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Research Article
Nutritional Composition and Heavy Metal Contamination of Prominent Fishmeal Samples

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Abstract
Background and Objective: Fishmeal is considered the most expensive major source of protein commonly used in domestic animal feeds and in commercial aquafeeds. This study aimed to investigate the proximate composition, mineral contents and heavy metal contamination of the five most populous fishmeal available within the South-West of Nigeria. **Materials and Methods:** Samples were collected from commercial fishmeal whole sellers and analyzed accordingly. Proximate composition, mineral contents and heavy metal composition determined. **Results:** Results reveal significant differences ($p<0.05$) in the values obtained. For proximate composition, Carbohydrate, Crude Protein, Crude Fat, Moisture Ash and Crude Fibre contents ranged from 6.27±0.07-19.87±0.10, 52.13±0.04-81.38±0.15, 3.73±0.06-6.84±0.05, 2.89±0.06-8.6±0.07, 4.08±0.06-5.21±0.02 and 1.65±0.02-9.3±0.14% among samples, respectively. Mineral contents (Na, K, Ca, Fe, Mg, P) for all five samples were significantly different at ($p<0.05$), while values of heavy metal contents revealed Cd, Pb, Hg, Cu, Zn and Cr concentrations ranging between 0.003±0.002-0.082±0.02, 0.002±0.02-0.00, 0.0016±0.00-0.0061±0.00, 0.291±0.03-1.059±1.56, 1.02±0.27-2.534±0.36 and 0.001±0.00-0.015±0.00 mg kg^{-1}, respectively. However, some values fell above the FAO/WHO permissible limit for heavy metals. **Conclusion:** It was concluded that more attention should be given to the sources of fishmeal used in feed production and constant monitoring of their chemical composition as not all fishmeal sold commercially are high-grade fishmeal.

Key words: Fishmeal, heavy metals, permissible limit, feed production, carbohydrate, crude protein, crude fat, moisture

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Feeding in aquaculture is heavily dependent on shmeal which represents the largest single cost item of most feed ingredients. The nutritive value of fishmeal varies depending on sources of input, place of harvest and addition of salt for preservation[1].

Fishmeal supplies a balanced amount of both essential nutrients like amino acids, fatty acids (docosahexaenoic acid or DHA and eicosapentaenoic acid or EPA) and phospholipids and mineral content, for optimum growth, development and reproduction[2]. However, the rising demand and limited supply make fishmeal an expensive protein source[3].

A variety of commercial fishmeal is available within the Lagos metropolis. According to some authors[4], the most prominent fishmeal producing countries and their fish species used for fishmeal production are Denmark (Pout, Sandeel, Sprat), the U.S.A. (Menhaden, Pollock), Chile (Anchovy and Horse mackerel), Peru (Anchovy), South Africa (Pilchard), Thailand (various species), China (various species), European Union (various species) Iceland and Norway (Capelin, Herrings, Blue whiting), Japan (Sardine/Pilchard). In Nigeria, the annual fishmeal importation stands at about 130,000 MT of which about 95% are imported while the rest are locally sourced from trash fishes and freshwater sun-dried clupeids[5]. The high cost and scarcity of good quality fishmeal have attracted various sharp practices in their commercial sales. In addition, when obtained locally, end-users have complained of fishmeal infested with insects, adulterated with cheap diluents such as ground bones, poultry by-products, sawdust, soybean meal, horns and hooves, blood meal, animal oil, prawn, wastes of tannery and sand which compromise the fundamental nutrients expected from a specific quantity of fishmeal[6].

The chemical composition, mineral content and excellent protein quality of fishmeal can differ, depending on the species of fish used[6,7], the freshness of the fish species[8], storage duration and conditions of storage[9,10], processing method and handling condition of the fresh materials[1,2,8,9,11-14], drying method and temperature[8,14] and whether it is made from whole fish, trash fish or the waste from processing operation[8]. Recent studies have also shown that fish feed contains a significant amount of contaminants including heavy metals like, lead, cadmium, chromium, mercury and arsenic, many of which are toxic at low concentrations and can bio-accumulate and bio-concentrate in fish. Another report[15] stated that fish consumption is a major avenue for pathogen and heavy metal exposure to man. Few studies[16,17] also revealed that any contamination of aqua feed can greatly affect both the fish and their consumers.

