



Nutritional Assessment of Yam-Based Complimentary Food in Protein-Energy Malnutrition of Weaned Wistar Rats

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Abstract

Complementary diets based on yam, soybean and orange-fleshed sweet potato leaves (OFSP) were formulated and fed to weaned Wistar rats. The rats were divided into six (6) groups, with five (5) rats in each group. Four diets were formulated (Diet 1 to 4), while corn starch (Diet 5) and Cerelac (Diet 6) served as the basal and standard diets, respectively. Nutritional parameters and growth performance in the weaned Wistar rats fed the diets were measured after a 28-day feeding trial. Protein values for the formulated diets ranged from $10.00 \pm 0.20\%$ (Diet 1) to $17.17 \pm 0.04\%$ (Diet 4), and ash content ranged from $5.16 \pm 0.02\%$ (Diet 4) to $5.97 \pm 0.02\%$ (Diet 3). The protein and ash contents of the standard diet were significantly ($p \leq 0.05$) lower ($15.00 \pm 0.00\%$ and $2.30 \pm 0.00\%$, respectively). Energy value was highest in the standard diet (397.82 ± 0.02 kcal/100 g), followed by 367.09 ± 0.04 kcal/100 g in the formulated Diet 4. Biological evaluation showed average feed intake ranging from 145.00 ± 2.00 g (basal diet) to 242.00 ± 2.00 g (standard diet). Rats fed the basal diet lost weight (-6.87 ± 0.02 g) and had a negative PER (-0.66 ± 0.00), while those fed the standard diet had the highest weight gain (59.87 ± 0.03 g), which was not significantly different ($p \leq 0.05$) from the weight gain of rats fed the formulated Diet 4 (59.80 ± 0.05 g). Biological Value (BV) and True Digestibility (TD) of the formulated diets (1 – 4) compared favourably with those of the standard diet. This study has shown that a complementary food based on yam, soybean and OFSP is a cheaper option and a good substitute to meet the protein-energy nutritional needs of infants.

Keywords: Assessment, Infants, Complementary, Nutrition, Feeding practices.

Introduction

Protein-energy malnutrition has been associated with high mortality among infants and children in our society today, as most families in rural areas and low-income earners can hardly afford a quality, protein-based complementary diet for their weaning infants. Malnutrition, especially protein-energy malnutrition (PEM), in early childhood has become a major global health problem. Many children under five (5) years of age in Nigeria and other developing countries are experiencing severe child food poverty, making nearly 50 per cent more likely to experience wasting, a life-threatening form of malnutrition (UNICEF, 2020). This nutritional problem results from the low nutritional value of traditional complementary foods, inappropriate complementary feeding practices, and the high cost of quality, protein-based complementary foods (WHO, 2023). This vulnerable population is fed only breast milk/milk and/or a starchy staple, such as rice, maize, or wheat. Less than 10 per cent of these children are fed fruits and vegetables, and even fewer, less than 5 per cent, are fed nutrient-dense foods such as eggs, fish, poultry, or meat (UNICEF, 2021). Weaning foods, also known as complementary foods, are foods that are readily consumed and digested by infants, and they provide additional nutrition to meet the growing child's needs (Capra et al., 2024). Complementary feeding is the practice of giving other foods and drinks in addition to breast milk to an infant when breast milk or milk formula alone are no longer adequate to meet the infant's nutritional requirements (Harouna et al., 2023). It is a step-by-step process whereby an infant first learns to move food to the back of the mouth and swallow, then gradually learns to appreciate new tastes and textures before going on to chew larger lumps of food (Udoh & Amodu, 2016).

