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Bioavailability of Selected Dietary Elements in a Locally Formulated Complementary Food

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Abstract: *The period of complementary feeding in infants can be described as a gradual transition from an exclusive milk diet to a complete range of foods eaten by adults and has been recommended to begin after six months of exclusive breast feeding. Dietary elements such as Ca, N, Fe and Na; are important nutrients in complementary nutrition not just as food 'component' but such that must be optimally absorbed from the gut if physiological functionality is desired. Therefore, the bioavailability of these nutrients in CF and BF were investigated using Male Wistar-strain weaning rat model. During the study, which lasted for 7days; weight gained, amount of food consumed, food efficiency and the respective bioavailability of Ca, N, Fe and Na were investigated using standard experimental procedures. The results show that significantly higher ((p≤ 0.05) quantities of CF and rat chow were consumed compared to BF. Meanwhile, there was no significant difference between quantity of CF consumed, and that of rat chow. Although the animals fed BF showed lower growth rate and weight gain than those fed CF and rat chow; the FER was highest in CF but least in rat chow, and seemed to increase with days until a retardation point when growth and development rates were no longer as rapid as they were previously. Ca is significantly more bioavailable in BF (99.775 ± 0.050) than in CF (86.386 ± 7.067) at p≤ 0.05. Although N and Fe are more bioavailable in animals fed CF than in those fed BF, the difference thereof was of no significant import. However, the bioavailability of Na among the two animal groups studied was significantly higher in animals fed CF (99.200 ± 1.506) than in those fed BF (68.475 ± 36.234). Both CF and BF were physiologically supportive to growth and development though, experimental animals fed CF showed higher weight gained than those fed BF and the mineral nutrients studied were optimally absorbed in the gut. This implied that with the right processing method(s) and informed formulation, locally formulated complementary food could also adequately support growth and development even in infants.*

Keywords: *Bioavailability, Food Efficiency Ratio, Physiological Support, Complementary Feeding, Growth.*

I. Introduction

Nutrition is a process by which 'organisms utilize food for maintenance of life, growth and normal function of organs and tissues and the production of energy' (World Health Organization, 1998). The period of complementary feeding in infants can be described as a gradual transition from an exclusive milk diet to a complete range of foods eaten by adults. While breast feeding for at least six months has been proven best (World Health Organization, 1985), there is the need to introduce complementary feeding thereafter to provide for optimum infant developmental requirements. During infancy, Physiological, immunological and neurological developments progress rapidly and are expressly influenced by nutritional exposure (Rosales *et al*., 2009). It has been recommend that after 6 months of age, nutritious and safe foods be gradually introduced to infants and be continued up to 2 years of age; thereafter the normal family diet be introduced (Yeung, 1998). Complementary feeding is not only one of the first important needs of the infant's body system, but also serves as a source of additional nutrients necessary for optimal growth and development (Fernandez *et al*., 2002). The rate of growth at this stage is incomparable to that at later period of life. Most of the growths in the nervous system and brain are completed in the first two years of life (Guthrie, 1989).

The family diets to which some infants are weaned are of low nutritional value (Onofiok & Nnanyelugo, 2005). Both qualitative and quantitative nutritional deprivations (prolonged) at infancy have been linked with several related physiological aberrations of which kwashiorkor and marasmus are common types (Bain *et al*., 2013). Traditional weaning foods, especially in West Africa have been argued to be of low nutritive value occasioned by uninformed formation and/or poor processing method and are characteristically of low protein, low energy density and fiber and high bulk (John & Tigani, 2007; Guiro *et al*., 1987). It has been noticed that whereas locally formulated foods are low in one mineral nutrient or the other, cereals form the primary component of most traditional weaning foods in West Africa and Sudan (Mohammed, 2014; John & Tigani, 2007). The protein content of maize and guinea corn is of poor quality, low in lysine and tryptophan, which are necessary for growth in the young (Oyenuga, 1968). Therefore, most of the locally made complementary foods have been implicated in protein-energy malnutrition in children during the weaning period (Bain *et al*., 2013).

Diets of animal origin have been shown to contain mineral elements in forms that are more readily absorbed (Pennington *et al.*, 1988), while dietary elements of plant origin are less available due to the presence of some anti-nutritional factors (World Health Organisation, 1998). Okoye (1992) observed that iron deficiency anemia might result from poor iron content of staple diet, poor absorption from the gut lumen and excessive concentration of phytate and tannins in the diet. The form of iron present in the staple diet could also influence healthy nutrition as it relates to iron. Zinc absorption is also impaired by the presence of phytates and fiber (World Health Organisation, 1998). Dietary calcium deficiency in Nigeria is attributed to the consumption of diets with high phytate and phosphate levels (Okonofua, 2005). Children often have nutritionally low calcium intake, giving rise to high prevalence of nutritional rickets (Oginni *et al*., 1996). Hence, this study investigated the bioavailability of selected dietary elements in a locally formulated complementary food against a branded conventional formula as a contribution toward solving nutritional challenges confronting African infants

II. Materials and Methods

Animals

Male Wistar-strain weaning albino rats weighing 40 - 55g purchased from the animal house of Babcock University Ilishan, Ogun State, Nigeria were used for this study. The animals were randomly distributed into 3 groups of 6 rats each, housed in metabolic cages. The rats were allowed to acclimatize on rat chow for 7 days. They were then fasted for 24hours before commencing the feeding experiment on them.

