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Determination of Mineral Trace Element and Proximate Analysis of Fish Feed

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ABSTRACT

Quality control in the feed industry does not only involve the verification of quality, standards established for each feed ingredient as it is received unto storage in the mill, but also involves the close monitoring of the quality of the ingredients through the period of storage prior to usage and during its processing. Quality control continues as ingredients emerge during the mixing process and as they finally go into storage as compound feed. Hence, proximate composition of four different directories' fish feed formulation were examined. The results obtained from the feed samples analyzed showed that the mean values (%) range of crude protein was 57.29 ± 0.19 to 62.61± 0.13; moisture content (5.12 ± 0.06 to 8.26 ± 0.06); crude fat (10.92 ± 0.14 to 13.07 ± 0.04); carbohydrate (32.72 ± 0.17 to 36.16 ± 0.14); crude fibre (0.45 ± 0.08 to 0.65 ± 0.02); ash content (5.91 ± 0.13 to 7.31 ± 0.06); and energy (0.54 ± 0.04 to 0.57 ± 0.03 KJ/g). The mean values (μg g^{-1}) of mineral nutrients analyzed ranged were Zn (9.64 ± 0.06 to 15.05 ± 0.06), Fe (6.01 ± 0.04 to 19.02 ± 0.03), Mn (2.57 ± 0.17 to 7.80 ± 0.06), Cu (4.92 ± 0.11 to 10.10 ± 0.08) and P (1.41 ± 0.004 to 3.10 ± 0.08). The percentage of crude protein in each feed formulation was comparatively equal to the same dietary formulations in the literature.

Keywords: aquaculture, atomic absorption spectrophotometer, energetic value, mineral compositions, Weende analysis

INTRODUCTION

Aquaculture is gaining attention worldwide as a means of improving world fish production which is currently on decline due to dwindling output from capture fishery (FAO 2009a). One major problem facing fish production is the need to obtain a balance between rapid fish growth and optimum use of the supplied feed (Ajani *et al*. 2011).

The growth of world aquaculture has been rapid during the last 50 years, increasing by approximately 10% per year in the last decade (Brugère and Ridler 2004). In the early 1950s, global production was less than a million tonnes whereas in 2004 it was 59.4 million tonnes at a value of US$ 70.3 billion (FAO 2007a). In 2005, global aquaculture production reached 63.0 million tonnes, valued at US$ 78.4 billion (FAO 2007b). Moreover, the sector has been growing at an average compound rate of 9.2% per year since 1990, increasing over 3.7-fold from 16.83 million tonnes in 1990 to 63.0 million tonnes in 2005. It has been estimated that the growth of aquaculture will continue over forthcoming decades as the demands for and the consumption of aquaculture products increases (Brugère and Ridler 2004; FAO 2006). Specifically, by 2020, global aquaculture will expand by 1.9%, while the highest output forecast is to increase by 3.3% (Brugère and Ridler 2004).

In fish culture, there is an increasing emphasis towards developing cost-effective fish meal substitute using terrestrial animal- and plant-based protein sources (Millamena 2002). Tacon (2007) reported that the global production of industrially compounded aqua feeds in 2005 was about 23.13 million tonnes. This figure compared favourably with Gills (2007), who estimated global aqua feed production to be approximately 25.4 million tonnes or 4% of global industrial annual feed production of 635 million tonnes in 2006. In the early 1980's, the animal feed manufacturing industry in China grew rapidly, however, over 95% of the feed produced is in mash form for pigs, poultry, cattle, sheep and only a small portion is produced in pellet form for rabbits, mink and shamp (Ariyawansa 2000). Aquaculture in Asia, Latin America and Africa is growing rapidly and this presents significant growth opportunities for the aquaculture feed sector (FAO 2007b). Commercial manufacture of compound fish feeds are just springing up in China and many other countries (Ariyawansa 2000). Asia accounted for 92.1% of global aquaculture production in 2005 (57.97 million tonnes), to which China contributed 74.6%, followed by Europe 2.14 million tonnes, South America 1.16 million tonnes, North America 0.86 million tonnes, Africa 0.66 million tonnes and Oceania 0.14 million tonnes (FAO 2007b). Aquaculture in Latin America is dominated by Chile and Brazil (50.9% and 18.4% of Latin America production in 2005). The remaining balance (30.7%) was produced by thirty other countries (FAO 2007b). Total production in Africa in 2005 was estimated to be 656,370 tonnes, to which Egypt alone contributed about 82.2%. Sub-Saharan accounted for 16.8% of the total African production. Aquaculture production in Sub-Saharan Africa (SSA) is dominated by Nigeria contributing about 51.5, while other nine top producers contributed about 41.0% of SSA production (FAO 2007b).

