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Evaluation of Heavy Metal Contamination in Some Selected Commercial Fish Feeds Used in Bangladesh

Md Murad Sarkar[1] · Md Fazle Rohani[2] · Mostafa Ali Reza Hossain[3] · Md Shahjahan[1]

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Abstract

Quality fish feed is the prime need for successful aquaculture. Feed qualities determine the fish flesh quality including appearance, color, odor, flavor, texture, nutritive value, and shelf-life. Nowadays, consumers are very much concerned about various issues regarding way of fish farming, types of feed ingredients used etc. The current study was conducted to assess the heavy metal contents and nutritional composition of some selected commercial fish feeds used in Bangladesh. The major heavy metal concentrations and proximate composition (moisture, crude protein, crude lipid, ash, crude fiber, *and carbohydrate*) of the collected feed samples were analyzed. The results showed that the feeds contained a number of heavy metals in varying proportions. The highest concentrations (mg/kg) of heavy metals such as lead *(Pb)*, cadmium (*Cd),* chromium *(Cr)*, copper *(Cu), and* zinc *(Zn)* analyzed in fish feed samples were *0.189, 0.027, 1.023, 0.303, and 1.468, respectively.* There were significant differences between the nutritive values provided by feed companies and the values observed in this finding. The present study recommends that adequate measures are required to be taken by commercial fish feed manufacturers to ensure the nutritional quality of feed as well as to avoid the contamination of feed from heavy metals. Otherwise, fish and human, the ultimate consumer, may be predisposed to the assimilation and accumulation of the assessed heavy metals.

Keywords Heavy metals · Feed ingredients · Proximate composition · Risk assessment

Introduction

Quality of fish feed is considered one of the most crucial factors that have a significant impact on the outcome of aquaculture practice. Intensive and semi-intensive aquaculture systems require the adequate supply of nutritionally balanced fish feeds. The use of well-balanced commercial feeds is the prerequisite for successful aquaculture production [1, 2]. Formulated commercial feed plays a key role in semi-intensive fish farming systems where higher stocking density of fish is maintained than the natural productivity of the water is able to support [3]. Commercial feed provides adequate nutrition as well as energy required to ensure the better growth of farmed fish, and is known to increase the carrying capacity of the culture systems, which enhances the fish production by several folds [4]. Fish production in culture system was found to be about 7.7 times higher when supplementary commercial feed was provided as compared to the culture without feed supplementation [5, 6]. Despite increased fish production, feed constitutes around 50–60% of the total operational cost in most of the aquaculture systems [7, 8]. Therefore, feed quality and its nutritional value are the two major factors in determining the profitability and sustainability of any aquaculture system. The global demand of formulated feed for farmed fishes was estimated to be 29.3 million tonnes in 2008 and has grown manifolds with increasing aquaculture practices in the world [9]. In 2019, 41 million tonnes of fish feeds was applied in world aquaculture [10]. With the ever-increasing quantitative requirement, demand for good-quality feed in aquaculture is increasing day by day. Nonetheless, despite the increasing demand of quantity and quality of fish feeds in aquaculture of Bangladesh, there has been very limited information on the quality as well as nutritional content of the feed manufactured in the country [11] and the imported ones as well.

✉ Md Shahjahan
mdshahjahan@bau.edu.bd

[1] Laboratory of Fish Ecophysiology, Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

[2] Department of Aquaculture, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

[3] Department of Fisheries Biology and Genetics, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

Feed quality can influence the production and economics of fish farms either directly or indirectly in many different ways [12]. Though fish feed plays the key role in the aquaculture production, contaminated feeds seriously affect not only the fish but also the vulnerable consumers that depend on fish as a source of protein as well as a staple food. Fish feed and the ingredients used can be contaminated by various undesirable substances that may be originated either from environment or from the manufacturing process. These contaminants may easily be transferred from feed to cultured fish and finally to the fish consumers. One of the major contaminants—heavy metals can concentrate into fish body through bioaccumulation [13, 14]. Heavy metals are of great concern as they are readily transferred through food chains and highly toxic and are not known to provide any essential biological functions [15, 16]. According to Fatih et al. [17], all the fish feeds contain quantifiable amount of a number of contaminants. Studies have found that fish and shellfish obtained from commercial aqua farms are contaminated with heavy metals in varying proportions [18].

