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Preliminary Assessment of Heavy Metal Concentrations in Selected Fish Feed Ingredients in Nigeria

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Abstract

Dearth of information exist on the heavy metal concentration (HM) of local fish feed ingredients in Nigeria, thus preliminary investigation on the concentration of lead (Pb), cadmium (Cd) (toxic heavy metals), copper (Cu), zinc (Zn) and chromium (Cr) (essential trace metals) present in some selected feed ingredients. The two toxic metals; lead and cadmium were found in fishmeal at the concentration of 0.30 mg/kg each. Cd content in soybean meal, groundnut cake, maize and soybean cake were 0.01, 0.3, 0.4 and 0.5 mg/kg respectively. Chromium was not detected in soybean cake and maize. Soybean meal and fishmeal had the same chromium content of 0.20 mg/kg, while highest concentration of chromium (1.00 mg/kg) was found in groundnut cake. Maize had the highest copper content of 1.00 mg/kg, groundnut cake 0.40 mg/kg, followed by 0.21 mg/kg in soybean cake and lowest concentration of 0.20 mg/kg was found in both soybean meal and maize. Fish meal had the highest zinc content of 1.70 mg/kg, followed by 0.91 mg/kg in maize and 0.90 mg found in soybean cake and meal, while groundnut cake had the least zinc content of 0.70 mg/kg. The values of the heavy metal content of the selected feed ingredients are far below fish's requirement for essential metals (copper, zinc and chromium). The results seem to buttress the need to fortify fish's feed with these essential metals from other sources. Otherwise fish and human the ultimate consumer may be predisposed to assimilation and bioaccumulation of cadmium and lead which are chemical analogues of zinc; especially with the current use of exogenous enzymes which may improve nutrient bioavailability.

Keywords: Heavy metals, Maize, Fishmeal, Plant protein sources

Introduction

The toxigenic and essential nature of heavy metals in the nutrition of animals has been established. However, dearth of information exits on the heavy metal concentration of feed ingredients which are the major route of entry into animals, particularly in developing countries [1]. Heavy metals are widely distributed into the environment with sources from weathering of parent materials and anthropogenic activities. The uptake of heavy metals in agricultural soils in Nigeria is of increasing concern [2]. Studies have revealed their accumulation at toxic levels which may be transferred to animals through ingestion of feed (produced from such crops) and to man through the food chain [3,4]. It is an established fact that heavy metals like lead and cadmium are toxic and are not required by animal and man even in small amounts. Fish exposure to these elements at low concentration for long period of time allows their bioaccumulation, which impair normal physiological activities, resulting in low performance and survival [5,6]. Cadmium is known to derive its toxicological properties from its chemical similarity to zinc (an essential nutrient) and once absorbed can remain bio-persistent [7], likewise lead is absorbed when zinc intake is insufficient [8,9]. Consequently, inadequate or unavailability of Zn in the diet of fish may predispose fish to assimilate these toxic metals (cadmium and lead).

Zinc and copper are essential to life. Zinc is an essential component of more than 80 metallo-enzymes, cofactor in many enzyme systems. It plays vital role in lipid, protein and carbohydrate metabolism. It also has positive role in wound healing. Copper is involved in iron metabolism, formation of bones, connective tissues and maintaining the integrity of myelin sheath of nerve fibres. The deficiencies of zinc and copper reduce appetite, lower digestibility of protein, lipid and carbohydrate [10] which result in growth retardation [11,12]. However, zinc availability and utilization depend (among others) on the level of available copper; it's metabolic antagonist due to their competition for binding sites on protein responsible for mineral absorption and or synthesis of metallo-enzyme [13]. Chromium is essential for normal lipid and carbohydrate, particularly glucose metabolism and its bioavailability may play a role in the level of available zinc to the fish [14]. It enhances growth rate (by enhancing the functions of various digestive organs), and improves efficiency of feed conversion. It is a potent antioxidant, hypocholesteremic agent and also improves immune system [15].