Except for Asia, where total farm-made aquafeed production was estimated at 19.3 million tonnes (De Silva and Hasan 2007), there is no accurate information on the current production of farm-made aqua feeds in the sub-Saharan except Nigeria and Latin America (FAO 2007b). Hecht (2007) noted that approximately 70% of the 35,570 tonnes of aqua feed used in Nigeria consisted of farm-made feeds. According to De Silva and Hasan (2007), farm-made aqua feed production within the selected Asian countries was as follows: China (10.88 million tonnes); India (6.16 million tonnes); Viet-Nam (800,000 tonnes); Thailand (762,173 tonnes); Philippines (384,896 tonnes); and India (275,850 tonnes). Michael *et al*. (1995) concluded that since cultured aquatic species are more sensitive to the quality of raw feed ingredients than other livestock and have higher nutritional requirements, only high quality raw materials are needed in

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aqua feeds.

Farmed fish and crustaceans are no different from terrestrial livestock in that their nutritional well-being and health is based on the ingestion and digestion of food containing 40 or so essential dietary nutrients depending on the species and on developmental status. Their nutrients may include specific proteins and amino acids, lipids and fatty acids, carbohydrates and sugars, minerals and vitamins (FAO 2009b). These important ingredients provide a balanced dietary protein source, essential poly-unsaturated and primary energy sources for intensive fish production (Webster *et al*. 1999). Fish meal is a major source of protein but very costly, hence fish producers look for alternative raw materials as a cheap protein source. Plant ingredients have high global availability at competitive prices, compared to fish meal and fish oil, and they have nutritional properties that can largely satisfy the nutritional requirement of fish (NRC 1993; Millamena 2002). Soya bean is the most common source of plant proteins used in compound aqua feeds, with feeds for herbivorous and omnivorous fish species and crustaceans containing 15 to 30% Soya bean meal, with average of 25% in 2008 (FAO 2011). In global usage terms, and based on the total compound aqua feed production of 27.1 million tonnes in 2007, it is estimated that the aqua feed sector consumed about 6.8 million tonnes of Soya bean meal (FAO 2011). Other plant proteins increasingly used include corn products, pulses, oil seeds meals and protein from other cereals products (FAO 2011). The focus on carbohydrate-rich fractions for production of biofuels may indeed provide an opportunity to use protein fractions for feed ingredients (FAO 2011).

From the literature, it is indicated that several of the agricultural by-products studied contain components which may affect their nutritive value (Karalazos 2007; Munguti *et al*. 2012). Literature in the utilization of papaya (*Carica papaya*) leaf meals in fish feeds is scarce (Munguti *et al*. 2012). The limited available information indicates that papaya leaf meal could be a good protein source because of its amino acid profile (Reyes and Fermin 2003). The papaya leaf and the unripe papaya fruit contain papain, which degrades protein into amino acids (Chaplin 2005). Research have shown that papain promotes promotes proteolytic digestion and thereby increases the protein digestibility of papaya leaf meal (Buchanan 1969). *C. papaya* peels contain lectins, which are toxic compounds relevant to fish and other animals but can be destroyed by heat treatment followed by aqueous methanol extraction or soaking in water for 24 h under refrigerated condition (Makkar and Becker 1999). Similarly, cassava contain a toxic component known as linamarin which causes cyanide poisoning, but toxicity may be removed by boiling and or sun drying (Tewe 1991).

