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Comparative Effects of Household and Manufactured Feeds on Heavy Metal Accumulation and Proximate Composition in *Labeo rohita* and *Oreochromis niloticus* under Tank Conditions

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This research evaluated the effects of household versus manufactured feeds on heavy metal accumulation and proximate composition in *Labeo rohita* and *Oreochromis niloticus* in controlled tank environments. Fish were raised under three feeding regimes: household feed, manufactured feed, and a control group. Analysis of heavy metals revealed that *L. rohita* receiving manufactured feed had the highest levels of chromium (8.464 mg/kg in muscle), cadmium (0.949 mg/kg in

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viscera), and lead (0.411 mg/kg in viscera), compared to the household-fed and control groups. In *O. niloticus*, elevated cadmium (Cd) and lead (Pb) levels were observed in fish-fed manufactured diets, whereas chromium levels were relatively lower. The findings indicate that manufactured feeds may increase the risk of heavy metal accumulation. Proximate composition analysis showed that *L. rohita* fed manufactured feed exhibited the highest crude protein (15.92%) and ash (5.23%) content, whereas household feed produced moderate protein levels (15.73%) and slightly elevated lipid content. In *O. niloticus*, household feed increased lipid content (3.11%) while slightly decreasing protein levels (14.33%) in comparison to manufactured feed (14.99%). The control group exhibited a higher moisture content for both species. These results highlight the significance of choosing safe and balanced feed formulations for sustainable aquaculture techniques by pointing to a trade-off between nutritional advantages and possible contamination hazards.

Keywords: Manufactured feed; household feed; heavy metals; proximate composition; Labeo rohita; Oreochromis niloticus.

1. INTRODUCTION

In Bangladesh, the fisheries and aquaculture sector is one of the major components of agricultural activities, playing a crucial role in economic development by ensuring food security and stimulating the growth of several subsidiary industries. Bangladesh holds the distinguished position of being the third-largest producer of inland fish worldwide, having attained self-sufficiency in its fisheries sector (DoF, 2023). Aquaculture plays a significant role, accounting for 57.39% of total production and providing approximately 60% of the country's animal protein consumption, which averages 62.5 grams per capita per day (DoF, 2023; Samanta *et al.* 2024). Nutrition and feed management are regarded as the most important elements determining aquaculture output and quality. Feed not only influences the development and health of cultured species, but it also determines the quality and safety of fish for human consumption.

The most important aquafarming methods in Bangladesh include polyculture (Extensive, semi-intensive, and intensive) and/or monoculture of several fish species, including shrimp, tilapia, exotic carp, prawns, and exotic carp (Rahman *et al.,* 2021). After pangas, tilapia (*Oreochromis niloticus*) is the third most noticeable fish species in Bangladesh, while rohu (*Labeo rohita*) is the second most common (Rahman *et al*., 2021) for their high market demand, fast growth, and adaptability to various culture systems. Both species are often raised in semi-intensive and intensive systems in Bangladesh, frequently using feed inputs that are produced domestically or manufactured.

However, Aquaculture is strongly reliant on formulated feed, and nowadays, environmental pollution and chemical contamination in fish feed have become a worldwide issue. Heavy metals, a significant contaminant, are particularly concerning due to their propensity for bioaccumulation in fish muscle, their capacity to traverse the food chain, and their poisonous characteristics (Maule *et al*., 2007; Sen *et al*., 2011). Fatih *et a*l. (2012) indicate that all fish meals contain measurable quantities of various pollutants. Research indicates that fish and shellfish sourced from commercial aquaculture are polluted with heavy metals in variable degrees (Burger & Gochfeld, 2005). Commercial aquafeeds available in Bangladesh have been found to contain detectable levels of toxic metals like chromium (Cr), cadmium (Cd), and lead (Pb), often exceeding safe limits and posing serious health risks through accumulation in fish tissues consumed by humans.

Rapid population growth in recent years has led to a rising global demand for protein sources (Fazio et al., 2023). Fish is an excellent source of protein, which helps improve blood quality, strengthen the immune system, and accelerate muscle tissue regeneration (Khan *et al*., 2025). In order to meet the demand, the aqua farm is increasing and is highly dependent on fish feed. High-quality, balanced feeds are essential for the sustainable development and viability of the successful and profitable fish production sector. Moreover, the quality of fish feed significantly influences water quality, growth rates, and the overall profitability of aquaculture farms, potentially impacting the sustainability of this essential sector (Sarkar *et al*., 2022).

