JABU Journal of Science and Technology (2016, Vol 2:4)

Nutritional Evaluation of Complementary Foods from Breadfruit, Breadnut and Groundnut

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ABSTRACT

Accessibility to nutritious and palatable high- protein infant diets made from local staple foods is essential for proper health and development of infants. Complementary foods of different ratios were formulated from breadfruit (*Artocarpus altilis*) pulp flour and breadnut (*Artocarpus camanis*) seed flour and roasted groundnut (*Arachis hypogeal*) which are locally available in Osun State, Nigeria. Four different infant diets were formulated: 100% Breadfruit (Basal diet), 80%:20% breadfruit-breadnut (BF-BN), 80%:20% breadfruit-groundnut (BF-GN) and 80%:10%:10% breadfruit-breadnut-groundnut (BF-BN-GN). The products were evaluated for their proximate composition (moisture, protein, fat, ash, crude fibre and carbohydrate) and used in animal feeding trials. The data obtained were compared with that of a commercial weaning food containing 16% protein, 9% fat, 5% ash and 61% carbohydrate (which serves as control). The protein, fat, ash, crude fibre and carbohydrate contents of BF-BN-GN diet were 18.29%, 10.20%, 4.60%, 3.58% and 57.43% respectively. There was significant difference ($p>0.05$) when this product is compared to the control diet. BF-GN and BF-BN diets also compared well with the control diet. The bioassay parameters: Protein Efficiency Ratio (PER) 3.96 and Net Protein Ratio (NPR) 4.65 for BF-BN-GN when compared with PER 4.20 and NPR 4.90 for commercial diet were favourable. The result for this work had shown that breadfruit and breadnut offered good potential in the formulation of complementary food. Both crops are available, nutritious and affordable and thus can be suitable in improving infant food formulation.

Keywords: *Breadfruit, Breadnut, Groundnut, Complementary foods, Formulation.*

INTRODUCTION

For the first few months of life, the human infant subsists on a diet of breast milk. Breastfeeding is acknowledged to be the optimal way of both feeding and caring for young infants (Baumslag and Michaels, 1995). Human breast milk provides the ideal food for human infants (WHO/UNICEF, 1998). It is also the cheapest means of feeding a child during the first six months of life. Breastfeeding is a caring practice (Dewey and Brown, 2003) and it is also a unique form of infant care that has been shown to be very important for infant development (UNICEF, 2000). During infancy, growth and maturation occurs rapidly and the demands of the body for nutrients are comparatively higher than any other period of life. It is well recognized that the period from birth to two years is the "critical window" for the promotion of optimal growth, health and development. In the first year of life, infants undergo periods of rapid growth when good nutrition is crucial (Davis, 2001). In fact, nutrition in the early years of life is a major determinant of healthy growth and development throughout childhood and of good health in adulthood (WHO, 2000).

Childhood malnutrition is very common in developing countries (FAO, 2004). This is because infants at this stage of development require a higher energy and protein in their diet so as to meet increasing demand for metabolism. Infant nutrition in the first two years of life has long-term consequences on the health and productivity of that individual. In developing countries, infants generally show satisfactory growth during the first six months of life when they are almost exclusively breastfed (Pelto *et al.,* 2003). Even with optimum breastfeeding children were stunted if they do not receive sufficient quantities of quality complementary foods after six months of age (FMOH, 2005). An estimated six percent or six hundred thousand under five deaths can be prevented by ensuring optimal complementary feeding (Davis, 2001).

Among many approaches needed to improve child survival and growth in developing countries is the provision of safe and nutritious infant foods (Pelto *et al.,* 2003). Infants at the early stage require energy and proteins in their diet so as to meet increasing demand for metabolism. The nutritional status of children less than 5 years of age is of particular concern, since the early years of life represent the period for optimal growth and development (Prechulek *et al.*, 1999; Happiness *et al.*, 2011). Their nutritional well-being reflects household, community and national investments in family health thereby contributing both directly and indirectly to overall country development and in particular, development of human resource (Central Bureau of Statistics, 1999).