Lipids are, along with proteins, the major organic components of fish and in most cases of their feeds; also carbohydrates are, at least quantitatively, very important (Millamena 2002). In fish, the lipids and their constituent fatty acids (FA) along with their metabolic derivatives, such as eicosanoids, play significant roles in various functions of organism such as growth, reproduction, health, etc. (Tocher 2003). Dietary lipids provide energy and essential fatty acids (EFA) to fish and they also assist the absorption of fat-soluble vitamins (NRC 1993). Lipids are of great importance not only to fish nutrition (Karalazos 2007). Studies have shown that the *n*-3 highly saturated fatty acids have numerous beneficial effects on human health and, undoubtedly, fish constitute the best sources of these nutrients in human diets (Simopoulos 2003). Alternative to fish oil, various lipid sources are been used in greater amount; among these are vegetable oils, especially those with high Ω-3 contents and poultry oil. The use of oil from farmed fish offal is also a potential Ω-3 source of other farmed fish (FAO 2011).

Considerable research (**Table 1A, 1B**) had been conducted to estimate and evaluate the suitability of various raw materials used as feed ingredient as alternative source for fish meal using proximate analysis. Proximate analysis has to do with analysis of foods and feeding stuff for nitrogen (protein), ether extract (fat) crude fibre and ash (mineral salts), in addition with soluble carbohydrate calculated by subtracting these values from the total. This study intends to analyze the nutrient composition of four raw feed materials obtained within our locality. These results obtained from this study could help provide a possible alternative to conventional feed meal.

MATERIALS AND METHODS

Methodology

The experimental samples were subjected to proximate analysis in accordance with Standard methods described by the Association of Official Analytical Chemist (AOAC 2005).

Ash content was determined by subjecting the sample with known weight (2.3 g) to ignition in a muffle furnace set at 600 ºC for 6 h after which the samples were cooled in a desiccator and weighed. The percentage ash was calculated from the formula:

$$\text{Ash content (\%)} = \frac{\text{Weight of ash x 100}}{\text{Original weight of sample}}$$

Moisture content was determined by subjecting the sample with known weight to drying in an oven at 100-102°C for 16 h. The loss in weight is reported as moisture content. The percentage dry matter content = 100 - % moisture content.

Crude protein was determined by the routine semi-micro Kjeldahl procedure. The percentage total nitrogen was calculated thus:

$$\text{\% Total Nitrogen} = \frac{(S - B) \text{ x N x } 140}{\text{Wt x } 1000}$$

where N = Normality of the acid

The percentage crude protein was calculated by multiplying the total nitrogen by conversion factor of 6.25.

Crude fibre was determined as loss of ignition of dried lipid-free residues after digestion with 1.25% or 0.255 N H_2SO_4 and 1.25% or 0.313 NaOH 10 mL of acetone was added to dissolve any organic constituent. The percentage fibre was obtained by the formula

$$\text{\% Crude fibre} = \frac{\text{Weight of residue - weight of ash x 100}}{\text{Sample weight}}$$

Nitrogen-free extract (% carbohydrate) was determined by subtracting sum of (moisture % + % crude fat + % crude protein + % ash) from 100.

The gross energy content of feed samples was determined using adiabatic bomb calorimeter using the Gallenkamp Auto bomb system. A 1 g of dried sample was placed into a crucible. Nickel firing wire was fixed between the electrodes and then a cotton string was wound from the pellet around the firing wire and the shorter electrode. The electrode assembly was then put into the calorimeter bomb. The water jacket of the bomb was filled with tap water and the calorimeter vessel was filled with water at 21-23 ºC and weighed to exactly 3 kg. The calorimeter vessel was placed into the water jacket. Before firing the calorimetry bomb the thermometer reading was recorded as the initial temperature. The bomb was then fired and when the temperature stabilised it was again recorded (final temperature).