Given the increasing reliance on aquaculture to meet protein demands, feed quality has become a critical factor influencing both the nutritional value and safety of cultured fish. While household feeds are often used for cost-

effectiveness, their composition and contamination levels remain largely unregulated. Manufactured feeds, though standardized, may also carry risks of toxic metal contamination. Therefore, a comparative assessment of these two feed types is essential to ensure safe and sustainable aquaculture practices. This study aims to fill that gap by evaluating the effects of household and manufactured feeds on the nutritional composition and heavy metal accumulation in two economically important fish species—*Labeo rohita* and *Oreochromis niloticus*. The findings are expected to guide feed selection for fish farmers and inform policy decisions to enhance fish quality and consumer health safety.

2. MATERIALS AND METHODS

2.1 Sample Collection

The study was conducted during the period November 2018 to May 2019 for *Labeo rohita* H and April 2019 to August 2019 for *Oreochromis niloticus* L. During the study period, the fingerlings of both specimens were collected from different nursery ponds of Rajshahi. The collected specimens were transported in a plastic container from the nursery pond to the field laboratory of the Department of Zoology, University of Rajshahi.

2.2 Experimental setup

2.2.1 Tank preparation

The feeding experiments were carried out in distinct tanks designated for each category of household and manufactured feed. The tanks were constructed from bricks and cement. The dimensions of each tank were 2.5 feet in length, 2.5 feet in width, and 1.75 feet in height. Tap water was the primary source of water supply for the tanks. Proper arrangements were meticulously established to guarantee sufficient oxygenation through the utilization of an electric air pump apparatus.

2.2.2 Diets and mode of feeding

This study utilized three distinct household feed mixtures alongside one commercially manufactured feed. The preparations for the household feeds involved the utilization of mustard oil cake, maize flour, wheat flour, and dried fish powder (Table 1). All components were procured from Saheb Bazar in Rajshahi, with except the dried fish powder, which was meticulously prepared by the researchers utilizing locally sourced *Puntius* sp., sun-dried, and subsequently crushed with an electric blender. All components were meticulously crushed to a fine powder prior to the pelleting process. Pellets were administered bi-daily, specifically in the morning and evening.

2.3 Chemical Analysis for Heavy Metal Detection

Samples of fish bodies were subjected to a drying process in an incubator (GALLENKAMP, Model: OH7050XX205) for a duration of 24 hours. The dried samples underwent digestion in 5 mL of HNO_3 and 2 mL of H_2O_2 utilizing a microwave oven (Butterfly, Eco+) for a duration of two minutes, adhering to the methodology outlined by Kabir *et al*. (2016) with minor adjustments. The feed samples, having been thoroughly dried, underwent direct digestion utilizing HNO_3 and H_2O_2. Upon cooling, the digested mixtures underwent filtration utilizing Whatman No. 42 filter paper, followed by a thorough rinsing with distilled water. The samples underwent analysis for heavy metals, specifically cadmium (Cd), chromium (Cr), and lead (Pb), utilizing an Atomic Absorption Spectrophotometer (AA-6800, SHIMADZU, Japan) at the Central Science Laboratory, University of Rajshahi, Bangladesh.

2.4 Proximate Composition analysis

Dried feed pellets and frozen whole fish samples were submitted to the Department of Aquaculture Laboratory, Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh, to analyze the proximate composition of various feeds and studied fish. Finely ground powder samples were used to assess the proximate composition, which includes moisture, ash, crude protein, crude fat, carbohydrate, and energy value, following standard protocols described by AOAC (1970) and supported by other researches (Khan *et al.,* 2024; Khan *et al*., 2025). The moisture content was determined by oven-drying the samples at 105°C until a consistent weight was reached. Samples were burned for six hours at 550°C in a muffle furnace to estimate the ash present. The Kjeldahl technique was used to test crude protein, and a Soxhlet extraction device using petroleum ether as the solvent was used to assess crude fat. Acid and alkali digestion were used in order to determine the crude fiber content. The difference was used to compute the carbohydrate content.

Table 1. Feed ingredients, heavy metal concentrations, and proximate composition of different feeds used in this study

Feed Type	Used Materials	Heavy Metals (mg/kg)			Proximate Composition (%)					
		Cr	Cd	Pb	Dry Matter	Crude Lipid	Crude Protein	Ash	Crude Fiber	Carbohydrate
Type-1	A mixture of maize flour 70% and mustard oil cake 30%	0.782	0.155	3.452	88.63	5.77	20.06	6.23	8.35	59.60
Type-2	A mixture of wheat flour 60% and mustard oil cake 40%	0.550	0.117	5.101	88.54	6.37	20.24	8.04	7.77	57.58
Type-3	A mixture of wheat flour 50%, mustard oil cake 20% and dried fish powder 30%	0.763	0.019	0.772	87.36	6.98	26.49	6.90	7.51	52.12
Type-4	Manufactured feed (Pellet)	1.673	0.265	8.698	86.92	6.79	26.01	9.56	7.67	49.97

2.5 Water Quality Monitoring

Water was supplied to the tanks for fish cultivation using submersible pumps. To analyze various physicochemical parameters, water samples were collected twice monthly at approximately 11:00 AM. A Celsius thermometer was employed to measure the atmospheric and water temperature. The pH of the water was measured using a digital pH meter (HANNA HI-98107), and the dissolved oxygen (DO) levels were determined using a digital DO meter (Lutron DO-5509). The average atmospheric temperature during the research period spanned from 12°C to 36°C, while the water temperature fluctuated between 10°C and 33°C. The pH values ranged from 6.92 to 7.15, and the dissolved oxygen levels were between 5.88 and 6.75 mg/L.