However, studies have shown a high prevalence of inappropriate complementary feeding practices among nursing mothers (Folake & Ebunoluwa, 2020). Cheap, nutrient-poor, unhealthy ultra-processed foods and sugar-sweetened beverages are aggressively marketed to parents and families and have become the new norm for feeding children. These unhealthy foods and beverages are consumed by an alarming proportion of young children experiencing food poverty, displacing more nutritious foods from their daily diets. Malnutrition is a significant public health problem in Nigeria; therefore, ensuring that complementary foods are nutrient-dense is crucial for preventing malnutrition and promoting healthy growth and development in infants (Udoh & Amodu, 2016). Improving feeding for children under two years of age is important, as they experience rapid growth and development and are prone to a range of illnesses (Capra et al., 2024). Children can become stunted if they do not receive sufficient complementary foods after six months of age, even with optimal breastfeeding (Castenmiller et al., 2019). A great number of under-five deaths can be prevented by ensuring an adequate weaning diet (Ariyo et al., 2021).

A variety of weaning diets with high nutritional value are available and can be used directly for the instant preparation of gruels. However, in many developing countries, such as Nigeria, these products are beyond the economic means of most families (Ariyo et al., 2021). Most mothers resort to traditional gruels such as pap (ogi) as weaning diets for infants. These gruels usually have low energy density and poor protein, vitamin and mineral content (Esan et al., 2022). There are different strategies that can be used to improve the nutritional value of complementary foods. A suitable, nutrient-dense traditional complementary food can be formulated by combining locally available foods that supplement each other, so that the new pattern of amino acids created by this combination becomes suitable for infant growth, development and general well-being (Sumbo et al., 2015). This means the nutritional status of such vulnerable infants will be improved if the increased use of inexpensive, locally available plant crops rich in both protein and energy to formulate their diets is encouraged. That is to say, the combination of locally available cereals, tubers and roots with inexpensive plant protein sources such as legumes, complemented with vegetables, will meet both the macro- and micronutrient needs of infants and growing children. In this study, yam (*Dioscorea rotundata*), soya beans (*Glycine max*), and orange-fleshed sweet potato leaves (*Ipomoea batatas* leaves) were used to formulate weaning diets to alleviate protein-energy malnutrition in weanling Wistar rats.

Materials and Methods

The materials used for the preparation and formulation of weaning diets were yam (*Dioscorea rotundata*), soya beans (*Glycine max*), and orange-fleshed sweet potato leaves (*Ipomoea batatas*). Soya beans were purchased from Mile III Market; yam was bought from Rumuokwuta Market; orange-fleshed sweet potato leaves were obtained from a farm in Rumuigbo; and Ceralac and cornstarch were purchased from a supermarket in Port Harcourt, Rivers State. The yam tubers were washed, peeled, and cut into flat slices. They were boiled for about 10 minutes, drained, and oven-dried for 24 hours at 650C. They were then ground into flour and stored in airtight containers. Soya beans were carefully sorted to remove dirt and stones, then boiled for 20–25 minutes. They were washed, drained, and oven-dried at 650C for 24 hours. They were milled into fine flour and packed in an airtight polythene bag for analysis and animal feed.

Leaves of orange-fleshed sweet potato were sorted, cleaned properly, and air-dried for 2 weeks. They were then ground using an electric grinder and stored for later use. The processed flours were used to formulate complementary diets. The tuber/legume/vegetable blends were formulated at varying ratios, with the vegetable ratio held constant. Ceralac served as the commercial diet (reference diet), while corn starch served as the basal diet. Thus;

Table 1. Diet formulation

Diets	Yam Flour	Soyabeans Flour	Ofsp Leaves Flour	Corn Flour	Ceralac	Total
1	80	10	10			100
2	70	20	10			100
3	60	30	10			100
4	50	40	10			100
5				100		100
6					100	100

Proximate Analysis: Moisture content, crude ash, crude fibre and crude protein of flour blends were determined according to AOAC (2012) methods. Crude protein content was determined by the micro Kjeldahl method (AOAC, 2012), crude fat by the Soxhlet extraction method (AOAC, 2012), and carbohydrate content was calculated by difference from 100. The sample's calorific/energy value was calculated using the AOAC (2010) method, applying the Atwater factors of 4, 9 and 4 for crude protein, crude fat and carbohydrate, respectively, as described by Zou et al. (2007).