Experimental Food Samples

The experimental complementary formula (CF) was made of wheat (*Triticum spp*.), groundnut (*Arachis hypogea*), soya bean (*Glycine max*) and guinea corn (*Sorghum bicolor*) in ratio 1:1:2:1. The study was conducted in two parts. The first part involved the formulation and analysis of different cereal and legume based complementary diets using staple foodstuffs of highly available locally. The foodstuffs and the proprietary formula were purchased from Ilishan main market, Ogun state. The soybeans and groundnut were to complement the nutrients deficient in the grains. The grains were sorted to remove the defective grains, sand granules, and other extraneous matters, followed by washing and drying at room temperature. Care was taken to avoid prolonged stay in water during washing so as to forestall the grains absorbing much water. This was followed by treatment with heat in the oven at suitable temperature as was previously determined for each of the legumes and cereals, in course of the study. Further, the heat-treated grains were proportionately pulled together and milled into finely particulate texture similar to that of 'powder', using a laboratory hammer mill. The fine flour was of particular sizes less than 300μm. The consistency of the flour particular size was ensured by sifting through a 300μm screen. Milled mixed grains and legumes of the combination thereof is what is referred to as CF in this study. The CF was sealed in transparent polyethylene packs of 25g and stored in air tight container at room temperature for both the feeding experiment and required chemical analyses. The following were the respective experimental animal groups placed on the food types investigated in this study:

Group 1- fed CF - Soya bean: Groundnut: Wheat: Guinea corn (40:20:20:20%w/w)
Group 2 - fed Nutrilac® (BF), a proprietary standard formula
Group 3 - fed Rat Chow (Control diet)

The foods were respectively analyzed for their proximate nutrient composition and then fed to experimental animals. Their nutritional parameters such as feed intake, growth rate, efficiency ratios, and bioavailability were assessed. The diets were again subjected to various nutritional evaluations and results obtained from CF group compared against those of the standard and control as bases for inference.

Determination of Proximate Ash, Moisture Ash, Ether extract and Crude Fiber Contents

The standard method of AOAC (2005) was used to determine the respective levels of ash, moisture, ether extract and crude fiber of the different sample studied.

Collection of the fecal matter

Fecal matter was collected on a daily basis from the litter compartment of the cage, and weighed using top loading balance. It was then homogenized and preserved for further analysis.

Analyses of Calcium, Iron and Sodium

Wet digestion of samples was performed using mixtures of acids: HNO_3: HCl (3:1), by the modified method of Demirel *et al*. (2008). The digest was subjected to Atomic Absorption Spectrophotometry to quantify the dietary elements of interest. The recovery study of the analytical procedure was carried out by spiking and harmonizing several already analyzed food samples with varied amounts of standard solutions of the respective dietary elements (Onianwa *et al.*, 2001).

Dietary Nitrogen Determination

The Method of Association of Official Analytical Chemist (2005) was adopted in determining the nitrogen content of the samples.

Determination of Bioavailability of the mineral nutrients investigated

The amount of each dietary element absorbed from the digestive tract of the animals, after being fed each food, is equivalent to the bioavailability of such mineral in that food. This was obtained as difference between food dietary element and that of faecal matter for each dietary element.