Since feed ingredients are the major constituent of feed, regular monitoring for their heavy metal content will go a long way in producing healthy feed that will enhance productivity and life of fish and human [16]. Consequently this study was designed to obtain quantitative information on the concentration of lead, cadmium, copper, zinc and chromium present in the major carbohydrate (maize,) animal protein (fishmeal) and plant protein ingredients (soybean cake, soybean meal and groundnut cake) used for fish feed.

Materials and Methods

Study area

Samples of feed ingredients were collected between December 2014 and March 2015 from toll millers in Aiyedoto Cooperative Farm Service Centre, Ojo, Ojo local government area of Lagos State, Nigeria.

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Five major feed ingredients including carbohydrate (maize), animal protein (fish meal) and plant proteins (groundnut cake, soybean cake and soybean meal) were collected for their assessment of heavy metal contents. Samples of the feed ingredients were collected randomly following [17] general guidelines on sampling with modification. The maize (MZ), soybean meal (SBM) and fish meal (FM) were collected with a sampling spear. The spear was inserted diagonally and horizontally as possible into a 50 kg bag per ton of the feed ingredients. The samples were pooled, mixed and then reduced to 1.50 kg in weight. The coarse ingredients groundnut cake (GNC) and soybean cake (SBC) were sampled by random selection of pieces from the entire consignment at the rate of 5 pieces per ton of ingredients. The pieces were ground, mixed and reduced in size to 1.50 kg for the determination of heavy metals.

Determination of heavy metals concentrations

The samples were prepared for analysis by following the methods described earlier [18,19]. The samples were dried in the oven at 60°C until constant weight was obtained. To 1 g of dried sample 10 mL of aqua ragia were added to each flask. The mixture were heated up to 150°C for about 2 h, after cooling the mixture were filtered using a 0.45 µm Whatman filter paper and brought to a volume of 10 mL with deionized water.

Quality assurance: Stock solution (Merck) of 1000 mg/L of the different metals was used to prepare the calibration standards. The potential contamination of the samples was evaluated by analyzing one acid blank in every batch. The determination of heavy metal was performed with the use of a Perkin Elmer and Oak Brown Atomic Absorption Spectrophotometer. The instrument's setting and operational conditions were done in accordance with the manufacturer's specifications. The detection limits for the metals are as given: Cadmium 0.002, lead 0.05, chromium 0.003, copper 0.001 and zinc 0.003 mg/kg. All chemicals used were of analytical reagent grade. The values of heavy metals (in triplicates) were calculated based on dry weights of the samples.

Statistical analysis

Statistical analysis was performed using the SPSS V. 17. 0 package for Windows. Analysis of variance (ANOVA) was used to compare the mean values and where significant differences were obtained, means were tested using Fisher's least significant difference test at P=0.05 significance level.

Results and Discussion

The results of heavy metal concentration in selected feed ingredients are presented in Table 1. Estimated percentage of fish feed composition is presented in Table 2. The different crude protein levels used in Table 2 were based on [20] requirements for warm water fishes.

The five heavy metals assessed were detected in fishmeal; the only animal protein used in fish feed production. Fishmeal has the highest concentration of lead (0.30 mg/kg) and zinc (1.70 mg/kg) with lower contents of cadmium (0.30 mg/kg) and of both chromium and copper (0.20 mg/kg). The high concentration of lead in FM may be due to the fact that FM is a by-product of fish; which are obtained from aquatic environment noted for heavy metal contamination [21]. However, the concentrations of toxic heavy metals; lead, cadmium and essential metals obtained in this study were below the permissible values reported by [21,22-24]. Since FM is an indispensable component of fish feed and judging by the results obtained in this assessment its use at high level in fish feed may increase the level of lead and cadmium. Nevertheless, bearing in mind the bioaccumulative and non-degradable tendencies of these metals. However, the low concentrations of essential mineral; Zn, Cr and Cu obtained in this assessment seem to suggest that part of the fish's essential minerals need may be provided by fish meal.