The energy content (KJ/g) of the sample was calculated as:

$$\text{\% Gross Energy} = \frac{\left[(\text{Final Temperature - Initial Temperature}) \text{ x } 10.82\right] - 0.0896}{\text{Sample weight (g)}}$$

where 10.82 is the factor of heat capacity of the system and 0.0896 represents the combined energy value (expressed in KJ) for the wire and the cotton thread used on the analysis (Karalazos 2007).

The crude fat content was determined quantitatively by extraction with a mixture of chloroform methanol (2:1). The mixture was allowed to stand overnight and lower lipid protein was transferred to a pre-treated and weighed flask and heated to dryness. The difference in the two weights of the wound joint flask gave the weight of the fat (Folch *et al.* 1957).

The mineral trace elements determined were Zn, Fe, Mn, Cu and P. This was achieved by digesting the sample using 5 mL of nitric acid and perchloric acid (Almoaruf *et al.* 2003). The digested samples were later centrifuge and the digested solutions were analyzed by atomic absorption spectrophotometry, Buck Model 205 Flame atomic Absorption Spectrophotometer, East Norwalk, United State of America available at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

Statistical analysis of data

The mean standard deviation for the proximate composition and mineral composition of the experimental feeds from replicate measurements were determined using the statistical package for social sciences (SPSS) software, 15.0 for window evaluation version. Experimental feed were subjected to one-way analysis of variance. Duncan's multiple range test (Duncan 1955) was used to determine significant differences between treatment means.

Table 1A Proximate composition of different farm-made feed ingredients.