2.6 Data Analysis

A one-way ANOVA was employed to ascertain differences among the feeds on fish species, utilizing a significance threshold of $P < 0.05$. The statistical analysis was conducted utilizing Microsoft Excel version 2013.

3. RESULTS AND DISCUSSION

In our preceding study, "Growth performance of *Labeo rohita* H. and *Oreochromis niloticus* L. with varieties of household feeds under tank condition (Islam and Sultana 2019)," we evaluated three distinct household feeds. Notably, household feed Type 3 exhibited the most favorable results regarding growth performance, feed conversion ratio, and the overall health status of the fish. In light of its exceptional outcomes, Type 3 was chosen as the representative household feed for the current investigation. This methodology provided a more pragmatic and market-oriented viewpoint by assessing the efficacy of the most advantageous household feed in comparison to a widely utilized manufactured feed.

3.1 Heavy Metal Accumulation in Fish Tissues

Various factors influence the bioaccumulation of heavy metals in fish, such as feeding habits, water temperature, pH, salinity, metal interactions, sediment, feed, gender, and age. The concentrations of Chromium (Cr), Cadmium (Cd), and Lead (Pb) in *Labeo rohita* and *Oreochromis niloticus* exhibited significant variation depending on the type of feed and the specific tissue analyzed.

(Table 2). In *L. rohita*, the muscle of fish that were fed manufactured feed exhibited the highest concentration of Cr at 8.464 mg/kg, whereas the control fish displayed the lowest concentration at 1.141 mg/kg. Cadmium (Cd) concentrations reached their zenith in the internal organs of the control fish, measuring 3.160 mg/kg, a figure that is markedly elevated compared to the 0.116 mg/kg observed in fish that were nourished with household feed.

High levels of lead (Pb) in fish tissue have the potential to harm human health if ingested through food. Fish contaminated with Pb can have adverse effects on a person's liver, brain, nervous system, kidneys, and reproductive system. Lead (Pb) concentrations were observed to be comparatively low across all treatments; however, they were marginally elevated in the viscera of fish treated with manufactured feed (0.411 mg/kg) and in the control group (0.422 mg/kg). Comparably, *O. niloticus* exhibited the highest concentrations of chromium (2.228 mg/kg) and cadmium (2.375 mg/kg) within the viscera of specimens that were provided with manufactured feed. The control fish muscle exhibited the lowest concentrations of Cr and Pb, recorded at 0.620 mg/kg and 0.095 mg/kg, respectively, suggesting a relatively negligible accumulation of these metals in the absence of supplemental feeding. Following the administration of various commercial fish feeds, Saha et al. (2021) reported the accumulation of several heavy metals in *L. rohita*, including Pb (4.74 mg/kg), Cd (1.02 mg/kg), and Cr (5.49 mg/kg), as well as in *O. niloticus*, with concentrations of Pb (8.03 mg/kg), Cd (1.35 mg/kg), and Cr (8.03 mg/kg). Resma et al. (2020) discovered that commercially farmed *L. rohita* had the greatest chromium (Cr) content (0.623 ± 0.06 mg/kg dry weight), followed by *Tilapia nilotica* (0.590 ± 0.05 mg/kg), whereas cadmium (Cd) concentrations exhibited the reverse trend. *T. nilotica* (0.004 ± 0.000 mg/kg) exceeds *L. rohita* (0.0035 ± 0.000 mg/kg).

In general, fish that were provided with manufactured feed exhibited a propensity to accumulate elevated concentrations of heavy metals, particularly chromium and cadmium, which may be attributable to the components or additives present in commercial formulations. This is consistent with findings by Saha et al. (2018) and Kundu et al. (2017), who discovered that commercial feeds in Bangladesh often include high levels of Cd, Pb, and Cr. Viscera samples consistently exhibited elevated metal concentrations compared to muscle tissues, underscoring the liver and digestive tract's function in the processing and storage of metals.