Mineral concentration in plant and plant products is determined majorly by their concentration in the soil. Also human's activities in the immediate environment, plant type and variety, post-harvest handling; processing methods and storage conditions are important factors in concentration of heavy metals in crops and their by-products [25,26,1]. Therefore the concentrations of heavy metals obtained in this study may have resulted from any or a combination of these factors.

The carbohydrate source; maize mostly used in production of fish feed in the country was contaminated with cadmium at a level of 0.40 mg/kg (higher than 0.30 mg/kg found in fishmeal. This result obtained is contrary to the findings of [25] who did not detect cadmium. But the value is higher than the 0.116 mg/kg reported by [27] and 0.23 mg/kg reported by [26]. The value is lower than 1.54 mg/kg reported by

HM	Feed ingredients					
	FM	GNC	SBC	SBM	MZ	MMC
Pb	0.30 ± 0.02^{a}	ND	ND	ND	ND	0.30 ± 0.00^{a}
Cd	0.30 ± 0.20^{a}	0.30 ± 0.10^{a}	0.50 ± 0.10^{a}	0.10 ± 0.00^{a}	0.40 ± 0.10^{a}	0.32 ± 0.15^{a}
Cr	0.20 ± 0.02^{a}	0.10 ± 0.02^{a}	ND	0.20 ± 0.00^{a}	ND	0.11 ± 0.00^{a}
Cu	0.20 ± 0.01^{a}	0.40 ± 0.30^{a}	0.21 ± 0.04^{a}	0.20 ± 0.00^{a}	0.10 ± 0.02^{a}	0.22 ± 0.11^{a}
Zn	1.70 ± 0.60^{a}	0.70 ± 0.40^{c}	0.90 ± 0.20^{bc}	0.90 ± 0.04^{bc}	0.91 ± 0.05^{bc}	1.02 ± 0.39^{ab}

± SD: Standard Deviation; HM: Heavy Metal; MMC: Mean heavy Metal Concentration of the ingredients; ND: Not Detected

Values in the same row and with the same superscript alphabet are not significantly different (p>0.05).

Table 1: Mean concentrations of heavy metals in selected feed ingredients (mg/kg ± SD).

Feed ingredients	Content of feed ingredients at different Protein levels*				
	27	32	35	38	40
MZ	49.8	37.25	34.25	29.25	25
PP	25.7	37	40	40	38
FM	14	15	15	20	26
Other ingredients	10.5	10.75	10.75	10.75	11

Notes: *Protein levels were calculated based on NRC, (1993) recommendation for warm water fishes. Assumption: Any of the three (PP) plant protein ingredients; GNC (groundnut cake), SBC (Soybean cake) or SBM (soybean meal) can be used on the basis of weight for weight at Crude protein level of 44%. Other ingredients: Wheat offal 5.25%, oil 2.5%, dicalcium phosphate 1.5%, vitamin-mineral premix 0.50%, vitamin C 0.50% and salt 0.25%.

Table 2: Percentage level of inclusion of feed ingredients in typical fish feed.