Bangladesh is one of the most suitable countries for aquaculture, and the current aquaculture production of the country is quite satisfactory and increasing by the years [19]. The increased aquaculture production has placed Bangladesh at the 5th position globally, in terms of total aquaculture production [20]. However, profitability of this vital sector has been gradually decreasing day by day due to higher price and poor quality of fish feed [21–24]. In addition, feed quality, acceptability, and utilization have significant impacts on water quality, growth, survival, and, finally, profitability as well as sustainability of this sector [25–27]. Therefore, good-quality feed is a prime need to ensure the successful, sustainable, and profitable fish production from aquaculture industry. Thus, the manufactured aqua-feeds should be assessed and evaluated by comparing the labeled information with those assessed in laboratory and at farm situation. Such comparisons are very useful and assist fish farmers to choose the right feeds as well as guide the manufacturers to produce feeds of required quality. Therefore, the present study was designed to assess the levels of heavy metals and nutritional composition in different fish feeds used in the commercial fish farms in Bangladesh to ensure aquaculture sustainability and the production of safe fish for human consumption.

Materials and Methods

Sample Collection

A total of 30 feed (nursery, hatchery, starter, grower, and finisher) samples manufactured by different feed companies were collected from feed dealers, retailers, and fish farms in Mymensingh, Rajshahi, Jashore, and Cumilla regions of Bangladesh. Proximate compositions of the collected feed samples declared by the companies were recorded by taking photograph of the labels on feed sac and leaflets and manuals supplied by the manufacturing companies. After collection of feed samples in polythene bags, the samples were kept at 4 °C temperature in a refrigerator and later were analyzed for proximate composition and heavy metals. The digestion and analysis were carried out in Fish Nutrition Laboratory and Interdisciplinary Institute for Food Security (IIFS) Laboratory of Bangladesh Agricultural University, Mymensingh, Bangladesh.

Heavy Metal Analysis

Electro-thermal Heater Digestion

Precisely 1 g from each feed sample was digested at 80 °C for 30 min in an electro-thermal heater (Model-VELP) after acid treatment with 10 ml of HNO_3 and 5 ml of $HClO_4$ solution. The digested samples were cooled and taken in a clean volumetric flask. Then, double distilled water was added up to 100 ml. Finally, Whatman Filter paper No. 42 was used to filter the solutions before keeping in sealed plastic bottles with proper labeling.

Blank Preparation

Using standard procedure, a blank containing same digestion inputs without sample was prepared to make sure that the impurity or contamination (if any) of chemicals used in the experiment did not bias the value. The value of blank found through the analysis by atomic absorption spectrophotometer (AAS) was subtracted from each of the sample value to get the true value.

Sample Analysis

In this study, a flame atomic absorption spectrophotometer (Model Shimadzu AA-7000) was used to determine heavy metal concentration where acetylene gas and air were used as fuel and oxidizer, respectively. Aspiration of the digested samples was performed using air acetylene flame. The concentrations of heavy metals were determined with the support of the standard curves. In this current study, the term BDL (below detectable limit) is defined as the limit (0.001 mg/kg) under which concentration of heavy metals cannot be determined by the flame atomic absorption spectrophotometer (Model Shimadzu AA-7000).

Proximate Composition Analysis

The collected samples were taken from the refrigerator and kept in room temperature for 1 h. The required amount of samples was finely ground by electric grinder and kept in an airtight container for subsequent analysis. The collected commercial feed samples were analyzed for proximate composition (moisture, crude protein, crude lipid, ash, crude fiber, and carbohydrate) according to standard procedures given by Association of Official Analytical Chemists (AOAC International) [28]. Triplicate samples of each commercial feed were used to determine the chemical compositions.

Data Processing

The data obtained in this finding were analyzed through the Microsoft Excel software (MS 2010).