Biological Evaluation: Animal Assay - Thirty weanling albino rats (Wistar strain) obtained from the animal house at the Choba campus, University of Port Harcourt, were used for the study. They were divided into six (6) groups of five (5) rats per group. They were weighed and randomly distributed to their respective groups so that the group mean did not differ by more than +2.0 g (Ijarotimi, & Keshinro, 2013). The rats were allowed to acclimatise to their new environment for four (4) days. At the end of this period, their initial weights were recorded, and the five (5) rats in each group were randomly assigned to the test and control diets. They were housed with facilities for faecal and spilled feed collection. Water was provided from plastic water bottles, and food was provided in specially designed metallic containers. They were fed ad libitum for 28 days, with weights taken weekly and at the end of the feeding period.

Faecal droppings from rats were collected daily throughout the study period. Faecal droppings from each group were pooled, dried at 1050C for 24 hours, and then ground into powder for faecal nitrogen determination. Data on feed consumption and spilled food were collected by recording the feed measured out for each rat at the beginning of each day. At the end of the day, the remaining and spilled food were collected, weighed, and the difference recorded at the end of the experiment. Weight gain or loss for individual rats was also recorded. At the end of the feeding period (28 days), the rats were dissected, and the liver, kidney, heart, and spleen were removed, weighed, and returned to each individual carcass. The carcasses were dried in an oven, weighed, ground thoroughly with a laboratory mortar and pestle, and stored for carcass nitrogen determination.

Faecal and Carcas Nitrogen Determination.

Faecal and Carcass nitrogen of the dried faeces and carcass, respectively, were determined by the Kjeldahl method (A.O.A.C., 2010).

Results

Table 2. Proximate Composition OF Sample

	Mosture (%)	Ash (%)	Crude Protein (%)	Crude Fat (%)	Fibre (%)	Carbohydrate (%)	Energy (Kcal/100g)
YF	7.00 ± 0.00 ^a	4.05 ± 0.06 ^a	2.05 ± 0.76 ^a	0.55 ± 0.00 ^a	10.71 ± 0.00 ^a	75.36 ± 0.00 ^a	322.94 ± 0.00 ^a
SBF	6.30 ± 0.10 ^b	18.60 ± 0.10 ^b	35.83 ± 0.10 ^b	14.63 ± 0.20 ^b	4.01 ± 0.10 ^b	20.63 ± 0.10 ^b	357.51 ± 1.80 ^b
OFSP	5.33 ± 0.10 ^c	17.50 ± 0.00 ^c	20.87 ± 0.00 ^c	1.50 ± 0.00 ^c	11.13 ± 0.00 ^c	43.6	271.66 ± 0.00 ^c
LF							

Values are reported as mean± standard deviation of triplicate determination

Mean in the same column with different superscript letters indicate statistical significant difference ($p \leq 0.05$)

DIET 1 YF (80): SF (10): OPLF (10)
 DIET 2 YF (70): SF (20): OPLF (10)
 DIET 3 YF (60): SF (30): OPLF (10)
 DIET 4 YF (50): SF (40): OPLF (10)
 DIET 5 BASAL DIET (Corn starch)
 DIET 6 STANDARD DIETS (Cerelec)

YF – Yam flour

SF – Soybean flour

OPLF – Orange Fleshed Sweet Potato Leave flour

Proximate composition and energy values of the samples

Soybean had the highest protein and ash contents, followed by orange-fleshed sweet potato leaves (OFSPL), while yam had the lowest values for protein and ash. Crude fat content was highest in soybean and lowest in yam. Carbohydrate content was highest in yam. The energy score (kcal/100g) of the samples shows that soybean had the highest value, followed by yam and then OFSPL.