	Ash	Moisture	Crude fat	Crude protein
Trash fish-rice bran (8:2)	5.4	62.5	5.6	15.6
Trash fish-broken rice	3.3	49.7	2.6	13.9
Soya bean cake-chicken bone-noodle waste	-	48.7	0.1	12.2
Compound feed	-	-	8.0	27.0
Trash fish	20.1 ± 0.04	4.2 ± 0.002	5.5 ± 0.02	68.2 ± 0.05
Blighia Unijugata Aril	5.50 ± 0.31	3.30 ± 0.12	50.82 ± 1.21	19.90 ± 0.71
Kernel	5.40 ± 0.16	6.10 ± 0.11	14.15 ± 0.91	14.00 ± 0.28
Aril+kernel	5.60 ± 0.62	4.70 ± 0.22	29.00 ± 2.11	16.70 ± 0.37
Floating pellet	3.71 - 3.55	-	0.27 - 0.55	16.53 - 17.27
Sinking pellet	3.39 - 3.59	-	0.47 - 0.62	15.77 - 16.63
Rice bran	14.79 - 18.84	-	8.22 - 13.07	-
Wheat bran	2.52 - 8.26	-	4.09 - 9.71	14.15 - 17.73
Mustard oil cake	6.99 - 9.08	-	10.73 - 15.52	35.17 - 37.15
Wheat flour	2.15 - 3.64	-	2.94 - 4.57	14.84 - 15.40
Fish meal	15.16 - 34.14	-	3.69 - 12.50	51.32 - 65.34
Cow (*Bos taurus*) blood meal	98 ± 1.7			420 ± 1.5
Cow (*Bos taurus*) offal	95 ± 1.6			409 ± 1.9
Cassava (*Manihot esculenta*) leaves	97 ± 5.2			286 ± 4.8
Cassava (*Manihot esculenta*) flour	92 ± 4.6			24 ± 4.8
Maize (*Zea mays*) bran	29 ± 3.3			118 ± 3.6
Maize (*Zea mays*) corn gluten	112 ± 1.3			550 ± 4.6
Arrow root (*Maranta arundinacea*) leaves	93 ± 2.3			314 ± 1.0
Sweet potato (*Ipomoea batatas*) leaves	113 ± 3.6			334 ± 3.6
Papaya (*Carica papaya*)	161 ± 1.2			279 ± 5.0
Mchicha (*Amaratus blitum*)	97 ± 3.6			359 ± 3.6
Avocado (*Persea americana*)	124 ± 1.2			182 ± 5.0
Lucerine (*Chamaecytisus palmensis*)	107 ± 3.6			329 ± 2.6
Sunflower (*Helianthus annuus*) seed cake	51 ± 0.1			259 ± 0.1
Cotton (*Gossypium* spp.) seed cake	63 ± 4.6			388 ± 7.2
Cabbage (*Brassica oleracea*)	137 ± 3.2			219 ± 3.2
	Crude fibre	**Carbohydrate**	**Dry matter**	**Source**
Trash fish-rice bran (8:2)	-	-	-	New and Csavas 1993
Trash fish-broken rice	-	-	-	
Soya bean cake-chicken bone-noodle waste	-	-	-	
Compound feed	-	-	-	
Trash fish	0.07 ± 0.01	-	-	Millamena *et al*. 2002
Blighia Unijugata Aril	11.21 ± 0.60	9.27		Oderinde *et al*. 2002
Kernel	6.33 ± 1.10	54.02		
Aril+kernel	8.14 ± 0.71	36.86		
Floating pellet	0.08 - 0.15	-	11.63 - 11.74	Ajani *et al*. 2011
Sinking pellet	0.09 - 0.16	-	11.53 - 11.87	
Rice bran	-	-	89.15 - 90.85	Hossain *et al*. 2012
Wheat bran	-	-	87.96 - 90.08	
Mustard oil cake	-	-	89.13 - 91.53	
Wheat flour	-	-	89.26 - 90.04	
Fish meal	-	-	86.21 - 90.52	
Cow (*Bos taurus*) blood meal	11 ± 1.5 (g/kg)		908 ± 1.6	Munguti *et al*. 2012
Cow (*Bos taurus*) offal	88 ± 1.6		912 ± 1.8	
Cassava (*Manihot esculenta*) leaves	145 ± 4.0		912 ± 4.7	
Cassava (*Manihot esculenta*) flour	70 ± 4.6		920 ± 4.5	
Maize (*Zea mays*) bran	155 ± 3.7		894 ± 3.2	
Maize (*Zea mays*) corn gluten	89 ± 0.7		913 ± 3.0	
Arrow root (*Maranta arundinacea*) leaves	106 ± 4.6		901± 2.9	
Sweet potato (*Ipomoea batatas*) leaves	116 ± 36		897 ± 1.6	
Papaya (*Carica papaya*)	128 ± 13		902 ± 2.9	
Mchicha (*Amaratus blitum*)	107 ± 36		891 ± 1.6	
Avocado (*Persea americana*)	130 ± 13		903 ± 2.9	
Lucerine (*Chamaecytisus palmensis*)	112 ± 36		898 ± 1.7	
Sunflower (*Helianthus annuus*) seed cake	368 ± 0.2		929 ± 1.7	
Cotton (*Gossypium* spp.) seed cake	249 ± 45		892 ± 2.0	
Cabbage (*Brassica oleracea*)	98 ± 3.4		901 ± 3.4	

Note: All authors presented their findings on percentage with exception of Munguti *et al.* (2012) who presented their results in g/kg

Table 1B Proximate composition (% dry matter) of feed ingredients of plant origin available in Philippines and India.