Results

Heavy Metal Analysis

The heavy metal concentrations in the collected feed samples were analyzed in the laboratory (Table 1). The highest concentration of Pb (0.189±0.006 mg/kg) was found in finisher feed manufactured by Tongue. The highest concentration of Cd (0.027±0.004 mg/kg) was observed in Pangas floating starter from AIT and Pabda, Gulsha floating nursery from QFL. The highest concentration of Cr (1.023±0.003 mg/kg) was recorded in Koi, Catfish hatchery powder manufactured by PFL. Three more feeds, viz., Koi floating pre-starter by RBFL, Pangas floating starter by AIT, and Tilapia finisher by Tongue were also found to be in excess of Cr when compared with global and Bangladesh standard. The highest concentration of Cu was 0.303±0.004 mg/kg, which was found in Common floating nursery by NFL. The highest concentration of Zn (1.468±0.019 mg/kg) was found in Pangas floating starter by AIT.

Proximate Composition

The proximate composition, such as moisture, crude protein, crude lipid, ash, crude fiber, and carbohydrate, of the collected feed samples was analyzed in the laboratory. There were notable differences between the nutritive values provided by companies and the values analyzed in the laboratory (Table 2). Result obtained from the analysis showed the moisture content of starter, grower, finisher, and mixed feeds ranged between 9.56 and 13.38%, 10.55 and 14.80%, 12.25 and 13.53%, and 10.85 and 13.84%, respectively (Table 2). The crude protein content of the analyzed feeds varied between 16.37 and 40.77%. Most of the analyzed feed samples contained lower mean crude protein than the company declared values. The crude lipid contents were found to be between 4.80 and 7.80%. Ash content of the analyzed feeds ranged from 7.41 to 27.04%. In addition, there was a huge difference between the value provided by the manufacturers and analyzed value as most of the companies did not provide actual value for ash content (Table 2). The crude fiber contents of feeds varied between 4.34 and 7.80%. Fiber contents of different feeds from all companies under study were significantly higher than the company declared maximum values. The carbohydrate content varied between 22.91 and 41.73%. Most of the carbohydrate values analyzed in the lab were found to differ with the values reported by the manufacturers.

Discussion

Heavy Metal Analysis

Fish feed contamination resulted from various types of contaminant sources might cause transmission of these potential contaminants to the farmed fish and ultimately to the consumers. Among the contaminants, heavy metals are one of the most risky ones that transmit into fish through bioaccumulation process [14]. It is a matter of great concern that heavy metals entered into the food chains cause various types of complexities in human as they are highly toxic [16].

Lead (Pb)

Locally available low-quality ingredients are often contaminated with different harmful heavy metals like Pb. Nonetheless, the Pb concentrations in most of the analyzed feed samples were below than the maximum allowable limit [29] (Table 3). Shamshad et al. [31] reported that the average lead content in shrimp feed that is mostly used in Bangladesh was 3.58 mg/kg. As a heavy metal, Pb may hamper the normal functions of the kidney, liver, brain, and reproductive system as well as nervous system in human [32, 33]. It can cause renal failure and liver damage [34] upon consumption of Pb-contaminated foods, and prolonged exposure may lead to mental retardation, comma, and even death in a severe case [35].

Cadmium (Cd)

The highest concentration of Cd (0.027±0.004 mg/kg) was observed in Pangas floating starter from AIT and Pabda, Gulsha floating nursery from QFL. Shamshad et al. [31] reported that the average Cd content in shrimp feed used in Bangladesh was less than 0.1 mg/kg. Ikem and Egilla [36] reported the average concentration of Cd was 2.37 mg/kg in fish feed, which was double than the acceptable limit. The highest amount of Cd was detected in the liver and kidney of fish [37]. Cadmium exposure in rainbow trout, *Oncorhynchus mykiss*, resulted growth reduction as well as biochemical parameters alteration [38]. Long-term Cd exposure may obstruct the formation of bone [39] and result in

Table 1 Heavy metal concentrations (mg/kg) of different fish feeds of different companies