Table 3: Proximate Composition of formulated diet

DIET	MOSTURE (%)	ASH (%)	CRUDE PROTEIN (%)	CRUDE FAT (%)	FIBRE (%)	CARBOHYD RATE (%)	ENERGY (kcal/100g)
1	8.26 ± 0.20 ^c	5.37±0.03 ^c	10.00±0.20 ^g	5.12±0.04 ^f	3.06±0.04 ^h	68.19±0.01b	358.84±0.04 ^f
2	8.45±0.05 ^c	5.25±0.05 ^c cd	12.98±0.03 ^e	7.39±0.04 ^d	6.92±0.06 ^b	59.01±0.04g	354.47±0.03 ^h
3	8.45±0.03 ^c	5.97±0.02 ^b	14.60±0.02 ^d	4.27±0.01 ^g	6.35±0.03 ^c	60.35±0.03f	338.23±0.02 ^j
4	8.35±0.04 ^d	5.16±0.02 ^d	17.17±0.04 ^b	8.81±0.05 ^b	5.73±0.02 ^d	54.78±0.05h	367.09±0.04 ^b
5	4.89±0.01 ^g	2.27±0.00 ^f	7.48±0.00 ^h	1.46±0.00 ^h	9.74±0.02 ^a	74.16±0.00a	339.70±0.00 ⁱ
6	2.50±0.00 ^h	2.30±0.00 ^f	15.00±0.00 ^c	9.00±0.00 ^a	7.00±0.00 ^b	64.20±0.00d	397.82±0.02 ^a

Table 3 shows the proximate composition of the formulated diets. The standard diet (Diet 6) had the lowest moisture content. The ash content of the formulated diets was significantly higher ($p < 0.05$) than that of the standard diet. The protein content was highest in Diet 4, followed by the standard diet. The standard diet (Diet 6) had the highest crude fat content, while the basal diet (Diet 5) had a significantly lower crude fat content ($p < 0.05$) than the formulated diets. The carbohydrate score was in the order; basal (Diet 5) > Diet 1 > Standard (Diet 6) > Diet 3 > Diet 2 > Diet 4 (Table 3). Energy values (kcal/100g) of the standard diet (Diet 6) were the highest, and the formulated diets were also high, whereas the basal diet (Diet 5) had the lowest energy value.

Table 3. Average Food Intake And Growth Parameters

Diet	Average feed intake (g)	Nitrogen Intake (g)	Protein Intake (g)	Carcass Nitrogen (g)	Faecal Nitrogen (g)	Weight Gain (g)
1	202.00±2.00 ^c	3.23±0.03 ^h	20.19±0.03 ⁱ	3.08±0.02 ⁱ	0.29±0.01c	19.93±0.04 ^f
2	209.00±2.00 ^{cd}	4.34±0.02 ^f	27.16±0.03 ^g	4.26±0.01 ^c	0.29±0.01 ^c	33.80±0.05 ^d
3	207.00±2.00 ^{cde}	4.84±0.02 ^e	30.25±0.01 ^f	4.57±0.03 ^d	0.56±0.00 ^a	39.60±0.15 ^c
4	222.00±2.00 ^b	5.88±0.04 ^b	36.75±0.04 ^b	5.81±0.01 ^a	0.31±0.00 ^b	59.80±0.05 ^a
5	145.00±2.00 ^f	1.67±0.03 ⁱ	10.44±0.02 ^j	2.59±0.03 ^j	0.21±0.00 ^d	-6.87±0.02 ^{ig}
6	242.00±2.00 ^a	5.57±0.02 ^c	36.30±0.01 ^c	5.82±0.02 ^a	0.29±0.00 ^c	59.87±0.03 ^a

Average feed intake (FI) was highest in rats fed the standard diet and lowest in those fed the basal diet. Diet 4 had the highest nitrogen intake, followed by the standard diet. The basal diet had the lowest nitrogen intake. Protein intake scores followed the same order as nitrogen intake. Rats fed the standard diet (Diet 6) had the highest weight gain, which was not significantly different ($p \leq 0.05$) from that of rats fed formulated Diet 4. Rats fed the basal diet (Diet 5) lost weight.

