Original Research Article

NUTRITIONAL QUALITY OF WEANING FOODS FORMULATED FROM MAIZE GRUEL 'OGI' AND CRAYFISH USING COMBINED TRADITIONAL PROCESSING TECHNOLOGY.

ABSTRACT

Aims: To investigate the nutritional quality of weaning foods produced from maize gruel 'ogi' and crayfish using combined traditional processing techniques (germination, fermentation and toasting).

Study design: Randomized block design

Place and Duration of Study: Department of Food Science and Technology, Federal University of Technology, Akure, Ondo State, Nigeria, between January 2013 and November 2014.

Methodology: Maize grains were germinated at room temperature for three days after which they were fermented for 24 h. the maize grains were milled into slurry and divided into two portions. The first portion was oven-dried at 50^{o}C and milled into flour while the second portion was toasted at 80^{o}C and milled into flour. The two flours were separately mixed with crayfish powder to obtain oven-dried crayfish-ogi blend and toasted crayfish-ogi blend. The microbiological quality of the blends was determined. The nutritional qualities of the crayfish enriched ogi blends were assessed biologically using animal feeding experiment to determine the growth rate, feed intake, protein quality parameters and haematological properties. A commercial weaning food (Crelac) and traditional weaning food, ordinary ogi (Maize gruel), were used as control diets

Results: The total mesophilic bacteria count of the *ogi* blends ranged from 1.2 to 2.5x 10^{3} cfu/g. Mold (1.0 x 10^{3}) were found in both oven-dried and toasted crayfish enriched *ogi* blends. Yeasts were found only in oven-dried enriched *ogi* blend (1.0 x 10^{3}cfu/g). Coliform, staphylococcus and salmonella were not detected in all the formulated diets. The growth rate of animals fed with crayfish enriched-ogi blends were lower than those fed with the cerelac, but higher than those fed with ordinary ogi. The protein efficiency ratio of animals fed with crayfish enriched ogi blends was was similar ($p= 0.05$) to those fed with cerelac diet. The net protein ratio, True digestibility, Biological value and Net protein utilization of animals fed with crayfish enriched ogi diet were significantly lower ($p<0.05$) than those fed with cerelac diet. The weight of the heart, liver, spleen and kidney of animals fed with crayfish-enriched *ogi* blends were significantly higher ($p=0.05$) than those fed with ordinary *ogi* but similar to the rats fed with casein and cerelac diets. The haematological variables of animals fed with crayfish enriched ogi diets, commercial weaning food (cerelac) and casein diet were not significantly ($p>0.05$) influenced by the dietary treatment .

Conclusion: Crayfish enriched ogi has potential as a functional weaning food with adaptable production technology (toasting) especially among rural dwellers.

Keywords: Quality evaluation, crayfish, enrichment, Ogi, germination, fermentation, toasting

1. INTRODUCTION

When breast milk is no longer enough to meet the nutritional needs of the infant at the age of four or six months and above, complementary foods (i.e., traditional or commercial weaning foods) should be added to the diet of the child. Several commercial weaning foods are marketed in Nigeria, but they are too expensive for people of low socio-economic status, especially those in the rural areas [1]. The most popular traditional weaning food in Nigeria which is fermented maize gruel known as 'ogi' has been implicated in the etiology of protein – energy malnutrition (PEM) in children during weaning period due to the low nutritive value characterized by low protein, low energy density and high bulk [2]. There is therefore a need to develop weaning foods with adequate protein that will promote growth in children from low cost local food sources using methods that are suitable at village level or at home.

Food processing techniques such as roasting, germination, milling, cooking, drying, fermentation and extrusion have the potential to enhance the nutrient bioavailability, nutrient density, food safety, storage stability, palatability, and convenience of supplementary foods suitable for infant mixtures [3]. Germination, fermentation and toasting of cereals are affordable and widely practiced processing techniques in Africa [4]. Fermentation enhances the nutrient of foods through biosynthesis and bioavailability of vitamins, essential amino acids, reducing the antinutrients and improving the protein quality and fibre digestibility [5, 6]. Germination unlocks many nutrients which are in bound forms in the food and thereby increases nutrient bio-availability, energy density and acceptability of the food [7, 8]. Toasting reduces anti-nutrients, improves the taste and nutrient quality of the food product and lowers the moisture content of such food product thereby increasing its shelf life [9]. An integrated approach that combines a variety of the traditional food processing techniques in the preparation of weaning food, including the addition of small amount of animal-source foods has been reported to be the best strategy to improve the nutrient content and bioavailability of micro- nutrients in plant-based diets in resource-poor settings [10] . The combination of two or more food processing techniques is more effective in removing antinutritional factors in cereal and thereby producing high nutrient dense weaning food [11]