SL No.	Company name	Feed type	Heavy metals (mg/kg)				
			Pb	Cd	Cr	Cu	Zn
Starter							
1	MFL	Koi, Shing, Magur floating starter	0.006±0.001	0.016±0.002	BDL	0.021±0.002	0.074±0.002
2	MFL	Catfish floating starter	0.080±0.004	0.020±0.003	BDL	0.068±0.004	1.16±0.03
3	IAFF	Koi floating starter	0.032±0.00	0.019±0.002	BDL	0.128±0.003	1.178±0.003
4	RBFL	Koi floating pre- starter	0.06±0.021	0.023±0.002	0.082±0.002	0.042±0.002	0.698±0.003
5	QFL	Pabda, Gulsha floating starter	BDL	0.021±0.002	BDL	0.152±0.002	1.465±0.046
6	AIT	Pangas starter	BDL	0.019±0.003	BDL	0.045±0.003	0.785±0.024
7	AIT	Pangas floating starter	0.133±0.003	0.027±0.004	0.056±0.002	0.094±0.004	1.468±0.019
8	Tongue	Shing, Magur starter	0.080±0.003	0.021±0.003	BDL	0.040±0.003	1.110±0.01
9	IAG	Catfish pre-starter	BDL	0.019±0.003	BDL	0.059±0.003	0.701±0.012
Grower							
10	MFL	Tilapia floating grower	BDL	0.018±0.002	BDL	0.102±0.003	0.944±0.006
11	AIT	Pangas grower	0.096±0.002	0.023±0.002	BDL	0.058±0.002	0.749±0.008
12	IAG	Koi grower	0.112±0.004	0.021±0.001	BDL	0.061±0.001	1.003±0.003
13	QFL	Pangas grower	BDL	0.019±0.002	BDL	0.111±0.004	0.665±0.004
14	QFL	Tilapia floating grower	0.028±0.005	0.020±0.003	BDL	0.075±0.004	0.722±0.004
15	SMS	Tilapia floating grower	BDL	0.020±0.003	BDL	0.025±0.004	0.926±0.004
Finisher							
16	MFL	Pangas floating finisher	0.043±0.002	0.022±0.004	BDL	0.038±0.007	0.593±0.003
17	MFL	Golda finisher	0.091±0.004	0.021±0.003	BDL	0.082±0.002	0.102±0.002
18	Tongue	Tilapia finisher	0.189±0.006	0.023±0.002	0.768±0.006	0.073±0.002	0.702±0.003
19	BFL	Pangas finisher	BDL	0.018±0.004	0.039±0.005	0.036±0.005	0.751±0.004
Mixed							
20	MFL	Tilapia nursery and grower	BDL	0.023±0.003	BDL	0.076±0.004	0.748±0.004
21	Tongue	Catfish nursery	BDL	0.021±0.001	BDL	0.049±0.004	0.651±0.004
22	QFL	Pabda, Gulsha floating nursery	0.138±0.005	0.027±0.004	0.026±0.005	0.061±0.003	0.965±0.005
23	NFL	Common floating nursery	0.117±0.005	0.021±0.003	BDL	0.303±0.004	0.776±0.004
24	PFL	Koi, Catfish hatchery powder	BDL	0.020±0.003	1.023±0.003	0.041±0.004	0.766±0.007
25	QFL	Tilapia hatchery	0.048±0.006	0.021±0.005	BDL	0.038±0.006	0.920±0.003
26	RBFL	Tilapia floating	0.048±0.006	0.021±0.005	BDL	0.008±0.001	0.719±0.005
27	MFL	Catfish feed	0.129±0.005	0.023±0.003	0.033±0.003	0.012±0.002	0.684±0.004
28	DH	Floating grower	0.048±0.006	0.016±0.005	BDL	0.043±0.003	1.003±0.003
29	LF	Carp and mixed	BDL	0.018±0.004	BDL	0.024±0.003	0.802±0.005
30	SMS	Pangas feed	0.080±0.004	0.020±0.004	BDL	0.134±0.003	0.954±0.004

BDL below detection limit

hypertensions and tumors [40], and even cancer in urinary bladder [41]. Mortality of aquatic insects, crustaceans, and teleosts is due to the exposure of Cd concentrations of 0.8 to 9.9 ppb at 4 to 33 days, and mortality rate increased with the increase of exposure time [42].