Ingredient	Moisture	Crude protein	Crude lipid	Crude fibre	Ash	Country
Corn germ meal	4.5	47.4	8.5	6.4	0.8	Philippines
Corn gluten meal	8.0	60.6	7.0	3.4	1.2	
Leucaena leaf meal, native	10.3	29.3	8.8	11.5	6.9	
Copra meal	7.9	22.0	6.7	17.3	9.7	
Corn meal	8.4	7.8	4.7	2.6	1.8	
Corn starch	11.9	0.4	0.2	1.1	0.1	
Flour bread	12.1	12.9	1.2	0.3	0.7	
Flour, whole wheat	11.3	15.3	1.7	0.8	1.1	
Germ, wheat	6.0	27.8	4.3	3.4	4.9	
Gluten, wheat	8.9	80.7	1.4	0.4	1.1	
Gluten, corn	7.3	62.6	7.7	2.2	1.6	
Rice bran	9.2	13.3	14.1	8.5	10.7	
Rice bran, tiki-tiki	10.7	18.0	2.0	8.0	9.6	
Rice hull	7.0	3.3	2.0	32.4	20.7	
Soya bean meal, full fat	5.6	35.8	19.8	4.9	5.6	
Soya bean meal, defatted	8.5	43.6	1.5	5.5	7.7	
Soy protein concentrate	5.7	56.9	1.0	5.1	8.3	
Wheat flour	13.2	10.9	1.1	0.6	0.5	
Wheat, pollard	9.5	15.4	4.5	10.3	5.8	
Finger millet		6.5	1.2	6.0	7.0	India
Sorghum (white)		8.0	2.5	3.0	2.8	
Maize		8.5	3.5	2.0	1.9	
Broken rice		8.5	0.4	0.6	0.8	
Wheat flour		11.0	0.4	0.1	0.7	
Wheat bran		12.8	3.2	11.1	8.4	
Rice polish		13.0	15.8	6.6	9.8	
Rice bran, de-oiled		15.2	0.2	17.0	10.1	
Corn gluten meal		61.2	2.2	1.5	1.0	
Wheat gluten		80.0	0.8	0.1	0.8	

Source : FAO, 2007b

RESULTS AND DISCUSSION

Proximate compositions

The proximate composition of four different types of feed is presented in **Table 2**. The moisture content in the samples ranged between 5.12 ± 0.06 to 8.26 ± 0.06% (**Table 2**). These fall between the range of 5 and 10%, which Butt *et al.* (1988) considered normal for a fish feed. Any fish feed that exceeds 13% moisture is especially prone to insect and would attack and thereby unsuitable. Materials with high moisture content should not be used after drying, Chow (1999).

Crude protein gives the amount of all the reduced nitrogen in the food in the form of amines, ammonium compound, urea, amino acid etc. The most important function of dietary protein is to supply amino feeds either directly or indirectly. These amino acids are then used by the organism involved to synthesis its own proteins. The percentage crude protein in each of the samples varies from 57.27 ± 0.19 to 62.61 ± 0.13% (**Table 2**). These values are relatively high when compared with 45.09% recommended dietary formulations for rainbow trait (Tacon 1990) and 32.36% guaranteed for Koi & Gold Fish (Jmw/Morning Mist Farm 2005). According to FR1 (1989), A_1, A_2 and B grade fish meal had more or less 59.61, 50.81 and 44.74% protein, respectively. Kim and Easter (2001) conducted a study on chemical composition of various fish and fish meal as feed ingredient and found ChaiBo fish contained 55% crude protein, some mixed small whole fish contained 51.9% as protein and fish meal contained 56.8% crude protein in dry weight basis. Hossain *et al.* (2012) reported protein percentage of mustard oil cake, wheat bran, wheat flour and fish meal estimated as 35.17-37.25, 14.84-15.40, 14.15-17.73 and 51.32-65.34%, respectively. Concentrate are often used in feeding fish that are intensely farmed. Fish concentrate with high protein content of 30 to 60% are currently being used in cat fish production for maximum performance (Akintomide *et al.* 2005).

The right energy to protein ratio for each developmental stage of the fish should be ensured and the needed quantities of essential vitamins and minerals should be included for excellent cropping. Feed with very high protein content should preferably be adjusted for vitamins and minerals content in order to have a balanced growth. The protein level read to produce maximum weight gain for juvenile E. Coioides is between 47 and 60% (Bl-Dakuir and George 1982).