Thus, this study aimed to investigate the nutritional composition and heavy metal contamination of the most commonly sold fishmeal samples within the Lagos metropolis.

MATERIALS AND METHODS

Study area and sample collection: This study was carried out in Lagos State, South-West Nigeria. Five different fishmeal samples were collected from Oko-Oba in Agege, Lagos State Nigeria. Samples were collected from 12th February to 2nd July, 2021. Oko-Oba is famous for its abattoir market and a central hub for livestock and aquafeed market.

Five different branded fishmeal samples, (A), (B), (C), (D) and (E), were collected from different aqua feed whole sellers in the Oko-Oba feed market. Samples were placed in clean polyethylene bags and transported to the Analytical Chemistry Laboratory of the Nigerian Institute for Oceanography and Marine Research (NIOMR) for analysis.

Determination of the proximate and mineral composition of five fishmeal samples: Collected fishmeal samples were weighed individually and used for chemical analysis. The estimation of carbohydrate, protein, fat, moisture ash and fibre were carried out[18-20]. Moisture content was estimated by the hot air oven method while mineral composition after wet digestion with a mixture of sulphuric acid, nitric and perchloric acid was determined using the atomic absorption spectrometer (AAS) (Buch Scientific, East Norwalk, CT 06855, USA) for, Calcium (Ca), Iron (Fe), Magnesium (Mg) and Phosphorous (P) while Potassium (K) and Sodium (Na) were determined using flame photometry.

Determination of heavy metal contents of five fishmeal samples: In this study, six different heavy metals were assessed after digestion of samples. The metals are, Cadmium (Cd), Lead (Pb), Mercury (Hg), Copper (Cu), Zinc (Zn) and Chromium (Cr), using an Atomic Absorption Spectrophotometer (AAS), model number ICE 3000 AA.

Statistical analysis: The data obtained were subjected to Analysis of Variance (ANOVA) and means were separated using Duncan's Multiple Range Test (DMRT) (Duncan, 1995) using the SPSS (Statistical Package Computer, Software 2004 version Chicago, Illinois, USA). Differences were regarded as significant at $p<0.05$ level[21].

RESULTS AND DISCUSSION

The experiment was carried out on 5 different branded fishmeal samples most common within the Lagos metropolis. Analytical conditions for the measurement of their proximate composition, mineral content and heavy metal concentrations are presented in Table 1, Table 2.

Sample (B) had the highest mean carbohydrate value (19.87±0.10%) while sample (C) had the lowest (6.27±0.07%) mean value, sample (C) had the highest mean crude protein value (81.38±0.15%) while sample (E) had the lowest (52.13±0.04%) mean value in Table 1.

The highest mean crude fat content was recorded in the sample (E) with a mean value of (6.84±0.05%) while sample (C) had the lowest (3.73±0.06%) mean value. Ash content was highest (5.21±0.02%) in the sample (E) while sample (C) had the lowest (4.08±0.06%) mean value. The fibre content was highest (9.3±0.14%) in the sample (E) while sample (C) recorded the lowest mean value of (1.65±0.02%).

The mineral content of fishmeal samples (A, B, C, D and E) recorded in this study revealed the highest values of Na (45.412±0.49 mg kg^{-1}), K (201.255±0.31 mg kg^{-1}), Ca (11.863±0.38 mg kg^{-1}), Fe (3.65±0.25 mg kg^{-1}), Mg (11.8566±0.22 mg kg^{-1}) and P (156.576±0.60 mg kg^{-1}) for samples B, A, A, B, E and E, respectively while lowest values of Na (15.502±0.07 mg kg^{-1}), K (101.662±0.68 mg kg^{-1}), Ca (8.978±0.05 mg kg^{-1}), Fe (1.437±0.03 mg kg^{-1}), Mg (9.637±0.02 mg kg^{-1}) and P (140.266±0.55 mg kg^{-1}) were recorded in sample A, D, B, C, B and A, respectively in Table 2.