Chromium (Cr)

A number of fish feeds were found to be with excess of chromium than either WHO standard, Bangladesh standard or both (Table 3). The highest concentration of Cr (1.023±0.003 mg/kg) was found in koi, catfish hatchery powder manufactured by PFL, which was about ten times higher than Bangladesh standard and more than twenty times higher than world standard [30]. Chromium is an essential nutrient that facilitates the action of insulin as well as assists the metabolism and storage of carbohydrate, fat, and protein [43]. Excessive level of Cr in fish feed may damage the kidneys, the liver, and blood cells through oxidation reactions [44, 45]. Moreover, high concentration of Cr in aquatic medium causes

Table 2 Proximate composition of different commercial fish feeds available in Bangladesh (% dry matter basis)

SL No.	Company name	Feed type	Proximate composition (%)					
			Moisture	Crude protein	Crude lipid	Ash	Crude fiber	Carbohydrate
Starter								
1	MFL	Koi, Shing, Magur floating starter	11.76±0.20 (12.00)	32.52±0.11 (30.00)	6.40±0.05 (3.00)	11.63±0.06 (18.00)	5.60±0.08 (6.00)	32.90±0.06 (37.00)
2	MFL	Catfish floating starter	12.61±0.08 (12.00)	33.19±0.05 (30.00)	7.30±0.04 (3.00)	11.79±0.07 (18.00)	5.29±0.04 (6.00)	29.82±0.09 (37.00)
3	IAFF	Koi floating starter	12.78±0.08 (11.00)	30.12±0.05 (33.00)	5.90±0.05 (7.00)	9.03±0.02 (18.00)	4.86±0.07 (6.00)	37.28±0.06 (28.00)
4	RBFL	Koi floating pre- starter	9.56±0.05 (11.00)	34.07±0.06 (33.00)	6.64±0.07 (8.00)	9.69±0.06 (12.00)	4.34±0.04 (5.00)	35.71±0.08 (28.00)
5	QFL	Pabda, Gulsha floating starter	9.88±0.06 (11.00)	35.53±0.06 (36.00)	6.45±0.04 (7.00)	9.40±0.05 (12.00)	4.43±0.03 (2.50)	34.31±0.06 (25.00)
6	AIT	Pangas starter	13.38±0.06 (12.00)	30.05±0.08 (28.00)	6.36±0.04 (7.00)	9.21±0.02 (21.00)	5.40±0.22 (7.00)	35.60±0.03 (33.00)
7	AIT	Pangas floating starter	12.12±0.04 (12.00)	31.92±0.04 (30.00)	6.56±0.04 (7.00)	9.66±0.03 (20.00)	5.64±0.02 (6.00)	34.10±0.03 (30.00)
8	Tongue	Shing, Magur starter	11.34±0.04 (12.00)	32.27±0.03 (30.00)	5.98±0.02 (7.00)	9.44±0.03 (20.00)	4.70±0.03 (6.00)	36.27±0.03 (30.00)
9	IAG	Catfish pre-starter	12.46±0.02 (11.00)	33.78±0.03 (35.00)	7.20±0.03 (8.00)	8.81±0.04 (17.00)	5.20±0.02 (4.00)	32.55±0.04 (26.00)
Grower								
10	MFL	Tilapia floating grower	11.66±0.04 (12.00)	30.29±0.05 (28.00)	7.26±0.02 (3.00)	11.05±0.02 (20.00)	4.40±0.02 (8.00)	35.34±0.05 (37.00)
11	AIT	Pangas grower	14.80±0.02 (12.00)	26.89±0.03 (25.00)	5.80±0.04 (6.00)	7.41±0.04 (13.00)	6.40±0.04 (8.00)	38.70±0.04 (37.00)
12	IAG	Koi grower	11.88±0.03 (11.00)	30.14±0.02 (32.00)	6.90±0.03 (6.00)	9.78±0.02 (19.00)	4.70±0.03 (-)	36.60±0.02 (34.00)
13	QFL	Pangas grower	15.69±0.02 (11.00)	26.02±0.03 (25.00)	6.20±0.03 (7.00)	9.50±0.02 (12.00)	6.90±0.02 (4.50)	35.69±0.03 (22.00)
14	QFL	Tilapia floating grower	10.55±0.03 (10.00)	28.16±0.03 (26.00)	5.88±0.04 (5.60)	7.98±0.03 (10.00)	5.70±0.04 (3.20)	41.73±0.02 (22.00)
15	SMS	Tilapia floating grower	12.07±0.03 (12.00)	31.77±0.04 (30.00)	5.95±0.04 (5.00)	10.90±0.03 (17.00)	4.90±0.03 (-)	34.41±0.03 (28.00)
Finisher								
16	MFL	Pangas floating finisher	12.25±0.04 (12.00)	27.19±0.02 (28.00)	6.20±0.03 (3.00)	10.95±0.04 (22.00)	6.70±0.03 (9.00)	36.71±0.02 (39.00)
17	MFL	Golda finisher	13.50±0.02 (12.00)	30.20±0.04 (38.00)	7.40±0.04 (5.00)	11.96±0.03 (-)	4.80±0.02 (5.00)	32.14±0.02 (-)
18	Tongue	Tilapia finisher	12.77±0.03 (12.00)	28.57±0.03 (25.00)	7.80±0.03 (5.00)	9.42±0.02 (22.00)	5.80±0.03 (9.00)	35.64±0.04 (40.00)
19	BFL	Pangas finisher	13.53±0.04 (12.00)	26.07±0.03 (25.00)	5.77±0.03 (4.00)	9.42±0.01 (-)	6.90±0.03 (8.00)	38.31±0.03 (-)
Mixed								
20	MFL	Tilapia nursery and grower	13.69±0.03 (12.00)	39.44±0.03 (35.00)	6.40±0.03 (6.00)	13.76±0.03 (16.00)	3.80±0.03 (5.00)	22.91±0.04 (31.00)