The dietary fat provides a highly concentrated form of energy on a grain to grain basis fats contain more than twice the energy of either carbohydrate or protein. The percentage crude fat in the samples ranged from 10.92 ± 0.14 – 13.07 ± 0.04% (**Table 2**). New (1987) reported that grouper require about 14% lipids in their diet. De Silva (1999) and Hansan *et al.* (1991) reported that mustard oil cake with 2-15% and fish meal with 5-205% lipid contents, respectively have a potential to be incorporated into aqua feed. Hossain *et al.* (2012) reported the mean range of crude lipid of 10.73-15.52% in mustard oil cake, 4.09-9.71% in wheat bran, 2.94-4.57% in wheat flour and 3.69-12.50% in fish meal.

Carbohydrate is important in the nutrition of fish. It is desirable to have some preferred carbohydrate in the feed to avoid excessive breakdown of the protein. The carbohydrate content of the samples ranged from 32.72 ± 0.17 to 36.16 ± 0.14% (**Table 2**). This is however high as compared to dietary formulations recommended for rainbow trout which ranges from 15 to 25% (Tacon 1990). It should be noted that the formulation recommended by Tacon are conservative in that emphasis has been placed on using high dietary inclusion levels of known quality ingredients.

The ash content in this study varied from 5.91 ± 0.13 to 7.31 ± 0.06% while the crude fibre range from 0.45 ± 0.08 to 0.65 ± 0.02% (**Table 2**). Hossain *et al.* (2012) reported the ash content of samples of fish feed ingredients of 14.79-18.84% in rice bran, 2.52-8.26 5 in wheat bran, 6.99-9.08% in mustard oil cake, 2.5-3.64% in wheat flour and 15.16-34.14% in fish meal. The percentage range of ash content and crude fibre was in agreement with submission of Millamena (2002) that crude fibre content tended to decrease while the ash content increased with increasing percentage replacement of fish meal with animal by-product meals. The ash of a foodstuff is the organic residue remaining after

Table 2 The proximate composition of four different types of feed.

	% Moisture	% Ash	% Protein	% Crude fat	% Carbohydrate	% Crude fibre	Energy (KJ/g)
Feed capital[1]	8.26 ± 0.06 c	5.91 ± 0.13 a	62.61 ± 0.13 d	13.07 ± 0.04 c	34.79 ± 0.17 b	0.45 ± 0.08 a	0.55 ± 0.03 a
Feed capital[2]	8.12 ± 0.04 c	6.41 ± 0.08 b	60.06 ± 0.03 c	12.16 ± 0.08 b	35.87 ± 0.14 c	0.54 ± 0.04 ab	0.54 ± 0.04 a
Sinking pellet	5.12 ± 0.06 a	7.31 ± 0.06 c	58.24 ± 0.08 b	10.92 ± 0.14 a	32.72 ± 0.17 a	0.65 ± 0.02 b	0.57 ± 0.03 a
Cap feed	6.06 ± 0.06 b	7.28 ± 0.04 c	57.29 ± 0.19 a	13.01 ± 0.07 c	36.16 ± 0.14 c	0.59 ± 0.09 ab	0.54 ± 0.04 a

Mean with different letter of the alphabet for each column are significantly different ($P < 0.05$) from each other

Table 3 Mineral composition of experimental feedstuffs evaluated (µg/g).

	Zn	Fe	Mn	Cu	P
Feed capital[1]	9.64 ± 0.06 a	7.01 ± 0.15 b	2.57 ± 0.17 a	5.61 ± 0.06 b	1.41 ± 0.04 a
Feed capital[2]	12.01 ± 0.08 c	19.02 ± 0.03 d	3.21 ± 0.27 b	4.92 ± 0.11 a	1.61 ± 0.08 a
Sinking pellet	15.05 ± 0.06 d	15.05 ± 0.03 c	6.49 ± 0.14 c	9.09 ± 0.06 c	2.86 ± 0.08 b
Cap feed	10.02 ± 0.03 b	6.01 ± 0.04 a	7.80 ± 0.06 d	10.10 ± 0.08 d	3.10 ± 0.08 c

Mean with different letter of the alphabet for each column are significantly different ($P < 0.05$) from each other

the organic matter has been burnt away. The ash obtained is not necessarily of exactly the same composition as the mineral matter in the original food as there may be losses due to vitalisation or some interaction between constituent. The ash figure can be regarded as a general measure of quality of the food. It is also a useful in identifying the authenticity of a food. When a high figure suggests the presences of an inorganic adulterant, it is often advisable to also determine the acid insoluble ash. The residue from ashing consists of inorganic constituents present in each sample. Hence the analysis of the elements present as possible dietary minerals are considered.