Data obtained from the analysis of heavy metals of all fishmeal samples are presented below. Sample (D) had the highest mean Cadmium content of 0.082±0.02 mg kg^{-1} while sample (B) had the lowest value of 0.082±0.02 mg kg^{-1} in Fig. 1. However, no presence of lead was detected in all samples except for sample (C) with a mean value of 0.002±0.02 mg kg^{-1} in Fig. 2. Mercury content was highest in sample (C) with a value of 0.0061±0.00 mg kg^{-1} and lowest in

Table 1: Proximate composition of fishmeal (A, B, C, D and E) samples

Samples	Carbohydrate (%)	Protein (%)	Fat (%)	Moisture (%)	Ash (%)	Fibre (%)
A	7.71±0.07[b]	76.13±0.18[d]	4.71±0.04[c]	4.62±0.04[b]	4.39±0.02[b]	2.44±0.09[b]
B	19.87±0.10[e]	57.63±0.24[b]	4.52±0.06[b]	8.39±0.07[d]	5.02±0.06[d]	4.57±0.27[d]
C	6.27±0.07[a]	81.38±0.15[e]	3.73±0.06[a]	2.89±0.06[a]	4.08±0.06[a]	1.65±0.02[a]
D	10.27±0.07[c]	67.38±0.04[c]	5.6±0.03[d]	8.6±0.07[e]	4.77±0.05[c]	3.38±0.04[c]
E	18.66±0.07[d]	52.13±0.04[a]	6.84±0.05[e]	7.86±0.04[c]	5.21±0.02[e]	9.3±0.14[e]

±SD: Standard deviation and values in the same row and with the same superscript alphabet are not significantly different (p>0.05)

Table 2: Mineral content of fishmeal (A, B, C, D and E) samples

Samples (mg kg^{-1})	A	B	C	D	E
Na	15.502±0.07[a]	45.412±0.49[d]	41.974±0.32[c]	26.003±0.10[b]	26.0067±0.09[b]
K	201.255±0.31[e]	160.429±0.17[d]	130.238±0.35[c]	101.662±0.68[a]	115.366±0.29[b]
Ca	11.863±0.38[b]	8.978±0.05[a]	9.626±0.01[a]	11.257±0.51[b]	11.0047±0.30[b]
Fe	1.457±0.03[a]	3.65±0.25[d]	1.437±0.03[a]	3.191±0.15[c]	2.4776±0.01[b]
Mg	11.594±0.5[c]	9.637±0.02[a]	10.703±0.66[b]	10.723±0.15[b]	11.8566±0.22[c]
P	140.266±0.55[a]	148.654±0.55[c]	156.576±0.60[e]	145.858±0.14[b]	152.383±0.30[d]

±SD: Standard deviation and values in the same row and with the same superscript alphabet are not significantly different (p>0.05)