Table 4. Protein Quality Parameters

DIET	FCR	NPR	PER	NPU (%)	TD (%)	BV (%)
1	0.10±0.01 ^{gh}	0.65±0.00 ^h	0.99±0.00 ^f	68.33±0.20 ^f	97.68±0.02 ^d	69.95±0.05 ^f
2	0.16±0.00 ^f	0.99±0.01 ^g	1.25±0.00 ^e	76.96±0.14 ^d	98.34±0.08 ^{bc}	78.26±0.12 ^d
3	0.19±0.00 ^e	1.08±0.00 ^{ef}	1.31±0.02 ^d	75.41±0.20 ^d	92.77±0.10 ^e	81.29±0.21 ^e
4	0.27±0.00 ^a	1.44±0.01 ^b	1.63±0.00 ^b	83.16±0.14 ^b	98.32±0.12 ^{bc}	84.58±0.22 ^b
5	-0.05±0.01 ⁱ	0.00±0.00 ⁱ	0.66±0.00 ^h	0.00±0.00 ⁱ	0.00±0.00 ⁱ	0.00±0.00 ⁱ
6	0.25±0.00 ^b	1.52±0.01 ^a	1.72±0.00 ^a	87.97±0.04 ^a	98.67±0.04 ^{ab}	89.16±0.06 ^a

Table 4 shows the effect of diets on protein utilisation in the test rats. The feed conversion ratio of rats fed formulated diets was in the order Diet 4 > Diet 6 > Diet 3 > Diet 2 > Diet 1. Rats fed the basal diet had a negative FCR. Net protein retention (NPR) and protein efficiency ratio (PER) were highest in rats fed Diet 6 (standard diet). Net protein utilisation (NPU) values ranged from Diet 6 > Diet 4 > Diet 2 > Diet 3 > Diet 1. Biological value (BV) was highest in rats fed Diet 6 (standard diet) (89.16±0.06).

Discussion

Proximate Analysis: Soybean had the highest ash and protein content, reflecting its adequacy as an excellent source of protein, both in quality and quantity, with its high mineral content (Rusiana et al., 2023; Qin et al., 2022). OFSPL also had appreciably high protein and ash content, while the protein content of yam was very low. Soybean and OFSPL flours, with their high protein content, are therefore better suited to complement yam flour in formulating low-cost, highly nutritious composite flour for infant feeding.

Crude fat was highest in soybeans and lowest in yam flour, whereas carbohydrate content was highest in yam flour. Soybeans are therefore energy dense due to their high protein and fat content. The energy value of the samples showed that soybeans had the highest energy content, which was significantly higher than that of the other samples ($p < 0.05$).

The proximate composition of the diets shows that the moisture content of the formulated diets was higher than that of the basal and standard diets. These values, however, remain within the acceptable range for complementary foods, which must not exceed 10% (Adepoju et al., 2016). Moisture levels below 10% are recommended to extend the shelf life of flour products. The higher the moisture content of a food, the lower its keeping quality, and vice versa. This fact is important to consider in local feeding practices in Nigeria, where most mothers prefer to prepare large quantities of dry infant foods and store them in containers to avoid regular processing and free up time and energy for other domestic work (Essien et al., 2010).

The ash content of the formulated diets was significantly higher ($p \leq 0.05$) than that of the reference/standard diet and the basal diet. The increase in ash content of the formulated diet could be due to the addition of soybean and orange-fleshed sweet potato leaves, both of which have high ash content. Similar increases in ash content have been reported by Yaseen et al. (2014) in green gram and by Bazez et al. (2016) in sprouted green gram.

The results show that the protein content of the formulated diets increased with the level of soybean substitution. Diet 4 had values that were significantly higher ($p < 0.05$) than those of the standard diet. The increase in crude protein

content of the formulated diets, with a corresponding rise in soybean flour ratio from diet 1 to diet 4, is in line with the established trend (Ezeokeke & Onuoha, 2016; Adeyemo & Onilude, 2017). The low protein content in the basal diet is not surprising, as it is a non-protein diet and therefore cannot support growth. This shows the inadequacy of corn gruel (pap) in supporting growth for weaning infants, as shown in this study. Protein is one of the most important nutrients required in weaning diets for a child's growth and development.