Table 2 (continued)

SL No.	Company name	Feed type	Proximate composition (%)					
			Moisture	Crude protein	Crude lipid	Ash	Crude fiber	Carbohydrate
21	Tongue	Catfish nursery	10.85±0.04 (12.00)	38.90±0.03 (35.00)	6.40±0.03 (8.00)	11.66±0.03 (18.00)	4.40±0.04 (5.00)	27.79±0.03 (26.00)
22	QFL	Pabda, Gulsha floating nursery	11.64±0.03 (11.00)	40.32±0.02 (40.00)	6.36±0.04 (8.00)	8.88±0.03 (10.00)	4.20±0.04 (3.00)	28.60±0.04 (20.00)
23	NFL	Common floating nursery	13.11±0.02 (12.00)	38.00±0.02 (33.00)	6.66±0.04 (4.00)	14.57±0.03 (8.00)	4.60±0.04 (-)	23.06±0.03 (-)
24	PFL	Koi, Catfish hatchery powder	12.19±0.02 (10.00)	33.07±0.02 (35.00)	5.70±0.04 (5.00)	14.29±0.03 (-)	6.26±0.04 (2.00)	28.49±0.04 (-)
25	QFL	Tilapia hatchery	12.41±0.02 (10.00)	40.77±0.03 (35.00)	6.35±0.03 (8.00)	12.73±0.02 (10.00)	4.80±0.04 (3.50)	22.94±0.03 (-)
26	RBFL	Tilapia floating	10.67±0.02 (11.00)	30.36±0.04 (28.00)	6.44±0.02 (5.00)	9.94±0.02 (4.00)	4.90±0.03 (9.00)	37.69±0.02 (38.00)
27	MFL	Catfish feed	12.76±0.04 (12.00)	31.33±0.03 (32.00)	5.90±0.03 (3.00)	12.23±0.02 (-)	5.80±0.03 (10.00)	31.98±0.03 (-)
28	DH	Floating grower	12.34±0.02 (11.00)	37.13±0.03 (35.00)	6.73±0.02 (6.00)	9.33±0.03 (16.00)	5.60±0.03 (5.00)	28.90±0.03 (-)
29	LF	Carp and mixed	13.25±0.03 (10.00)	16.37±0.04 (20.00)	4.80±0.03 (4.00)	27.04±0.02 (21.00)	7.80±0.03 (6.00)	30.74±0.03 (25.00)
30	SMS	Pangas feed	13.84±0.02 (10.00)	30.36±0.04 (32.00)	6.20±0.04 (5.00)	15.45±0.03 (17.00)	5.20±0.04 (6.00)	28.95±0.02 (-)