Crayfish which is classified as an animal polypeptide is a freshwater crustacean resembling small lobster and it is commonly found in Nigerian coastal water. Crayfish is relatively cheap, affordable and readily available throughout the year. A review of nutritional value of crayfish showed that it is a good source of protein (36 -45%) with a superior biological value, true digestibility, net protein utilization, high content of essential amino acid, and protein efficiency is favourable compared to casein [12,13]. It is very low in carbohydrate but rich in vitamin D, A and mineral elements such as calcium, potassium, copper, zinc and iodine, [14, 15].

In the effort to curb problem of protein-energy malnutrition (PEM) among the infants in Nigeria, a number of weaning foods have been formulated from locally available food materials [2,16,17,18]. Most of these formulated complementary foods are still not accessible to many nursing mothers, as a result of the high cost of food materials and production processes [19]. The present study is therefore aimed at producing weaning foods from ogi flour and crayfish flour mixes using a combination of traditional processing techniques and evaluates the microbiological and nutritional quality of the formulated diets.

2. MATERIALS AND METHODS

2.1 Materials

White maize *(Zea mays*), white crayfish (*euastacus spp)* and commercial weaning food (cerelac) were purchased from Oba market in Akure Ondo state Nigeria.

2.2 Preparation of crayfish enriched ogi blends

The maize grains were soaked overnight after which they were germinated for 3 days. The germinated grains were dried at 60 ^{o}C for 14 hours and the radicles were removed. The germinated grains were steeped in water for 24 hours for fermentation to take place. The germinated - fermented grains were wet-milled, sieved and the slurry obtained was allowed to settle after which it was dewatered using muslin cloth. Ogi cake obtained was pulverized, sieved and divided into two portions. The first portion was oven dried at 50 ^{o}C for 24 hours while the second portion was toasted at 70 ^{o}C to 80^{o}C using open cast iron. The crayfish were cleaned and milled into flour. The two ogi flours were separately mixed with crayfish powder in ratio of 80:15 respectively to obtain oven-dried crayfish-ogi blend and toasted crayfish-ogi blend. The choice of these mixing ratios was based on the target protein which is 18%. This mixing ratio was determined by using Quarto pro 8 software programme.

2.3 Microbiological analysis

The formulated weaning diets were examined microbiologically using the procedure of Olutiola *et al*., [20] after serial dilution. The total microbial load was determined using nutrient agar in a plate count while molds and yeasts were examined using potato dextro agar. Staphylococcus aureus, coliform and salmonella were determined using manitol salt agar, macconkey agar and deoxycholate citrate agar respectively.

2.4 Experimental Diets

The experimental diets which consist of formulated diets (crayfish enriched-ogi diets), commercial weaning food (cerelac) and casein were prepared at 10% protein level (iso-nitrogenous diets). A Basal diet (ordinary *ogi*) was also prepared. Composition of experimental diets is shown in Table 1. Diet 1 is the basal diet (ordinary *ogi*), diet 2 is the control (casein diet) while diets 3, 4 and 5 are cerelac, oven dried crayfish enriched *ogi* and toasted crayfish enriched *ogi* respectively.