Mineral element concentrations

Minerals are very important in maintaining physiological processes. They are constituents of the teeth, bones, tissues, blood, muscle and nerve cells in animals. Dietary minerals are chemical elements required by living organism other than carbon, hydrogen, nitrogen and oxygen which are ubiquitous in organic molecules. The dietary and major minerals content of samples are shown in **Table 3**. The value of Fe and Zn are much higher in Feed capital[2] and Sinking pellet than feed capital[1] and Capfeeds.

Cu and Zn are considered as micro-nutrients; the WHO limits for these metals have not yet been established (Oderinde *et al*. 2009). The value of Cu ranged from 4.92 ± 0.11 to 10.10 ± 0.08 μgg^{-1} while Zn ranged from 9.64 ± 0.06 to 15.05 ± 0.06 μgg^{-1}. Allaway (1968) reported these elements range in agricultural products to be between 4 and 15 ppm for Cu, and 15 to 200 μgg^{-1} for Zn. However, the concentration of these elements in all the samples was within this range. According to Tacon (1990), the concentration of Zn for feed formulation is 75 μgg^{-1} and that of Cu is 4.5 μgg^{-1} while Mn is 37.5 μgg^{-1}. The value of Mn in the samples ranged from 2.57 ± 0.17 to 7.80 ± 0.06 $\mu gg^{-}1$ and these values were within the range as stipulated by Tacon (1990). The permissible limit of Pb for plants based on ADI (Acceptable Daily Intake) for Pb is 10 μgg^{-1} (Oderinde *et al*. 2009). The mean range of Pb for all the samples in this study are 1.41 ± 0.04 to 3.10 ± 0.08 μgg^{-1} and these values were within this range.

Though much is known about the functional role of a number of elements, the mineral nutrition lies in obtaining the correct amount of supplementation in the right format in the right time (Oderinde *et al*. 2009). Mg and Zn have important role in the metabolism of cholesterol as well as heart disease (Oderinde *et al*. 2009). The presence of Mn may be correlated with therapeutic properties against diabetic and cardiovascular diseases (Schwart 1975). Deficiency or excess of Cu, Mn, Zn, Ca, Mg and k may cause a number of diseases and also as a co-factor for various enzymes and variety of different metabolic processes (Oderinde and Ajayi 1998). Phosphorus (P) is also one of the essential minerals for all animals. It plays a critical role in metabolism, as well as a part of the energy currency of the cell, in cellular regulatory mechanisms, and in bones. Bone is the main storage organ for P containing 85% of the body's total P. Through its involvement in these metabolic and structure processes, P is essential for animal to attain their optimum genetic potential in growth and feed efficiency as well as skeletal development. Because of the key role of P in bone development and mineralization, the requirement of the animal for this mineral is highest during the time the animal is growing (Applegate 2003). Phosphorus content in the feed samples varied from 1.41 ± 0.04 to 3.10 ± 0.08%. The minimum percentage P recommended by Tacon and JMW/Morning Mist farm is 0.70, thus, the P content is also high.

CONCLUSION

This study tends to estimate the feed composition of some local feed raw materials using the proximate analysis. The percentage protein is relatively equal when compared with other dietary formulations earlier discussed. With the development of fish feed industry in Nigeria, attention must be given to the quality control of raw materials and pellet feed. Moreover, it is particularly important that an understanding of possible degeneration of fish feed in storage, especially when the temperature exceeds 30ºC should be considered by fish farmers. Hence, the need for regular feed analysis and control.

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