Traditional infant porridges in Nigeria are usually made from local staples like Sorghum, maize, millet and oat resulting in gruels which have low nutritional value in terms of micronutrients and macronutrients (Dewey and Brown, 2003). The traditional infant foods have been implicated in the etiology of protein-energy-malnutrition (PEM) in children during weaning. This may be due to the low nutritive value characterized by low protein, low energy density and high bulk (Ajibola *et al.,* 2016).

Although a number of commercial infant foods exist, most families in the low and middle income earning groups cannot afford them. It is therefore expedient to formulate infant foods with adequate protein that will promote growth in children from cheap raw material using appropriate methods of processing that are adaptable to the community or home level (Dewey and Brown, 2003). In developing countries, some high-protein infant foods have been developed by supplementing cereals with legumes like soybeans, cowpeas and melons (Akpapunan and Sefa - Dedeh, 1995). Fashakin and Ogunsola (1982) formulated "Nut-ogi" (a mixture of corn gruel and peanut). Adepeju and Abiodun (2011) formulated cowpea-melon-ogi (a mixture of corn gruel with defatted melon seed and germinated cowpea) other useful combinations have been adopted by the food processing industries. However, the demand for carbohydrate sources (maize, sorghum or millet) is ever increasing owing to their increased utilization. Furthermore, the population is increasing and the requirement for cereals and cereal based foods is equally on the rise. In view of the high prices of commercial and traditional complementary foods therefore, the search for locally available, cheap and highly nutritious carbohydrate sources for complementary food formulation becomes imperative.

Breadfruit (*Artocarpus altilis*) and breadnut (*Artocarpus cummanis*) are tropical fruits. They are native to Malaysia and countries of the south pacific and Caribbean (Omobuwajo, 2007). They are now cultivated in west African countries. They belong to the Mulberry family Moraceae. The tree produces fruit twice a year, from March to June and July to September with some fruiting throughout the year (Omobuwajo, 2007). Their nutritive values especially carbohydrate, protein, fat and mineral contents is comparable with or even superior to some cereal food grains

(Adebowale *et al.,* 2008). Breadfruit and breadnut are considered by many locals as gifts from God. This is because people believe that the trees can be planted and left alone without proper care or management and will grow well and produce many edible fruits (Tuivavalagi and Samuelu, 2007). In west Africa, most especially Nigeria, breadfruit and breadnut consumption was stigmatized due to their association with slavery, food shortages and poverty (Roberts – Nkrumah and Badrie, 2005). In Nigeria, breadfruit is regarded as the poor man's substitute for yam because it is used in several traditional food preparations as a replacement of yam, but costs less than one-third the cost of procuring yam at the market (Adebowale *et al.,* 2008). Breadfruit is extremely cheap as two mature fruits each weighing about 1.5kg can be obtained for the #100:00k and can provides a meal for four adults. They can be boiled, fried, roasted or made into pottage. Most important food use of breadfruit is by boiling and pounding into a paste akin to pounded yam and eaten with soup. This is of special livelihood significance in Ile-Ife,Osun State, Nigeria during April – June/July, when the preferred yams and cocoyams are out of season and unavailable (Omobuwajo, 2007). Groundnut (*Arachis hypogeal*) also known as peanut, a member of the family legume. It is native to regions like South America, Mexico, and Central America. However it is successfully grown in other part of the world as well. Groundnut is known for its nutritional and health benefits. Five main nutrients required by the body to maintain and repair the tissues namely energy, protein, phosphorus, thiamin, and niacin, are found in good quantity in groundnut (Rai *et al.*, 1993; Freeman *et al.,* 1999). Groundnut is rich in vitamins and contains at least 13 different types of vitamin that include vitamin A, B, C and E, groundnut is rich in 26 essential minerals including calcium, Iron, Zinc, boron.