Table 1: Composition of experimental diet (g/100g)

Ingredients	N-free diet	Casein diet	Cerelac diet	Oven-dried enriched ogi diet	Toasted enriched ogi diet
Ordinary ogi	71.80	60.30	5.63	16.24	16.24
Casein	-	11.50	-	-	-
Cerelac	-	-	66.67	-	-
Oven-dried enriched ogi	-	-	-	55.56	-

Toasted enriched ogi	-	-	-	-	55.56
Glucose	5.00	5.00	5.00	5.00	5.00
Sucrose	10.00	10.00	10.00	10.00	10.00
Non-nutritive cellulose	5.00	5.00	5.00	5.00	5.00
Vegetable oil	5.00	5.00	5.00	5.00	5.00
Mineral mixture	2.00	2.00	2.00	2.00	2.00
Vitamin mixture	1.00	1.00	1.00	1.00	1.00
NaCl	0.2	0.2	0.2	0.2	0.2
Total	100.00	100.00	100.00	100.00	100.00

2.5 Animal Experiment

In this study, thirty weanling albino rats of the Wistar strain weighing between 30 – 65g at the beginning of experiment were obtained from the Department of Biochemistry, University of Ilorin, Kwara state, Nigeria. The rats were weighed and divided into five groups. They were randomly distributed in metabolic cages and fed on normal (pellet) diets for a period of 7 days for proper acclimatisation to the environment before commencement of the experiments. After the acclimatisation period, the animals were then re-weighed and grouped into five groups of six rats each per group such that the differences in their mean weights were ±2g. Two groups of animals were administered with the formulated diets (oven-dried crayfish enriched ogi and toasted crayfish enriched ogi). The remaining three groups of animals were administered with cerelac (a commercial weaning food), ordinary ogi and casein. Food and water were provided *ad libitum* to the rats for 28days. During this period dietary intake per day and weight of the animals were recorded. Five days before the end of feeding experiment, the faeces and urine were collected separately from each rat and pooled together at the end of the experiment. Pooled samples of faeces were dried in an oven at 80ºC for 12 hours, cooled and weighed. A few drops of dilute sulphuric acid (H2SO4) were added to the urine, which was kept under frozen conditions. Nitrogen in the urine and faeces was determined by micro-Kjeldahl method [21]. The biological value (BV), true digestibility (TD), net protein utilization (NPU), protein efficiency ratio (PER), feed efficiency ratio (FER) and net protein ratio (NPR) were calculated.

2.6 Haematological Evaluations

At the end of the experiment, all the rats were starved for 3 hours and weighed after which each rat was anaesthetised and sacrificed. Blood samples from each rat were collected into sample bottles containing a few milligram of EDTA prior to haematological analysis. The packed cell volume (PCV) was estimated by spinning about 75µl of each blood sample in heparinised capillary tubes in a haematocrit microcentrifuge for 5 minutes, and the total red blood cell (RBC) and white blood cell (WBC) counts were determined. The haemoglobin concentration (Hb) was estimated using the cyano-methaemoglobin concentration method, while the lymphocyte, neutrophil, monocyte, basophill and eosinophil were determined [22, 23]. The heart, lungs, spleen, kidneys and liver were removed, blotted free of blood and weighed [22]. The values were subsequently expressed in g/kg of body weight

2.7 Statistical analysis

All analyses were carried out in triplicates. Means were tested for differences using Analysis of Variance (ANOVA) using Statistical Analysis System Software (SAS version 9.2, SAS institute, Cary, NC). Significant differences between mean values were determined by Duncan's Multiple Range Test and accepted at $P \leq 0.05$. Data are reported as mean ± standard deviation from the mean.

3. RESULTS AND DISCUSSION

3.1 Microbial analysis

The result of *coliform, staphylococcus, salmonella*, mould, yeast and total viable count of the formulated diets are shown in Table 2. *Coliform, Staphylococcus and Salmonella* spp were absent in the formulated diets. This shows that the food will be fit for human consumption. The total viable count in all the formulated diets are below the maximum level of 1.0 $x10^5$ recommend by PAG [24]. However, all the formulated weaning diets would require cooking before feeding to children during which most of these microorganisms would be destroyed. The reduction in the total viable count of toasted enriched ogi diets may be due to toasting which was done at high temperature. (70-80^oC) and might have destroyed all the pathogenic microorganisms.

