S. K. (2012). Nutrition status of children under-five years in cassava consuming communities in nambale, Busia of western Kenya. *Food and Nutrition Sciences*, *03* (06), 796–801. https://doi.org/10.4236/fns.2012.36107

[10] Isingoma, B. E., Mbugua, S. K., & Karuri, E. G. (2019). Nutritional status of children 7–36 months old from millet consuming communities of Masindi district, western Uganda. *BMC Nutrition*, *5* (1). https://doi.org/10.1186/s40795-019-0273-z

[11] Ufot, E. I., Idorenyin G. E. & Barthlomew, N. E. (2018). Evanson Inyang, U. (2018). Comparative study on the chemical composition and amino acid profile of periwinkle and rock snail meat powders. *International Journal of Food Science and Biotechnology*, *3* (2), 54. https://doi.org/10.11648/j.ijfsb.20180302.13

[12] Akpang, I., & Oscar, E. (20[illegible]). Proximate composition and mineral content[illegible] of ed[illegible] part of four species of shellfishes fro[illegible] the calaba[illegible] river, Nigeria. *Annual Research & [illegible] in [illegible]ology*, *26* (1), 1–10. https://doi[illegible]rg/10.9[illegible]2018/35649

[13] Abeshu, M. A[illegible] Le[illegible]a, A., & Geleta, B. (2016). Complem[illegible] feedin[illegible] Review of recommendations, feedi[illegible]g practic[illegible]nd adequacy of homemade co[illegible]entary food preparations in developing [illegible]untrie[illegible] Lessons from Ethiopia. *Frontiers in [illegible]utrition*, *3*. ht[illegible]ps://doi.org/10.3389/fnut.2016.00041

[14] [illegible]ederal Ministry of Health (FMH) (2005). National policy on infant [illegible]nd young child feeding in Nigeria. Abuja, Nigeria.

[15] Udo[illegible]., & Amodu, O. K. (2016). Complementary feeding practices among mothers and nutritional status [illegible] infants in Akpabuyo Area, Cross River State Nigeria. *SpringerPlus*, *5* (1), 2073. https://doi.org/10.1186/s40064-016-3751-7

[16] O[illegible]inna-Echem, P. C., Barber, L. I., & Enyi, C. I. (2018). Proximate composition and sensory properties of complementary food formulated from malted pre-gelatinized maize, soybean and carrot flours. *Journal of Food Research*, *7* (2), 17. https://doi.org/10.5539/jfr.v7n2p17

[17] Kolawole, F. L., Akinwande, B. A., & Ade-Omowaye, B. I. O. (2020). Physicochemical properties of novel cookies produced from orange-fleshed sweet potato cookies enriched with sclerotium of edible mushroom (Pleurotus tuberregium). *Journal of the Saudi Society of Agricultural Sciences*, *19* (2), 174–178. https://doi.org/10.1016/j.jssas.2018.09.001

[18] Iombor, T. T., Umoh, E. J., & Olakumi, E. (2009). Proximate Composition and Organoleptic Properties of Complementary Food Formulated from Millet (Pennisetum psychostachynum), Soybeans (Glycine max) and Crayfish (Euastacus spp). *Pakistan Journal of Nutrition : PJN*, *8*(10), 1676–1679. https://doi.org/10.3923/pjn.2009.1676.1679

[19] FAO/WHO. (1991). Codex standards for processed cereal-based (including guidelines on formulated

supplementary foods for older infants and young children). World Health Organization, Geneva, Switzerland.

[20] World Health Organization. (2006). *The World Health Report 2006: Working together for health* (2006th ed.). World Health Organization.

[21] World Health Organization. (2003). *The world health report 2003: Shaping the future*. World Health Organization.

[22] World Health Organization (WHO). (2012). *World health statistics 2012*. World Health Organization.

[23] Mitchell Lewis, S., Dacie, J. V., Bain, B. J., & Bates, I. (2001). *Dacie and Lewis's Practical Haematology* (9th edition). Churchill Livingstone.

[24] Chipili, G., Van Graan, A., Lombard, C. J., & Van Niekerk, E. (2022). The efficacy of fish as an early complementary food on the linear growth of infants aged 6–7 months: A randomised controlled trial. *Nutrients*, *14* (11), 2191. https://doi.org/10.3390/nu14112191

[25] Mwangome, M. K., Fegan, G., Mbunya, R., Prentice, A. M., & Berkley, J. A. (2012). Reliability and accuracy of anthropometry performed by community health workers among infants under 6 months in rural Kenya: Reliability of MUAC in infants under 6 months. *Tropical Medicine & International Health: TM & IH*, *17* (5), 622–629. https://doi.org/10.1111/j.1365-3156.2012.02959.x

[26] Jones, G., & Samanta, D. (2022). *Macrocytosis. In: StatPearls [Internet]. Treasure Island (FL)*. StatPearls Publishing.

[27] *Joint FAO/WHO expert meeting on the public health risks of histamine and other biogenic amines from fish and fishery products: Handbook*. (2013). World Health Organization.

[28] Evaluation of Health and Nutritional Properties of Probiotics in Food Including Powder Milk with Live Acid Bacteria. (n.d.). *Report of a Joint FAO/WHO Expert Consultation*.

[29] Ouma, J. O., Mulama, D. H., Otieno, L., Owuoth, J., Ogutu, B., Oyieko, J., Korir, J. C., Sifuna, P., Singoei, V., Owira, V., Gondii, S. M., Andagalu, B., & Otieno, W. (2021). Clinical laboratory hematology reference values among infants aged 1month to 17 months in Kombewa Sub-County, Kisumu: A cross sectional study of rural population in western Kenya. *PLOS ONE*, *16* (3), e0244786. https://doi.org/10.1371/journal.pone.0244786

[30] Ughasoro, M. D., Emodi, I. J., Okafor, H. U., & Ibe, B. C. (2015). Prevalence and risk factors of anaemia in paediatric patients in south-east Nigeria. *South African Journal of Child Health*, *9* (1), 14. https://doi.org/10.7196/sajch.760

[31] Mainasara, A., Ibrahim, K., Uko, E., Jiya, N., Erhabor, O., Umar, A., Muhammad, S., Sanusi, M., Garba, A., [illegible]da, M., Ladipo, S., Haruna, L., Sani, L., Onuigwe, F., Danyaro, M., & Bello, Z. (2017). Prevalence of anaemia among children attending paediatrics department of UDUTH, Sokoto, North-Western Nigeria. *International Blood Research & Reviews*, *7* (1), 1–10. https://doi.org/10.9734/ibrr/2017/29225

[32] World Health Organization (2008). Worldwide prevalence of anemia 1993-2005. WHO Global Database on Anaemia. Geneva: World Health Organization, 2008.

[33] Linderkamp, O., Zilow, E. P., & Zilow, G. (1992). Kritische Hamoglobinwerte bei Neugeborenen, Sauglingen und Kindern [The critical hemoglobin value in newborn infants, infants and children. *Beitr Infusionsther*, *30*, 235–246

[34] Ruel, N.T., Menon, P., Loechl, C. & Pelto, G. (2005). Donated fortified cereal blends improve the nutrient density of traditional complementary foods in Haiti, but iron and zinc gaps remain for infants. *Food and Nutrition Buletin*, 25(4): 361-376. https://doi.org/10.1177/156482650402500406.