In the effort to curb problem of protein-energy –malnutrition (PEM) among infants in Nigeria, a lot of complementary foods have been formulated from locally available food materials(Ikujenlola and Fashakin, 2005; Ijarotimi, 2006; Abiose *et al*., 2015). Most of these complementary foods are still not accessible to many nursing mothers as a result of the high cost of the food materials. The present study was therefore aimed at producing complementary foods from breadfruit flour, breadnut flour (both are neglected food crops) and groundnut flours mixes and evaluates the nutritional quality of the formulated diets.

MATERIALS AND METHODS

Procurement and processing of the complementary Diets: Breadfruit, breadnut and groundnut were purchased at the Ile-Ife Central Market while the commercial baby food was purchased from a supermarket in lle -lfe. The vitamin and mineral were obtained from Pfizer Nig. Plc but mixed by the researcher. Thirty albino rats (Wister strain) of both sexes and weight between 29-38g were obtained from the Faculty of Health Sciences, Obafemi Awolowo University, Ile-Ife. All chemicals used were of analytical grade.

Preparation of Breadfruit Flour: Freshly harvested mature green and wholesome fruits were obtained from Ile-Ife, Osun State, Nigeria. The fruits were washed in clean water from the mains to remove adhering latex and dirt. Then the fruits were peeled manually using a sharp stainless knife and sliced. The core was separated and then pregelatinized. The pulp was dried in hot air oven at a temperature of 60 ^{o}C for 6 – 8 hours. The dried pulp was milled using hammer mill. The ground pulp were packed in polyethylene bags, sealed and stored in the refrigerator for further use. The flow chart for the production of breadfruit flour is shown in Figure 1.

Preparation of breadnut: Breadnuts seeds were sorted, washed and dried in a solar dryer at 55 ^{o}C for 4 days, dehulled and roasted in a gas oven at 120 ^{o}C for 20 minutes then milled using hammer mill and the resulting flour sieved. The flow chart is shown in Figure 2.

Preparation of Groundnut Flour: Groundnut was cleaned and graded after which it was steamed and dried. It was then roasted at 130 ^oC for 25 minutes in a gas oven, then dehulled and milled to obtain groundnut flour. The flow chart for the preparation of groundnut flour is illustrated in Figure 3.

Unripe Breadfruit

↓

Washing

↓

Peeling

↓

Slicing

↓

Drying (60 ^oC, 6-8 hrs)

↓

Milling

↓

Sieving

↓

Breadfriut flour

Fig. 1: Flow Chart for the Preparation of Breadfruit Flour

Source: Mayaki *et al*., (2003)

Breadnut seeds

↓

Sorting

↓

Cleaning / Washing

↓

Drying (55 ^{o}C, 4 d)

↓

Dehulling

↓

Roasting (120 ^{o}C, 20 Min)

↓

Milling

↓

Sieving

↓

Breadnut Flour

Fig.2: Production of Breadnut seed Flour

Source:Nelson-Quartey and Amagloh, (2007)

Groundnut

↓
Cleaning and sorting
↓
Steaming
↓
Drying
↓
Roasting (130 °C, 25Min.)
↓
Dehulling
↓
Milling
↓
Sieving
↓
Groundnut seed flour

Fig. 3: Preparation of Groundnut Flour.

Source: Regena, (2010)

Formulation of the Experimental diets

Basal Diet: The breadfruit flour was mixed in a kenwood mixer for 10 minutes with sugar, vegetable oil, cod liver oil, mineral and vitamin mix to obtain basal diet. Similar processing method was followed for the other diets (Table 1).

The Experimental and control diets: The basal diet was mixed with individual protein source as recommended to achieve an Isonitrogenous diet at 10% protein level. The protein content of the experimental diets was reduced to the same level and they were named the isocaloric diets.

Breadfruit-breadnut diet: This diet was obtained by mixing 800gm of the basal diet with 200gm breadnut flour in a kenwood mixer for 10 minutes, packed in a plastic container, labeled breadfruit-breadnut diet, and stored in the refrigerator.

Breadfruit-groundnut Diet: This diet was obtained by mixing 800gm of the basal diet with 200gm groundnut flour in a kenwood mixer for 10 minutes tagged breadfruit-groundnut diet. It is then packed in a plastic container and stored in the refrigerator.