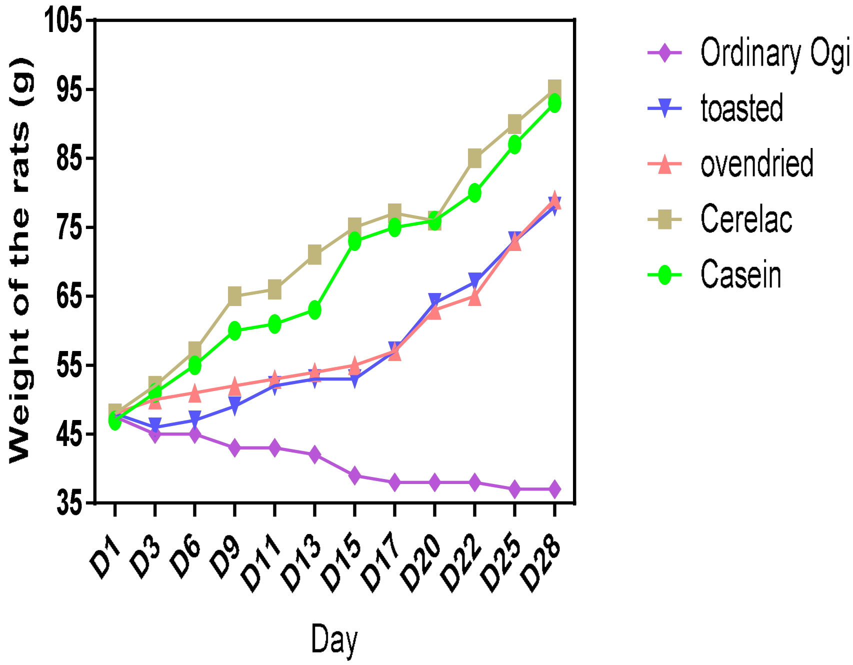
Table 2: Microbiological quality of enriched *ogi* (cfu/g)

	counts	
Micro-organism	**Ovendried**	**Toasted**
Coliform	0	0
Staphylococcus	0	0
Salmonella	0	0
Molds (sfu/g)	$1x10^3$	$1x10^3$

Yeast	$1x10^3$	0
Total viable count	$1.8x10^3$	$1.2x10^3$

3.2 Growth Performance and nutrient utilization of the experimental animals

The food intake of rats fed on the formulated diets, cerelac and casein ranged from 148.5g (oven-dried enriched ogi) to 182.2g (cerelac diet) (Table 3). Food intake of animals fed with casein and cerelac diet was significantly (p=0.05) higher than that of animals fed with oven-dried and toasted enriched ogi. A similar trend was observed in the protein intake of the experimental animals (Table3). The growth performance and weight gain /loss of the experimental animals are presented in Figure 1. The weight gain of the experimental animals ranged from 33.0 g to 46.8 g. It was observed that the weight gains of animals placed on experimental diets (oven-dried crayfish-ogi and toasted crayfish-ogi) were lower than those of animals fed with cerelac and casein diets but were higher than those of animal fed with ordinary ogi. Weight gain of animals fed with oven-dried crayfish-ogi was similar to that of animals fed with toasted crayfish-ogi. Weight gain of animals fed with cerelac and casein diet agreed with their food intake. Similar observation was reported by Ibironke, [25]. Ibironke et al. [15] reported that the diet formulated from maize flour and crayfish (10% and 15%) promoted growth more than the milk based commercial diet. Animals fed with ordinary ogi diet did not show any appreciable growth. This may be due to the fact that the diet lacked adequate nutrient such as protein with balanced amino acids. This agrees with the previous results that cereals are deficient in essential amino acid, such as lysine and tryptophan, hence, was not nutritionally adequate to promote growth [3,8,9].



D…….1042010 = Days of feeding

Fig. 1: Growth rate of rats fed with formulated weaning diets, cerelac and casein

Table 3: Nutrient utilization of rats fed with enriched ogi, casein and Cerelac

Parameters	**casein**	**cerelac**	**Oven-dried enriched ogi**	**Toasted enriched ogi**
Food intake (g)	164.6[a]	182.2[a]	148.5[b]	149.6[b]
Protein intake (g)	17.8[a]	18.5[a]	14.5[b]	15.0[b]
Nitrogen consumed	0.61	0.62	0.47	0.56
Feacal nitrogen	0.15	0.20	0.20	0.23
Urinary nitrogen	0.09	0.13	0.14	0.17
Nitrogen retained	0.37	0.28	0.13	0.16