Crude fat content was highest in the standard diet 6, followed by the formulated diet 4. The basal diet had the lowest crude fat content. Fat is another important component of the infant diet, as it provides essential fatty acids, facilitates the absorption of fat-soluble vitamins, and enhances dietary energy density and sensory quality (Solomon, 2005). The energy density of fat (9 kcal/g) is more than double that of protein and carbohydrate (4 kcal/g); hence, fat content is the most important factor influencing energy density. Fat content in the formulated diet increased with greater soybean substitution. Islamyat et al. (2016) reported this earlier. High fat content tends to affect the shelf-life stability of a food sample. This is because fat can undergo oxidative deterioration, leading to acidification and spoilage, whereas samples with low fat content are less prone to these changes. A food sample with high fat content is more liable to spoilage than one with low fat content (Bazez et al., 2016).

The crude fibre content of formulated diets ranged from 3.06 ± 0.04 (Diet 1) to 6.92 ± 0.06 (Diet 2) and was lower than those of the basal diet (9.74 ± 0.00) and standard diet (7.00 ± 0.00) (Table 2). Weaning foods with low fibre content are important because they support children's safety, given the capacity of their stomachs. Food with high fibre content causes indigestion in infants; therefore, weaning diets are expected to have low fibre content (Olorunfemi et al., 2006).

The basal diet had the highest carbohydrate content (74.16 ± 0.00), which was expected because it was the non-protein diet. Diet 1, with a 10% soybean substitution, had a carbohydrate score of 68.19 ± 0.01 . The carbohydrate content of subsequent diets 2 to 4 decreased significantly ($p \leq 0.05$) with decreasing yam flour (Table 4.1). This result is similar to that reported by Anuonye et al. (2014) and Bazaz et al. (2016). This observed trend could be due to yam flour being the major carbohydrate source among the samples used. All diets from 1 to 6 will meet the FAO/WHO (1998) RDA for carbohydrate intake of about 60-95g per day, which is sufficient to meet the energy needs of breastfed babies.

The calculated energy density of the standard diet was significantly higher ($p \leq 0.05$) than that of the formulated diets. For a child to meet daily energy requirements, intake depends on the energy density of complementary foods, the number of meals, and the child's stomach capacity (Dewey & Brown, 2003). The feed intake, protein intake, faecal/carcass nitrogen, and weight gain of rats fed Diets 1 to 6 are presented in Table 3. The quantity of food consumed (feed intake) depends largely on the palatability and suitability of the test diets. The mean feed intake was highest in rats fed the standard diet (Diet 6), followed by those fed the formulated Diet 4. Weight gain followed the same trend, with the highest mean body weight in rats fed the standard diet, and no significant difference ($p \leq 0.05$) from the mean body weight of rats fed the formulated Diet 4. This trend supports the fact that body weight change depends largely on both the amount of feed consumed and the ability to utilise the food (Essien et al., 2010). A similar trend was reported by Yolande et al. (2017). However, a much lower body weight was observed in animals fed Diet 1 (19.93 ± 0.41), while animals fed the basal diet lost weight (-6.87 ± 0.02). This is no doubt due to the lower quantity of protein source added to the diets consumed by these rats. Weight loss in rats fed basal diets has been reported severally (Akinsola et al., 2017). There was an increased protein and nitrogen intake in test animals as the quantity of protein supplied to the diets increased.

Rats fed standard diets (Diet 6) had the highest carcass nitrogen which was not significantly different ($p \leq 0.05$) from carcass value for rats fed diet 4 (table 3). This may be due to the high level of protein in these diets which consequently led to increase in protein intake. The least carcass nitrogen was observed in rats fed basal diet, due to poor protein quality in the diet. Rats fed basal diet also recorded the least faecal nitrogen content while rats fed diet 3 had the highest (0.21 ± 0.00 and 0.56 ± 0.00) respectively. Rats fed formulated diets and those fed standard diets had no significant difference in faecal nitrogen content.