[28] for maize grains grown at different locations in Nigeria. The soil types and anthropogenic activities could have contributed to these variations. Also presently in the country little attention is given to proper handling and storage of agricultural produce by rural farmers who are the major producers. Since the maize samples used in this assessment were collected from toll millers, the ubiquitous nature of cadmium and perhaps handling could have contributed to the higher values obtained in this study. The cadmium contents for SBC, GNC and SBM were 0.50, 0.30, 0.1 mg/kg for SBC, GNC and SBM respectively. Dearth of information exist on the cadmium content of these oil seed by-products, but the value found in soybean meal is lower than 0.75 mg/kg found in Saudi Arabia soybean meal reported by Seeni [29]. However, higher concentration of cadmium found in SBC and GNC as against soybean meal may have arisen from the different processing methods adopted and factory set up in the production of cakes and meal. Cakes are produced through mechanical and hydraulic removal of oil. A process mostly handled by small scale producers in the country in less sophisticated set up, which may allow for diffuse source of cadmium. This may have predisposed cakes of both plants products to cadmium contamination [30,31]. The values of cadmium except for that of soybean meal were above the stipulated safe limit of 0.2 mg/kg recommended by ref. [32]. Judging from the results obtained from this assessment, efforts must be geared at sourcing for maize with low or no cadmium contamination, while soybean meal may be a better ingredient for preparation of fish feed than its cake's counterpart.

The concentration of essential metals found in the plant ingredients are as presented: 1.0 mg/kg of chromium was found in GNC, the highest level recorded in all assessed feed ingredients, while SBM contained 0.2 mg/kg which is lower than 0.27 mg/kg found in Saudi Arabia soybean meal [29]. No chromium was detected in SBC and maize. Lowest content of copper (0.10 mg/kg) was found in maize, followed by (0.2 mg/kg and 0.21 mg/kg) found in SBM and SBC respectively, with highest copper content of 0.40 mg/kg found in GNC. Maize had the highest concentration of zinc 0.91 mg/kg among the plant feed ingredients, followed by 0.90 mg/kg found in both SBC and SBM, while lowest copper concentration of 0.70 mg/kg was found in GNC. Conclusively the values of essential metals detected in the local ingredients used for fish feed were below values reported by [21,13] for materials of vegetable origin. The content of copper were below values reported by [27,33] for maize, while the value of copper found in SBM were higher that the value reported by [34]. Also the values of zinc detected in maize in this study were lower than 2.01 mg/kg reported by [25] but higher than 0.66 mg/kg reported by [1]. Never the less, these plant feed ingredients could contribute to fish essential mineral need.

Generally of great concern in the heavy metal content of the assessed ingredients is the presence of lead and cadmium found in fishmeal and maize which are highly indispensable ingredient in the production of fish feeds in Nigeria. The concern can be viewed from these perspectives; with low content of essential trace minerals associated with plant protein sources and or perhaps lack of proper supplementation of these metals, particularly zinc, the fish may be predisposed to the assimilation of cadmium its chemical analog or lead. This may seriously impair fish performance and health. Especially, at early stage of development, when the level of inclusion of fishmeal and plant protein sources (GNC, SBC and SBM Table 2) in fish's feed are always high due to high protein (40% crude protein or more) [20] required by fish at this stage. Also the recent use of high level of plant protein and inclusion of phytase to boost mineral availability may also improve availability of toxic metals [35].

Conclusion

The results obtained in this study revealed the presence of heavy toxic metals; Pb and Cd and low concentration of essential trace metals (Cr, Cu and Zn) in the selected feed ingredients, which may predispose fish to assimilation of toxic heavy metals. A situation which calls for:

Regular monitoring and assessment of fish feed ingredients for their heavy metal contents by the designated authorities at the local government, state and national levels. There is need to enforce compliance and sanctions for any defaulter to the limit set by the authorities and governmental bodies saddled with these responsibilities.

Supplementation of the essential heavy metals to meet fish's requirement particularly zinc (which is a major determinant in the absorption of cadmium and lead); in quantity and state that allow for their bio- availability and assimilation to prevent the absorption of toxic heavy metals will go a long way in ensuring the production of safe feed for fish in Nigeria.

However, since it is impossible to completely eliminate the presence of undesirable substances like cadmium from the environment, there is need to employ the following:

Regular training and enlightenment programs should be given to farmers, toll millers and small scale oil seed cake producers on the need for proper storage and handling of fish feed ingredients as these will reduce (or preventing where possible) the level of toxic heavy metals in feed ingredients, fish and man the ultimate consumer.

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