Figures in the parentheses indicate the proximate composition declared by the company

Table 3 Standard safety level of heavy metals (mg/kg)

Metals	World standard (mg/kg)	References	Bangladesh standard (mg/kg) Fish and Animal Feed Act 2011, Bangladesh
Pb	2.00	[29]	0.30
Cd	1.00	[29]	0.05
Cr	0.05	[30]	0.10
Cu	10.00	[29]	5.00
Zn	150.00	[29]	50.00

various cellular as well nuclear abnormalities in fish erythrocytes [46]. Ikem and Egilla [36] reported that the average concentration of Cr was 1.42 mg/kg in diet (dry weight) of fish feed. Cr has carcinogenic effects on human and uptake in human body for a long time can cause disruption of cellular integrity and functions by damaging protein and lipid membrane [47, 48].

Copper (Cu)

Copper is an essential part of several enzymes and necessary for hemoglobin synthesis. However, excessive amount of Cu can be toxic to fish, invertebrates, and amphibians. Cu has potential to be bio-accumulated in various organs of fish and molluscs [49]. Wide range of abnormalities including cirrhosis, necrosis, gastrointestinal problems, and low blood pressure as well as fetal mortality may be resulted from Cu toxicity [50].

Zinc (Zn)

Zn plays an essential role in ensuring the normal growth and metabolism of animals. The amount of Zn present in all the fish feed examined is far below than the world standard of 150 mg/kg set by WHO [29] and Bangladesh standard of 50 mg/kg as set in Fish and Animal Feed Act 2011, Bangladesh (Table 3). Low level of Zn may accelerate the metabolic process of fish in favor of the growth [51]. Zn deficiency has been observed in farmed fish and shellfish and caused slow growth, cataracts, skeletal abnormalities, and much reduced activity of various Zn metalloenzymes [51]. On the other hand, Zn causes toxicity when exceeds the physiological requirements that may result in growth retardation, general enfeeblement, and pathological as well as metabolic changes in fish [52]. Moreover, higher level of Zn may cause reduced growth as well as may alter the serum biochemical parameters in fish [53]. Nonetheless, all the feeds analyzed in this study were found with much less Zn level than both the World and Bangladesh standard.

Proximate Composition

Proper supplementation of nutrients is essential for optimum growth, health, and reproduction of fish and other aquatic animals both in terms of quantity and quality. Therefore, supply of feeds and fertilizers in right quantity and quality needs to be ensured to guarantee the optimum nutrients and energy requirements of the species and the production goals of the system are attained [54].

Protein is the major growth-promoting factor in feed. The protein requirement of fish is influenced by various factors such as fish size, water temperature, feeding rate, availability and quality of natural foods, and overall digestible energy content of diet [55, 56]. Most of the analyzed feed samples contained lower mean crude protein which might be due to the use of low-quality ingredients as protein sources for the preparation of fish feeds. A number of feeds analyzed in the present study were found to be with lower protein contents than written on the feed bags and on the folders/leaflets provided by the manufacturers. The more alarming is many feed contained lesser percentages of protein level than what is required by the standard feeds for different fish/fish group at different life stages, as set in the Fish and Animal Feed Act 2011, Bangladesh. Higher level of non-protein nitrogenous substances (NPN) in fish feeds might also cause lower mean crude protein content in the fish feeds. Wilson [56] reported that most of the commercial catfish feeds contain 32% crude protein. Increased and profitable production of catfish was achieved through the use of high amounts of protein (35% or more) in their diet [57]. The optimum ranges of protein for carp culture reported by Sen et al. [58] and Mohanty et al. [59] were 35–45% and 40%, respectively. Optimum dietary protein for rohu broodstock was 25% that resulted best reproductive performance [60]. According to Mohanty and Kaushik [61], optimum protein level for rohu cultivation under pond condition was 25–30%. Carp spawn, fry and grow-out fish, and broodstock need a protein requirement of 25–35% [62].