Breadfruit-breadnut-groundnut Diet: The diet was formulated by mixing 800gm of basal diet with 100g breadnut flour and l00g groundnut seed flour in the Kenwood mixer, packed, labeled as breadfruit-breadnut-groundnut diet and stored in the refrigerator.

Commercial Diet: Commercial baby food, which is a cereal with vegetable based protein, was used in this work as a control for the formulated diets. The nutrient composition of the commercial baby food is shown in Table 2.

Table 1: Composition of the Experimental Diets

Ingredients	Basal diet (A)	Breadfruit-breadnut diet	Breadfruit-groundnut diet	Breadfruit-breadnut-groundnut diet
Breadfruit (g)	809	609	609	609
Breadnut (g)	-	200	-	100
Groundnut (g)	-	-	200	100
Vitamin premix (mg)	10	10	10	10
Mineral premix (g)	16	16	16	16
Vegetable oil (g)	100	100	100	100
Cod liver oil (g)	5	5	5	5
Sugar (g)	60	60	60	60

Table 2: Proximate analysis of the commercial baby food (Per 100g).

Protein	16.0
Ash	2.0
Crude fibre	5.0
Fat	9.0
Moisture	4.0
Carbohydrate	64.0

Source: Nestle Nigeria Plc, 2014

Experimental Animals: In this study, thirty weanling albino rats (Wistar strain) of both sexes weighing 29-38 g were obtained from Faculty of Health Sciences, Obafemi Awolowo University, Ile- Ife. They were weighed and randomly distributed in the metabolic cages and fed normal (pellet) diet for a period of 7 days for proper acclimatization to the environment before the commencement of the experiments. After the acclimatization period, the animals were then reweighed and grouped into six groups of five rats each per group such that the differences in their mean weights were ±2gm. A group of five animals served as control for the experimental groups, were sacrificed and tissues from liver, kidney and *plantaris* muscle of the hind-leg were removed, weighed and frozen until nitrogen was determined from which protein was calculated. The remaining animals were placed on the experimental diets and water *ad libitum* over a period of twenty eight days. During this period dietary intake per day and weight of the animals were recorded.

Analysis of the formulated diets and experimental animals

Animal Tissues Evaluation

At the end of the experiment, each rat was anaesthetized and sacrificed. Tissues from the heart, kidney and *plantaris* muscle were removed and weighed. The values were subsequently expressed in g/kg of body weights. These were freeze dried and used for nitrogen determination through which net protein ratio (NPR) and protein efficiency ratio (NPR) were calculated.

Proximate Analysis: Proximate analyses (Protein, fat, ash, crude fibre, moisture and carbohydrate by difference) of commercial (control) and the experimental diets were carried out using AOAC (2005) methods.

RESULTS AND DISCUSSION

The proximate compositions of the ingredients and dietary samples in grams per 100g of diet (Mean ± SEM) were shown on Table 3. In terms of protein, all the diets compared well with the control diet. Their protein contents meet the normal required standards for infant diet (FAO/WHO, 1992) which must not be less than 15.00%. Breadfruit-breadnut diet had a value of 14.79% which is very close to the required standard value; the value observed for basal diet is as expected since the diet was not fortified with a protein source. With the simple technology involved in the formulation of Breadfruit-breadnut-groundnut diet, it is more likely to prevent against protein energy malnutrition in infants compared to the basal diet. Both groundnut and breadnut seeds increased the protein content of breadfruit by three and two times respectively since breadfruit averagely contains 6.02g/l00g (Adepeju and Abiodun, 2011). The high fat content obtained in breadfruit-groundnut diet may be due to the fact that groundnut seed is an oil seed. Fat contributes to energy density, one of the primary requirements in the formulation or improvement of infant food (Brown, 1991). All the formulation containing groundnut had higher fat content indicating that at least 10% of legumes should be incorporated in infant food formulation to improve fat content and energy density. The fat content in the diet meets the normal required standards recommended for infant diet (FAO/WHO, 1992). The value obtained for the basal diet (3.28%) is far below the recommended value of 10% and cannot therefore meet the nutritional requirements of a growing baby.