Table 2. Heavy metal concentrations detected in cultured fish under different feed treatments

Specimen	Sl. No.	Sample description	Cr (mg/kg)	Cd (mg/kg)	Pb (mg/kg)
Labeo rohita	1	Manufactured feed (muscle)	8.464	0.800	0.125
	2	Manufactured feed (viscera)	8.038	0.949	0.411
	3	Household feed (muscle)	5.072	0.340	0.156
	4	Household feed (viscera)	5.093	0.116	0.080
	5	Control/without feed (muscle)	1.141	3.160	0.422
	6	Control/without feed (viscera)	1.683	1.732	0.354
Oreochromis niloticus	7	Manufactured feed (muscle)	1.657	1.987	0.417
	8	Manufactured feed (viscera)	2.228	2.375	0.192
	9	Household feed (muscle)	1.513	2.080	0.437
	10	Household feed (viscera)	1.040	1.546	0.132
	11	Control/without feed (muscle)	0.620	0.971	0.095
	12	Control/without feed (viscera)	0.683	1.033	0.130

Table 3. Proximate Composition analysis after rearing of fishes using different feeds (% Wet basis)

Fish species	Sample type	Moisture %	Crude Lipid %	Crude protein %	Ash %	Crude Fiber %	Carbohydrate %
Labeo rohita	control	75.26	1.86	14.66	4.18	1.16	2.88
	Household feed	74.74	2.44	15.73	4.53	1.23	1.33
	Manufactured feed	71.81	2.48	15.92	5.23	1.18	3.38
Oreochromis niloticus	control	72.65	2.33	15.10	4.17	1.23	4.52
	Household feed	75.70	3.11	14.33	4.80	1.55	0.51
	Manufactured feed	74.55	2.10	14.99	5.43	1.22	1.71

3.2 Proximate Composition

The proximate composition of *Labeo rohita* and *Oreochromis niloticus* exhibited significant differences contingent upon the type of feed utilized. In *L. rohita*, the most elevated crude protein content (15.92%) was recorded in specimens nourished with manufactured feed, with household feed (15.73%) and the control group (14.66%) following closely behind (Table 3). Comparably, *O. niloticus* exhibited a fairly consistent protein range (14.33–15.10%), with the control group demonstrating marginally elevated protein levels compared to the household-fed group. The moisture content exhibited a slight elevation in household-fed *O. niloticus*, recorded at 75.70%, in contrast to those receiving manufactured feed at 74.55%, and the control group at 72.65%. Conversely, *L. rohita*, which was provided with manufactured feed, demonstrated the lowest moisture content at 71.81%. The highest crude lipid levels were observed in household-fed *O. niloticus* at 3.11% and in manufactured-fed *L. rohita* at 2.48%, suggesting a direct correlation between feed formulation and fat deposition. The ash content was observed to be comparatively elevated in fish provided with manufactured feeds, specifically recorded at 5.23% for *L. rohita* and 5.43% for *O. niloticus* (Table 3). The levels of crude fiber were consistently low across all groups, remaining below 1.6%. Notably, household-fed *O. niloticus* exhibited a slightly elevated value of 1.55%, while *L. rohita* recorded 1.23%. This increase can likely be attributed to the presence of indigestible plant matter in the household feed. The carbohydrate content exhibited significant variation, with *O. niloticus* demonstrating the highest level in the control group at 4.52%, while the lowest was recorded in household feed at 0.51%. Conversely, *L. rohita* exhibited elevated carbohydrate levels when provided with manufactured feed, registering at 3.38%. Suwannatrai *et al.* (2023) delineated the proximate composition of *Oreochromis niloticus*, revealing a moisture content of 80.57%, crude protein at 14.27%, crude fat at 2.44%, ash at 1.01%, crude fiber at 1.06%, and carbohydrate at 0.60%. According to Ullah *et al.* (2022), *Oreochromis mossambicus* had moisture 77.61%, protein 18.73%, fat 1.91%, ash 1.04%, and carbohydrate 0.13%, while *L. rohita* had moisture 77.35%, protein 18.41%, fat 3.03%, and ash 1.04%. Abbas *et al*. (2023), *L. rohita* fed with various commercial diets had protein levels of 16.29-17.47%, lipids of 3.13-4.02%, and ash of 2.79-3.82%.

Overall, manufactured feed increased muscle protein and fat deposition in *L. rohita* while decreasing moisture and ash, which is comparable with results seen in *O. niloticus* on high-energy diets. This demonstrates that meal design and raising circumstances are important factors influencing fish muscle composition and nutritional quality.

4. CONCLUSION

The research demonstrated that the use of manufactured feeds significantly improved the proximate composition of *Labeo rohita* and *Oreochromis niloticus*, notably elevating their protein and lipid levels. Nonetheless, these feeds resulted in an increased accumulation of chromium and Cadmium. Conversely, household feeds yielded a marginally diminished nutritional quality while simultaneously presenting a relatively lower metal load. The results underscore the importance of harmonizing nutritional advantages with possible toxicological hazards in the selection of feed for sustainable aquaculture practices.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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