III. Result

Food intake of the rat

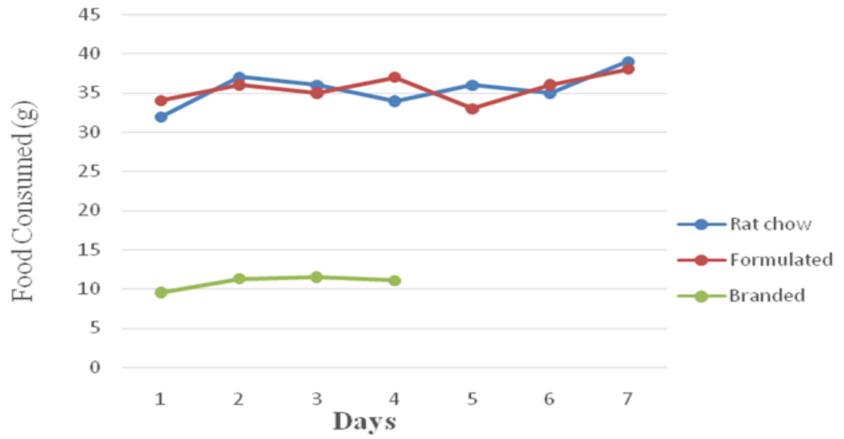

Figure 1: Quantity of food consumed by the experimental rats

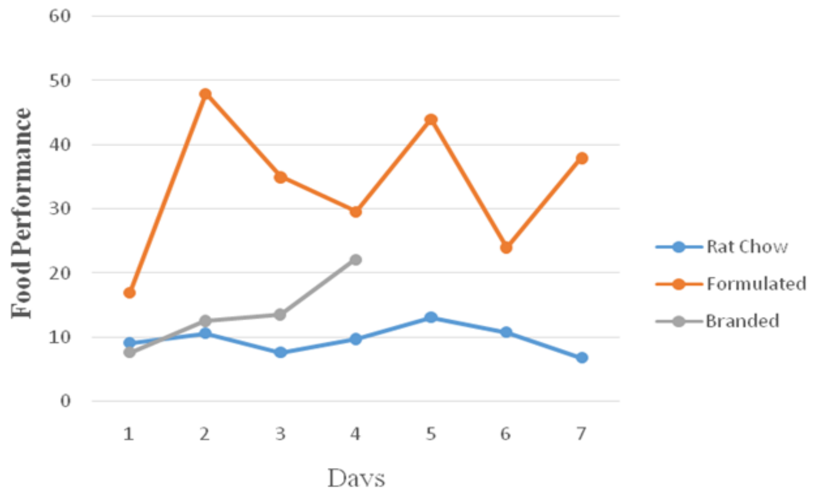

Figure 2: Food efficiency ratio (FER) of the studied complementary diet in male Albino Wistar rat model.

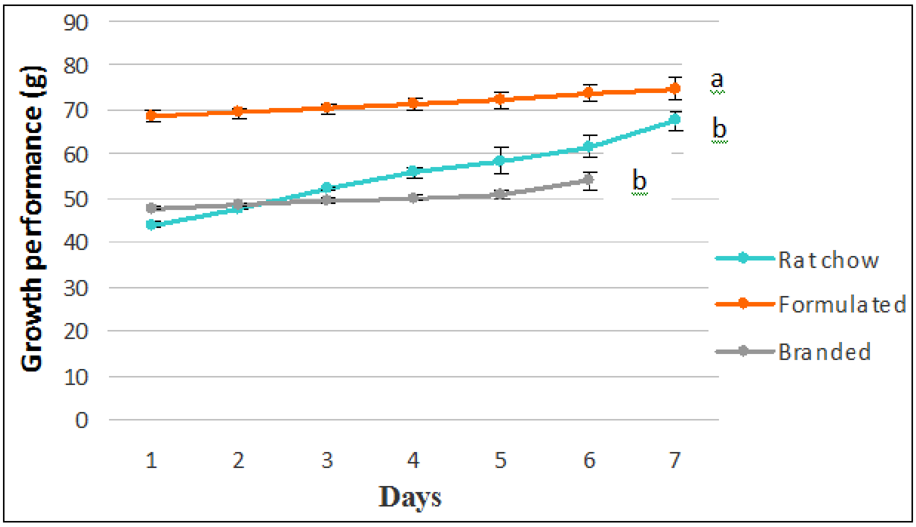

Figure 3: Growth performance of the complementary formulae studied using male Albino Wistar rat model
Note: Different alphabets indicate significant difference when mean values are compared ($p \leq 0.05$)

Table 1: Calcium bioavailability of the Test Complementary Formula and Branded Formula

Average Fecal Matter (FM) (g)		Average Food Consumed (FC) (g)		Average Ca (g) in Food Consumed				Average Ca absorbed (g)		% Ca absorbed	
CF	BF	CF	BF	CF		BF		CF	BF	CF	BF
				FC	FM	FC	FM				
1.914	0.635	35.571	10.833	0.073	0.009	1.083	0.003	0.063	1.080	86.386[a] ±7.067	99.775[b] ±0.050

Note: Different alphabets indicate significant difference when mean values are compared ($p \leq 0.05$)

Table II: Nitrogen bioavailability of the Test Complementary Formula and Branded Formula

Average Fecal Matter (FM) (g)		Average Food Consumed (FC) (g)		Average N (g) in				Average N absorbed (g)		% N absorbed	
CF	BF	CF	BF	CF		BF		CF	BF	CF	BF
				FC	FM	FC	FM				
1.914	0.635	35.571	10.833	0.737	0.048	0.156	0.017	0.687	0.139	93.314[a] ±4.281	88.75[a] ±0.754