Similarly, differences were found between the analyzed and company-declared crude lipid values, even though the differences were not significant. According to Hasan [54], lipids are primarily used in the formulated feed as a source of energy to maximize protein sparing effect of feed. Wilson [56] reported that lipid level in catfish diet should be 5 to 6%. Luquet [63] stated that dietary lipid levels of 5 to 6% are often used in tilapia diet. Dietary phospholipids (PL), particularly phosphatidyl choline, are required for growth and survival of fish larvae [64, 65]. Optimum dietary lipid requirement for rohu fish was reported 9% [66] and 8% [67]. About 7.5% was the optimal lipid requirement for mrigal fry [68]. Carp feeds require a crude lipid of 8% for spawn and fry, and 6% for the grow-out and broodstock [62]. Not only is the analyzed crude lipid content of a number of analyzed fish feeds lower than the company-declared crude lipid content, but it was also found to be with lower level than the requirement according to Fish and Animal Feed Act 2011, Bangladesh.

Ash as minerals plays significant role as a nutrient in fish diet [69, 70]. Mrigal and rohu fingerlings need calcium and phosphorus requirement of 0.19% and 0.75%, respectively [71, 72]. Dietary phosphorus deficiency causes various organ-specific abnormalities in catla [73]. Meena et al. [74] reported that rohu fingerlings require 30 mg Zn/kg of feed. Crude fiber provides physical bulk to the feed. Certain amount of fiber in feed helps in better binding and plays an important role in the easy passage of feed through alimentary canal. High dietary fiber may reduce the digestibility as well as efficiency of nutrients, but low dietary level of fiber may be beneficial for the growth of fish [75]. The requirements of crude fiber for carp feeds are 6% for spawn and 8% for fry, grow-out, and broodstock feed [62]. Nonetheless, excessive fiber content results lower digestibility of nutrients. Feed containing more than 8–12% fiber content is undesirable for fish because it would result in the decrease of the quality of a usable nutrient in the feed [76]. Growth performance and nutrient digestibility of Sharpsnout sea bream were found to be unaffected by the addition of fiber up to 5% in diet [77]. Growth performance of gilthead sea bream was not affected with the addition of fiber in the diet up to 18% [78]. In the present study, the analyzed crude fiber content of all the feeds was within the safe dietary limit for fish. Thus, the fiber content of these feeds may not have any negative effects on fish.

Carbohydrate is considered an important component of feed, which has protein sparing effect. The activities of supplying energy by essential carbohydrates seem to have an overall beneficial effect in terms of improving growth and protein utilization of most shrimp and prawn as well as fish. Optimum growth of carp spawn, fry, and fingerlings was observed at 26% carbohydrate supplementation [58]. Carps and catfish can tolerate higher level of carbohydrate supplementation in their diet [79]. Diet containing 45% gelatinized carbohydrate was efficiently utilized by rohu, *Labeo rohita* [79].

Conclusion

The results of the present study revealed that feeds analyzed contained a number of heavy metals in varying proportions with potential to predispose farmed fish to assimilation of toxic heavy metals. The nutritional compositions of the feeds are not similar with the company-provided values. In order to continue sustainable aquaculture production and to ensure safe fish for human consumption, regular monitoring of the fish feed for their nutritional value as well as assessment of heavy metal contents by the nominated authorities at the local government, state, and national levels is the need of time. It is recommended that adequate measures should be taken by fish feed manufacturers to ensure the nutritional quality of feed as well as to avoid contamination of the feeds from heavy metals. On the other hand, supplementation of the essential heavy metals to satisfy the requirement of fish specially zinc in quality and level that synchronizes their bio-availability and assimilation to prevent the absorption of toxic heavy must be ensured. There is also a need to enforce compliance and sanctions to the defaulters when and if the limits set by the government are not maintained. Regular trainings and awareness building program should be arranged for the feed ingredient providers, feed manufacturers, technicians, dealers, farmers, and hatchery owners on the importance of safe and quality feed, proper handling, packaging, transport, and storage. These measures would be useful to gradually reduce the level of toxic heavy metals in the feed ingredients, the consuming fish and human, the ultimate consumer.

Author Contribution Md Murad Sarkar performed the experiments and collected data. Md Fazle Rohani drafted the manuscript. Mostafa Ali Reza Hossain assisted in data analysis and edited the manuscript. Md Shahjahan assisted in the experimental design and edited the manuscript. All authors reviewed and approved the final manuscript.

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Data Availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Declarations

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