The crude fibre content of the breadfruit-breadnut-groundnut, breadfruit-breadnut and breadfruit-groundnut are 3.58%, 3.05% and 3.31% respectively. All the products had fibre contents within the proposed range of less than 5% for infant (*Codex Alimentarius,* 2000). These values are low as compared with that of the control diet. A very low level of fibre content in weaning food has been recommended (Ajibola et al., 2016). The low fibre content will encourage high digestibility and absorption of the diets by the infants. For moisture, ash and carbohydrate contents, the moisture content of all the diets were higher than that of the control diet. However these values still fall within the expected range for weaning diet which must not exceed 10 %. The high value of moisture content observed in the formulated diets may be due to the type of drying technique used for the production of the constituents' breadfruit, breadnut and groundnut flours in the diet preparation as well as packaging and storage conditions. The cabinet drier was used. Moisture content is an indication of product shelf life, a very important measure of product quality: the lower the moisture content, the longer the expected shelf life. Roasting breadnut and groundnut reduced the moisture content considerably indicating the suitability of the roasted seeds for developing products with a longer shelf life. The ash content of the diets were lower than that of the control diet but falls within the recommended value for weaning food which must not exceed 5%.The carbohydrate content of the diets was obtained by difference. It indicated the caloric or energy values of the diets and was found to be 57.43 g, 57.79 g, 63.60 g, and 61.00 g for Breadfruit-breadnut-groundnut, breadfruit-groundnut, breadfruit-breadnut and Commercial diet respectively. Infant diet is expected to be appreciably high in carbohydrate content. The basal diet had a carbohydrate content of (88.82%) indicating its low values for protein and fat. Breadfruit-groundnut diet had the highest value of energy. This is as expected since groundnut is an oil seed although the values were still within the required standard for infant diet. All the diets were suitable for infant food formulation with respect to their energy values.

Table 3: The proximate composition of flours and the experimental diets

Dietary sample	Protein (g/100g)	Fat (g/100g)	Crude fibre (g/100g)	Moisture (g/100g)	Ash (g/100g)	Carbohydrate (g/100g)	Energy (Kcal)
BF	6.69±0.50	2.60±0.10	0.80±0.40	7.82±0.20	3.00±0.50	79.09±0.40	366.36±0.30
BN	12.10±0.20	7.30±0.30	1.70±0.10	6.26±0.11	4.40±0.30	68.24±0.11	387.06±0.10
GN	23.58±0.10	40.20±0.30	1.80±0.20	5.68±0.50	8.90±0.4	19.84±0.20	535.48±0.20
BASAL	6.02±0.30	3.28±0.11	2.20±0.50	6.59±0.55	1.93±0.20	88.82±0.60	379.12± 0.50
BF-BN	14.79±0.40	8.20±0.20	3.05±0.10	5.23±0.50	4.20±0.20	63.60±0.30	387.36±0.20
BF-GN	17.53±0.40	12.60±0.60	3.31±0.60	5.14±0.80	3.24±0.50	57.79±0.20	414.68±0.10
BF-BN-GN	18.29±0.50	10.20±0.50	3.58±0.80	5.20±0.50	4.60±0.40	57.43±0.60	394.68±0.50
Comm	16.00±0.40	9.00± 0.20	5.00±0.20	4.00±0.30	5.00±0.50	61.00±0.10	389.00± 0.30

BF- Breadfruit flour, BN- Breadnut flour, GN- Groundnut flour, BASAL- Basal diet, BF-BN- Breadfruit-breadnut diet, BR-GN -Breadfruit-groundnut diet, BF-BN-GN -Breadfruit-breadnut-groundnut diet, Comm-Commercial baby food

Animal Feeding Experiment

The animals fed with the basal diet were found to become leaner and weaker each passing day of the experiment. Changes were observed in their disposition and in their consumption rate. Loss of weight was dramatic from average weight of 33.28gm at day one to 28.06 gm on the twenty eighth days. This implies the basal diet does not support growth well in rats, perhaps due to its low protein value (Adepeju *et al.*, 2016). On the other hand, the animals fed with other diets increased in weight especially in the Commercial diet group followed by the breadfruit-breadnut-groundnut, then by the breadfruit-groundnut and lastly by breadfruit-breadnut as shown in Figure 4. There was a great vitality exhibited by all the animals on the experimental diets (except basal group) and the commercial diet- throughout the experiment. The breadfruit-breadnut-groundnut group followed the control (Commercial) group closely in all respects in the latter days of the experiment.