Protein Quality Parameters of Rats Fed Formulated Diets.

The feed conversion ratio (FCR) of rats fed the reference diet 6 was higher than that of rats fed the formulated diet, with no significant difference ($p \leq 0.05$) from those fed Diet 4. Rats on the basal diet (Diet 5) had negative FCR values (-0.05 ± 0.01). Although the feed conversion ratio is a measure of the weight gain of test rats, it has limitations in

providing precise information on feed protein quality. Net protein retention (NPR), which measures the protein required for growth, was highest in rats fed Diet 6 (standard diets) (1.52 ± 0.01) but was not significantly different ($p < 0.05$) from that of rats fed formulated diet 4 (1.44 ± 0.01). This indicates comparable weight gain relative to protein content. Meanwhile, Diets 1 and 2 showed low NPR values, which may explain the slow weight gain.

The Protein Efficiency Ratio (PER), which accounts for differences in protein intake, was highest in rats fed the standard diet (1.72 ± 0.00), followed by those fed Diet 4 (1.63 ± 0.00). Rats fed basal diets had a negative PER (-0.66 ± 0.00). This result is comparable to the 1.62 reported for the standard diet (Nutrend) by Anyalogu et al. (2003), who also reported a PER of -2.50 for rats fed a basal diet. However, it is lower than the PER of 2.04 reported for rats fed cerelac (Shikiri et al., 2015) and the PERs for rats fed formulated diets, which ranged from 2.10 to 2.32, with a value of 2.24 for rats fed cerelac (Adeoti et al., 2018). The negative PER obtained for rats fed the basal diet confirms the inability of corn gruel (pap) to support growth. PER seems to be the most widely used method for determining protein quality in foodstuffs useful in human nutrition (Essien et al., 2010). All the rats fed formulated diets, as well as those fed standard diets, had NPU values higher than the 60% recommended by FAO/WHO/UNICEF/Protein Advisory Group (PAG) of the United Nations (2007). The high NPU values obtained in this study may be due to a better-balanced amino acid pattern in the evaluated diets (Onyeike & Uzoka, 2006).

True digestibility (TD) values for rats fed formulated diets ranged from $92.77 \pm 0.10\%$ to $98.34 \pm 0.08\%$. True digestibility provides a more accurate estimate of digested nitrogen than apparent digestibility (AD). Such high TD values have been reported ($92.90 \pm 0.93\%$ to $97.20 \pm 0.25\%$) by Essien et al. (2010). The high TD values recorded in this study indicate that the formulated diets were well digested and utilised by the test animals, thereby enhancing their growth. The Biological Values (BV) of the test animals in this study ranged from $69.95 \pm 0.05\%$ in Diet 1 to $89.16 \pm 0.06\%$ in Diet 6. Studies have shown that a food or diet with a biological value of 70% or more can support growth if the diet provides adequate energy. Results from this study show that, apart from Diet 1, all the formulated diets had BV scores above 70%, indicating the good growth-promoting quality of these diets.

Conclusion

It can be deduced from this study that ready-to-eat weaning diets can be formulated from locally available, low-cost food crops that are available all year round, such as yam, soybean and orange-fleshed sweet potato leaves. These food items can be dried, ground into powder and preserved, thereby making them available all year round while retaining nutrients. Nutritional evaluation of these flour blends revealed that Diet 3 and Diet 4 had higher nutritional value than the other formulated diets (Diet 1 and Diet 2) and could meet a growing child's or infant's protein and energy needs. The best diet combination, however, was Diet 4, which compared favourably with the standard diet.

Recommendations

Based on the findings of this study, the following recommendations were made:

1. There is a need for more awareness of the nutrient potential of the locally available low-cost complementary foods.
2. Nursing mothers who cannot afford commercial complementary diets are encouraged to use these flour blends for optimal results to enhance their infants' health and growth.
3. The effect of these diets in alleviating protein energy malnutrition (PEM) should be carried out with PEM children.

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