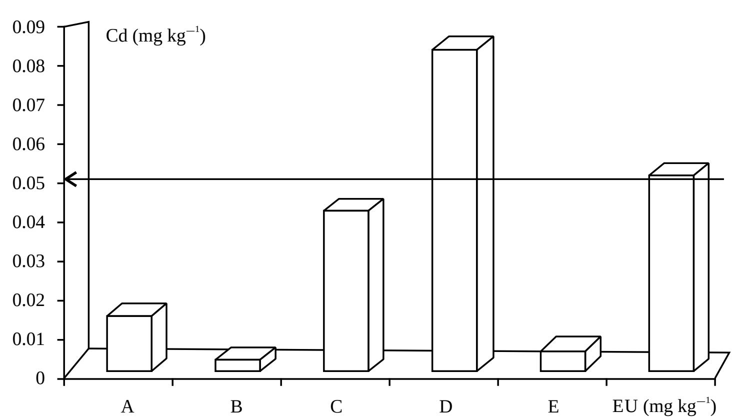

Fig. 1: Cadmium (Cd) concentration of five different samples of fishmeal

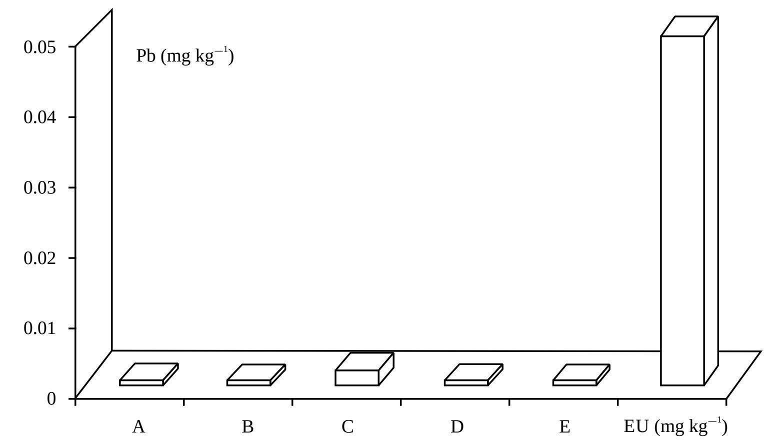

Fig. 2: Lead (Pb) concentration of five different samples of fishmeal

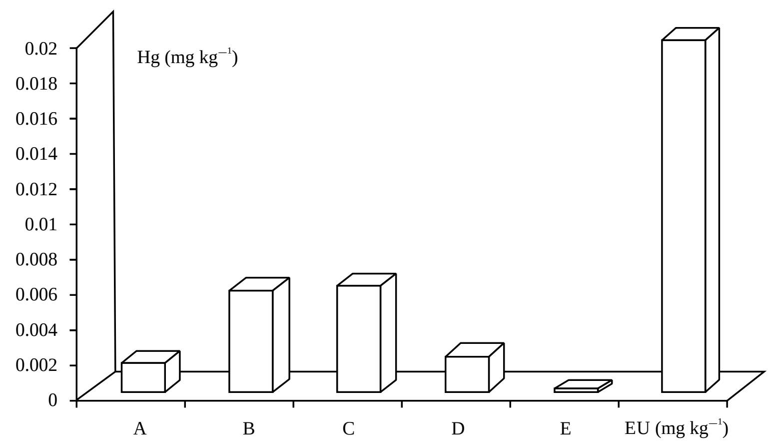

Fig. 3: Mercury (Hg) concentration of five different samples of fishmeal

sample (A) with a value of 0.0061$\pm$0.00 mg kg^{-1} in Fig. 3. The mean highest Copper content was recorded in sample (C) with a value of 1.02$\pm$0.02 mg kg^{-1} while the lowest value was recorded in the sample (A) with a value of 0.29$\pm$0.06 mg kg^{-1} in Fig. 4. Zinc contents were highest in the sample (C) with a value of 2.53$\pm$0.11 mg kg^{-1} while the lowest value was recorded in sample (B) with a value of 1.02$\pm$0.08 mg kg^{-1} in Fig. 5. Chromium concentrations recorded was highest in sample (A) with a value of 0.015$\pm$0.003 mg kg^{-1} while the lowest value was recorded in the sample (B and C) with values of 0.001$\pm$0.009 and 0.001$\pm$0.003 mg kg^{-1}, respectively in Fig. 6.

Fishmeal is the preferred animal protein supplement in the diets of farm animals and is often the major source of protein in diets for fish and shrimp. From a nutritional standpoint, fishmeal of good quality contains between 60-72% crude protein by weight[22]. This places samples (B) and (E) as medium quality fishmeal. This was not unexpected as they contain the highest ash content among all samples analyzed in this study. Report[1] stated that, there is an inverse relationship between crude protein and total ash content of fishmeal samples which agrees with the findings of this study. Sample (A), (C) and (D) could be categorized as high-quality fishmeal and this agrees with the findings of Ayssiwede *et al.*[23], who categorized fishmeal produced in Senegal into high-quality fishmeal containing 58-75% crude protein with ash content less than 25%.

The variation in protein content among fishmeal samples analyzed in this study may be related to factors such as the species of fish used for fishmeal, the freshness of fish species during processing, conditions and length of storage, amount of residual oil, processing method and handling condition and drying temperature[24].

According to report[25], the lipids found in fishes can be separated into both liquid fish oils and solid fats. Although most of the obtained oil is usually extracted during the processing of fishmeal, the remaining lipid typically represents between 6 and 10% by weight but can also range from 4-20%.