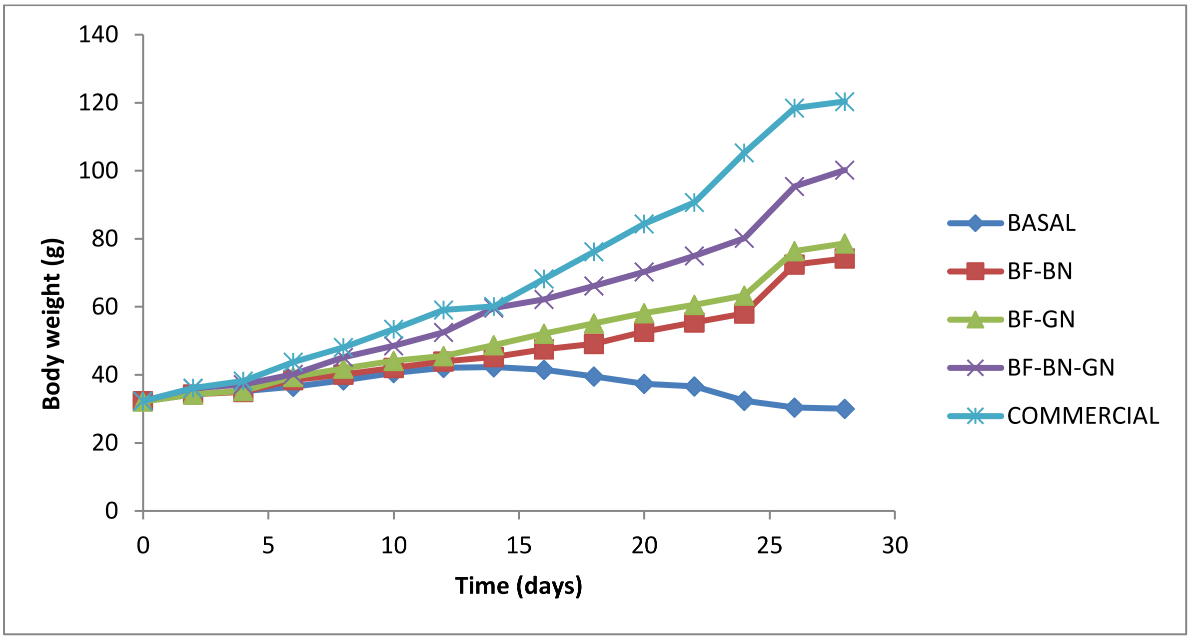

Fig. 4: Changes in mean weight of the experimental animals

The tissues of animal.fed with basal diets were found to be very small and indeed much smaller than those of animals from other experimental groups. There was large fat deposition in and around the adipose tissues of the animals fed Commercial diet.

The efficacy of the mixture of vegetable protein over the use of individual protein was confirmed by the weight of various tissues as given in Table 4.

Table 4. Weight of various tissues of the experimental animals.