Values followed by different superscript on the same row are significantly different (p=0.5)

The results of Feed efficiency ratio (FER), protein efficiency ratio (PER) and net protein ratio (NPR) of the experimental animals are shown in Figure 2. The feed efficiency ratio (FER) of different diets varied from 0.22g (toasted enriched ogi diet) to 0.26g (casein diet). The FER of rats fed with casein and cerelac were not significantly different (P=0.05) but were higher than those of rats fed with toasted crayfish enriched ogi and oven-dried crayfish enriched ogi diets. The corrected PERs of the different diets varied from 2.3 (toasted crayfish enriched *ogi*) to 2.5 (Casein diet). The corrected PERs of the formulated diets were similar to those of cerelac and casein diets. The PAG (Protein Advisory Group) and U.S. Department of Agriculture guidelines recommend a PER of not less than 2.1 and preferably greater than 2.3 for weaning food and corn-based blends [18,26,27]. The net protein ratio (NPR) of the diets ranged from 2.6 (toasted enriched ogi) to 3.25 (Casein diets). NPR is a more accurate measure of protein quality than PER as it allows for the evaluation of maintenance requirement and results are independent of feed intake. The NPR of the formulated diets was lower than those of casein and cerelac diets. Similar report was obtained by Fashakin, [28].

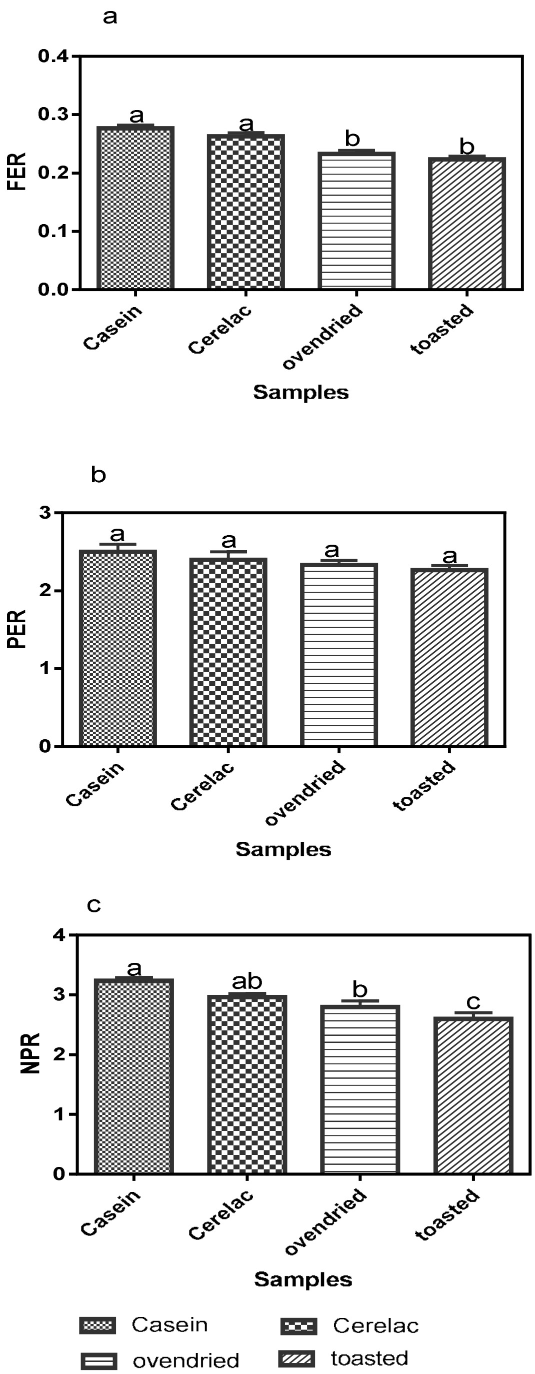


Fig. 2: (a) The Feed Efficiency Ratio (FER), (b) Protein Efficiency Ratio (PER) and (c) Net Protein Ratio (NPR) of rats fed on different weaning diets and casein