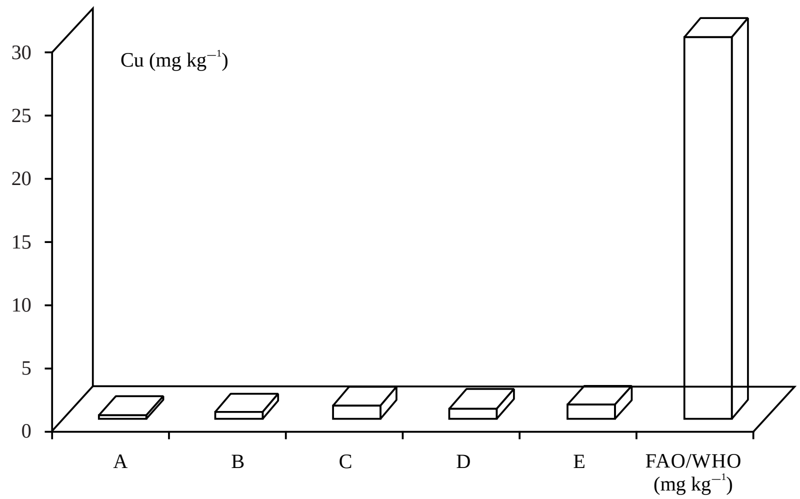

Fig. 4: Cupper (Cu) concentration of five different samples of fishmeal

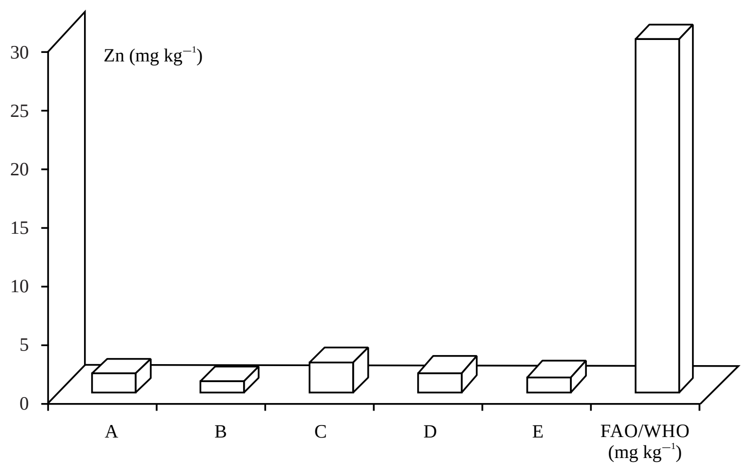

Fig. 5: Zinc (Zn) concentration of five different samples of fishmeal

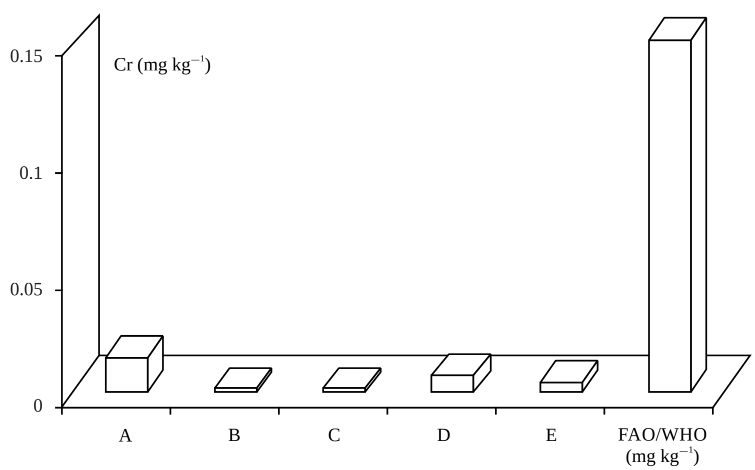

Fig. 6: Chromium (Cr) concentration of five different samples of fishmeal

In this study, the analyzed fat contents varied considerably ($p<0.05$) among the different fishmeal samples. Values obtained are similar to the findings of Ayssiwede *et al.*[23].

Minerals are known to contain interesting functional properties that are useful for growth and development. As integrals of bones and teeth, minerals provide strength and rigidity to skeletal structures and as components of organs, blood pigments, enzymes and organic compounds in tissues, they are very necessary for optimal metabolic functions involving the transfer of energy and exchange of gases. They are also indispensable for the maintenance of acid-base equilibrium and osmotic relationship with the aquatic environment and for integration activities involving the nervous and endocrine systems when in their ionic states in body fluids. The values of various minerals obtained in this study show significant difference ($p<0.05$) among samples as they contained appreciable amounts of Na, K, Ca, Fe, Mg and P, suggesting that these fishmeal samples are a good source of nutrient minerals.