Dietary sample	Liver	Kidney	Muscle
BF-BN	2.92±0.02	0.64±0.02	0.90±0.02
BF-GN	3.48±0.01	0.66±0.01	0.95±0.01
BF-BN-GN	4.87±0.03	0.84±0.05	1.63±0.02
Commercial	5.23±0.02	0.86±0.01	1.70±0.02
Basal	1.52±0.30	0.24±0.10	0.38±0.10
Control (zero-day animal.)	1.74±0.02	0.26±0.02	0.47±0.02

* The zero day animals (control) are the animal sacrificed on the first day of the experiment. The tissues collected from these animals served as the initial level for the other animal's tissues at the end of the experiment. BF-BN -Breadfruit-breadnut, BF-BN- Breadfruit-groundnut, BF-BN-GN-Breadfruit-breadnut-groundnut)

The livers of animals fed the breadfruit-breadnut-groundnut diet had the highest weights when compared with that of the breadfruit-breadnut diet and breadfruit-groundnut diet groups. There was no significant difference (P>O.01) in weight of tissues of breadfruit-breadnut-groundnut group animal and Commercial diet group. This can be because both breadnut and groundnut used in the diet formulation were high in protein and may complement each other in the diet. The weight of kidney of breadfruit-breadnut diet group was almost same as that of breadfruit-groundnut group but higher than that of basal diet group.

The calculated Protein Efficiency Ratio (PER) values (calculated with the formula, weight gain per amount of protein consumed) and the Net Protein Retention (NPR) are indicated on Table 5.

Table 5: Protein efficiency ratio (PER) and Net protein ratio (NPR) of dietary sample (Mean ± SEM)

DIETARY SAMPLE	PER	NPR
BF-BN	3.20±0.10	3.31±0.02
BF-GN	3.42±0.01	3.90±0.05
BF-BN-GN	3.96±0.02	4.65±0.02
Commercial	4.36±0.01	4.90±0.03

BF-BN – Breadfruit-breadnut diet, BF-GN – Breadfruit-groundnut diet, BF-BN-GN – Breadfruit-breadnut-groundnut diet

The mean PER values are 4.36, 3.96, 3.42 and 3.20 for Commercial, Breadfruit-breadnut-groundnut, Breadfruit-groundnut and Breadfruit-breadnut respectively. The most favourable values were apparent in the control and those fed breadfruit-breadnut-groundnut diet whereas PER and NPR were inferior in groups receiving individual protein sources. The Breadfruit-breadnut-groundnut diet compared fairly well with Commercial which further confirmed its efficacy. The values of PER obtained in these diets exceeded the recommended values which is 2.1 (Ijarotimi, 2016). This shows that all the diets were far above the recommended requirement. This further ascertained that breadfruit and breadnut are good ingredients in complementary food formulation since the nutritional quality of food indicates their suitability for feeding young children (Livingstone et al., 1993). The NPR values followed the same pattern with commercial taking the lead, followed by the mixed diet and then Breadfruit-groundnut and finally by Breadfruit-breadnut groups. The NPR values followed the same pattern with commercial diet taking the lead, followed by the mixed diet and then Breadfruit-groundnut and finally by Breadfruit-breadnut diet group.

Table 6: Total protein level (mg/N) in various tissues of experimental animals

Dietary sample	Liver	Kidney	Muscle
BF-BN	81.40±0.20	53.85±0.80	46.62±0.20
BF-GN	86.50±0.30	56.80±0.20	48.78±0.50
BF-BN-GN	97.30±0.50	68.42±0.20	67.32±0.20
Basal	61.30±0.40	33.52±0.50	32.84±0.40
Commercial	130.72±0.10	74.70±0.20	78.06±0.10
Control(zero day animal)	62.40±0.50	32.43±0.20	35.66±0.30

Breadfruit-groundnut diet compared well so far with Breadfruit-breadnut-groundnut due to the effect groundnut (legume) which tends to improve the nutritional quality of the diet (protein).

The total protein level in the tissues is shown in Table 5. The control animals showed a clear lead over all other groups followed by the animal fed with the Breadfruit-breadnut-groundnut diet.

CONCLUSION

The study showed that the formulated diets promote growth better than the basal diet. The tissue weight measurement of the rats fed the formulated diets were better than that of the basal diet and compared favorably well with that of rats fed with control (commercial) diet. The study indicated that breadfruit-breadnut-groundnut, Breadfruit-breadnut and Breadfruit-groundnut diets may support growth in infants. The implications of these findings are not far reaching since all the components used in the formulation were obtained from local market. This would indicate that the diet formulated would be cheaper and more accessible to average mothers.

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