The results of true digestibility (TD), biological value (BV), net protein utilization (NPU) and protein retention efficiency (PRE) are illustrated in (Fig 3). TD, BV, NPU and PRE ranged from76.0 to 89.8%, 66.5 to 87.6%, 50.5 to77.4% and 42 to 51 respectively. The TD, BV and NPU of casein and cerelac were higher (p≤ 0.05) than those of oven-dried *and* toasted crayfish enriched *ogi* . The results obtained in the present study are similar to those observed by Obizoba [29], who reported BV values of 67.6 to 75.9% and NPU values of 51.8 to 62.3% for the weaning food prepared from malted corn plus crayfish. The lower values of TD, BV and NPU in the toasted diet may be due to roasting as it affects the availability of some amino acids. Similar report was obtained by Dahiya and Kapoor, [9] who showed that PER, TD, BV and NPU decreased on roasting. The effect of roasting on availability of amino acid can be minimized by roasting at a reduced temperature. Since protein retention efficiency (PRE) was obtained by multiplying NPR by 16, the trend of the result obtained for PRE is similar to that of NPR (Fig. 2.).

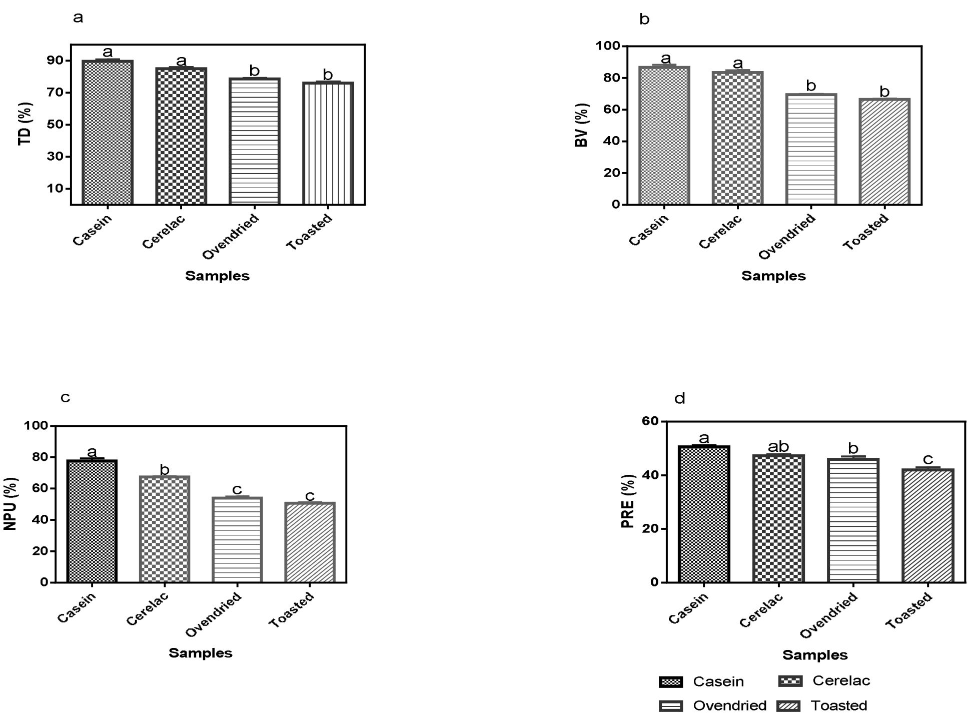


Fig. 3: (a) The True Digestibility (TD), (b) Biological Value (BV), (c) Net protein Utilization (NPU) and (d) Protein Retention Efficiency of rats fed with different weaning diets and casein

3.3 Organ weights and haematological parameters of animals fed with cerelac, casein, formulated diets and ordinary ogi

The weight of some vital organs of animals fed with cerelac, casein, formulated diets and ordinary ogi are shown in Table 4. The heart weight, the liver weight, the spleen weight and kidney weight ranged from 0.20 to 0.37g, 2.19 to 4.4g, 0.13 to 0.42 g and 0.35 to 0.78g respectively. The weights of the heart, the kidney, the spleen and liver of animals fed with oven dried and toasted crayfish enriched ogi compared favorably with those of standard diet (Casein and Cerelac). This indicates that the formulated diets may not result in abnormal development of the vital organs.