Cadmium (Cd), a nonessential nutrient is regarded as a toxic trace element that biochemically replaces Zn and causes high blood pressure. Chronic exposure of Cd causes respiratory distress, lung and breast cancers, anaemia, haemorrhagic injuries and cardiovascular disorders and consequently damages the liver and kidney. In this study, the results of Cd recorded from the five fishmeal samples were found to be, 0.014, 0.003, 0.041, 0.082 and 0.0056 mg kg^{-1} for samples A, B, C, D and E respectively. There was no significant difference ($p>0.05$) among samples A, B, C and E. However, sample D showed a remarkable difference ($p<0.05$) from all other samples with a value of 0.082 mg kg^{-1} and exceeding the FAO/WHO permissible limit of 0.05 mg kg^{-1}. This high value may be due to either natural pollution (volcanic activity, weathering of bedrocks) of the aquatic environment were the fish is caught for fishmeal purposes or anthropogenic factors (mining activities, incineration of waste and agricultural use) induced during the processing of fish for fishmeal. The values obtained in this study are not similar to the report of Uzairu *et al.*[26] with values of 0.03 mg kg^{-1} obtained from feed.

Toxic lead (Pb) concentrations in humans are known to cause several diseases and body malfunctions including damage to the central and peripheral nervous system, growth and development, cognitive development, renal system, blood circulation, mental retardation, reproductive health and eventually can cause death[27,28]. In this study, Pb values in samples A, B, C, D and E fell below the FAO/WHO permissible limit of 0.02 mg kg^{-1}. Report[29] stated that origin of mercury (Hg) in fishmeal and feed materials could be natural (volcanic activity) as well as anthropogenic (industrial pollution).

Copper (Cu) is an essential trace element that is necessary for normal biological activities of amino acids and is required for some essential enzymes such as superoxide dismutase, cytochrome oxides and lysyl oxides. However, studies have shown that Cu is highly toxic in aquatic environments and has effects on fish, invertebrates and amphibians. In humans, excess copper might result in dermatitis, metallic taste in mouth, hair and skin decoloration[30,31]. In this study, copper concentration in all samples of fishmeal analyzed fell below the FAO/WHO permissible limit of 30 mg kg^{-1}. This value is similar to the findings of Yahaya *et al.*[32] who worked on the content of some heavy metals in compound fish feed in Northern Nigeria.

The values of Zinc (Zn) detected in the five fishmeal samples in this study were similar to the findings with a value of 1.7 and 2.01 mg kg^{-1} reported[33]. There was also no significant difference ($p>0.05$) among the five samples analyzed. Abdel-Warith *et al.*[34]. reported that zinc is required for normal development and metabolism but if its level exceeds the physiological requirements, it can act as a toxicant.

Chromium (Cr) is an essential nutrient that facilities the action of insulin as well as helps the metabolism and storage of carbohydrates, fat and protein[35]. However, Chromium is known to be one of the most environmentally toxic pollutants. High levels of chromium disrupt the sugar metabolism cause heart conditions and also damage the kidneys, liver and blood cells through oxidation reactions[36]. The estimated levels of chromium in all fishmeal samples in the present study were lower than the limits permitted by the FAO/WHO in human foods and range between 0.1 and 0.5 mg kg^{-1}. The values obtained in this study are similar to the findings of Adeniji and Okedeyi[37] who worked on the preliminary assessment of heavy metals in selected feed ingredients in Nigeria.

CONCLUSION

This research revealed highly concerning levels of toxic Cadmium levels in a commercial fishmeal sample with concentrations much greater than recommended limits. The proximate composition and mineral contents of these fishmeal samples also vary significantly among the different samples analyzed. More attention should be paid to the source of fishmeal used in feed production and constant monitoring of their chemical composition as not all fishmeal sold commercially are high-grade fishmeal.

SIGNIFICANCE STATEMENT

This study exposes deleterious levels of heavy metals in branded and prominent commercial fishmeal samples sold to aqua-feed producers. Keen attention by relevant stakeholders must be given to the quality standards of ingredients used in aqua-feed production.

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