Note: Same alphabet indicates there is no significant difference when mean values are compared ($p \leq 0.05$)

Table III: Iron bioavailability of the Test Complementary Formula and Branded Formula

Average Fecal Matter (FM) (g)		Average Food Consumed (FC) (g)		Average Fe (g) in				Average Fe absorbed (g)		% Fe absorbed	
CF	BF	CF	BF	CF		BF		CF	BF	CF	BF
				FC	FM	FC	FM				
1.914	0.635	35.571	10.833	60.471	0.435	1.370	0.024	60.037	1.346	99.300[a] ±0.816	98.250[a] ±0.741

Note: Same alphabet indicates there is no significant difference when mean values are compared ($p \leq 0.05$)

Table IV: Sodium bioavailability of the Test Complementary Formula and Branded Formula

Average Fecal Matter (FM) (g)		Average Food Consumed (FC) (g)		Average Na (g) in				Average Na absorbed (g)		% Na absorbed	
CF	BF	CF	BF	CF		BF		CF	BF	CF	BF
				FC	FM	FC	FM				
1.914	0.635	35.571	10.833	8.913	0.105	0.328	0.109	8.839	0.219	99.200[a] ±1.506	68.475[b] ±36.234

Note: Different alphabets indicate significant difference when mean values are compared ($p \leq 0.05$)

IV. Discussion

Food Consumed

Figure 1 presents the respective quantities of formulated complementary food (CF), branded complementary food (BF) and rat chaw consumed by the different experimental animal groups. The figure showed that significantly higher (($p \leq 0.05$) quantities of CF and rat chaw were consumed compared to BF. Meanwhile, there was no significant difference between quantity of CF consumed, and that of rat chaw. The foregoing demonstrates that the animals preferred CF and rat chaw to BF as sources of metabolic energy and anabolic carbon. The observed food consumption pattern is slightly predicated upon the crunchy texture of CF and rat chaw. Besides being denser in nutrients and low in fibre, BF was not served crunchy but fluidly.

Food Efficiency Ratio and Weight Gained by Experimental Animals

The Food Efficiency Ratios (FER) of the respective food studied are presented in Figure 2. The result showed that the quantity of food required to bring about 1g of weight gained is highest in CF but least rat chaw, and seemed to increase with days until a retardation point when growth and development rates are not as rapid as they were previously. The food efficiency ratio is a reflection of the degree to which a particular food is physiologically supportive to promoting increase in the number and size of cells within the body system of the organism. Therefore, it could also be asserted that the three food kinds studied; CF, BF and rat chow, provided physiological supports for the animals to grow, but in varied degrees and higher in CF than in BF and rat chow. The animals fed BF showed lower growth rate and weight gain than those fed CF and rat chow (Figure 3).

Bioavailability of Calcium, Nitrogen, Iron and Sodium

The extents to which calcium, nitrogen, iron and sodium (Ca, N, Fe and Na) in the complementary formulae studied, using the animal model afore-mentioned, were bioavailable are shown on Tables 1, 2, 3 and 4 respectively. Ca was significantly more bioavailable in group fed BF (99.775 ± 0.050) than in those fed CF (86.386 ± 7.067) at $p \leq 0.05$. Although N and Fe are more bioavailable in animals fed CF than in those fed BF, the difference thereof was of no significant import. However, the bioavailability of Na among the two animal groups studied was significantly higher in animals fed CF (99.200 ± 1.506) than in those fed BF (68.475 ± 36.234). Ca has been demonstrated to mediate several physiological and biochemical processes such as muscle contraction, skeletal development, blood clotting and cell signaling among the lot (Christian & Stewart, 2010) and therefore, occupies an important position in human nutrition; that of the developing infant not preclusive. For any nutrient to be metabolically functional, it most be retrieved from the matrix of the food in the gastrointestinal tract and be made available for the desired cellular process(es) requiring it. Nitrogen in food represents an estimate of its protein content (Webb, 2013) and its maximal absorption could also be an indication that proteases were minimally, if at all, inhibited. Na is a bodily electrolyte and functions critically in homeostatic balancing (Tjtze, 2014), while iron mediates plasma substance transfer and immunological functioning (Christian & Stewart, 2010). Hence, the degrees to which these dietary elements are absorbed (after being taken in healthy amounts) are significant in healthy infant nutrition.

V. Conclusion

Adopting the most suitable processing method and armed with empirical information, legumes and cereals could be compounded into complementary formulae that are adequate in dietary elements such as Ca, N, Fe and Na. The mineral nutrients therein would also be maximally bioavailable to provide optimum physiological support needful for growth and development. It is, however, recommended that the formulated complementary food reported in this study be subjected to conclusive clinical investigation before adopting it as infant formula.

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