The results of haematological parameters of animals fed with cerelac, casein, formulated dietsi and ordinary ogi are shown in Table 5. The blood indices varied: packed cell volume (PCV) 30.25 to 33.0 %, haemoglobin concentration (Hb) 10.03 to 11.28%, red blood cell (RBC) 64.45 to 73.08 $x10^5$, white blood cell (WBC) 52.0 to 101.5 x 10^5, erythrocyte sedimentation rate 1.23 to 1.65, lymphocyte 50.18 to 53.15%, basophil 2.0 to 11.25%, neutrophil 30.5 to 37.35% and monocytes 7.75 to 10.0%. PCV measures the ratio of the volume occupied by red blood cell to the volume of whole blood cell. It is a convenient and rapid measure of the degree of anaemia [18]. Low PCV, HBc and serum protein have been associated with protein deficiency [25]. The PCV, Hb and RBC of rats fed with basal diet were lower than those fed with casein, cerelac and formulated diets. Similar results were reported by Osundahunsi and Aworh [30]. The values obtained for PCV, RBC, WBC and Hb of the rats fed with formulated diets were similar to those fed with casein and cerelac. The results show the adequacy of the formulated diets in blood formation. This suggests that the feeding of formulated diets will support haematopoietic activities of the body.

Table 4: Organ weights (g) of rats fed with crayfish enriched-ogi, casein, cerelac and ordinary 'ogi'

Dietary group	Heart (g)	liver (g)	Spleen (g)	Kidney (g)
Cerelac	0.28^{b}	4.02^{ab}	0.31^{ab}	0.72^{ab}
Casein	0.37^{a}	4.49^{a}	o.42^{a}	0.78^{a}
Oven-dried Enriched 'ogi'	0.29^{b}	3.79^{b}	0.29^{b}	0.55^{ab}
Toasted Enriched 'ogi'	0.31^{ab}	3.80^{b}	0.29^{b}	0.53^{ab}
Ordinary'Ogi' diet	0.20^{c}	2.19^{c}	0.13^{c}	0.35^{b}

Values with different superscript on the same column are significantly different (p=0.5)

Table 5: Haematological parameters of rats fed with formulated diets, casein and cerelac

Parameters	Toasted enriched ogi	Oven-dried enriched ogi	Casein	Cerelac	Ogi
Packed cell volume (%)	30.50	30.75	32.00	33.00	30.25
Haemaglobin (g/100ml)	10.38	10.25	10.73	11.28	10.03
Red blood cell (x 10^5)	67.55	67.30	70.98	73.08	64.45
White blood cell (x10^2)	76.63^{b}	52.01^{c}	66.51^{bc}	68.01^{bc}	101.5^{a}
Erythrocyte sedimentation rate	1.23^{b}	1.35^{ab}	1.38^{ab}	1.35^{ab}	1.65^{a}
Lymphocytes (%)	53.15	51.00	50.18	51.00	54.25
Monocytes (%)	9.00	8.00	7.75	9.00	10.00
Eosinophil (%)	2.50	2.75	2.00	2.00	3.50
Basophil (%)	1.25^{ab}	1.75^{a}	1.25^{ab}	1.50^{a}	2.01^{a}
Neutrophil (%)	36.75^{a}	30.51^{b}	37.25^{a}	36.01^{a}	31.25^{b}

Conclusion

The study showed that the formulated diets promote growth better than ordinary ogi. The haematological indices and organ weight measurement of the rats fed the formulated diets were better than that of ordinary ogi and compared favourably with that of rats fed with standard casein and Cerelac. The study indicated that oven dried enriched ogi and toasted enriched ogi may support growth in children than ordinary ogi which is currently in use as traditional weaning foods in Nigeria. The implications of these findings are far reaching since all the components used in the formulation are obtained from local market and toasting is a processing method that can easily be practiced at home. Adoption of toasted enriched ogi may make the product a potentially more functional and more accessible weaning food.

COMPETING INTERESTS

We declared no competing interests exist

ETHICAL APPROVAL

This study was approved by the ethical review committee of the Federal University of Technology, Akure, Ondo State, Nigeria

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