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Proximate analysis of local ingredients as a prospective resource for feed production in Bangladesh

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Abstract. The proximate composition of local feedstuffs cost-effective for livestock and aqua feed formulation and production is mainly unidentified among different farming stakeholders. This study was conducted to investigate the proximate analysis and the market price of 230 samples of 18 different local ingredients collected from various areas in Bangladesh. Among the assessed energy and protein sources local ingredients, all the proximate components were statistically significant ($P \leq 0.05$). The broken rice had higher moisture, crude protein, ether extract, and nitrogen-free extract content in the energy source ingredients. In contrast, B-grade rice polish had a high crude fiber content (20.12±2.26%) and ash (18.76±1.27%). Animal-based protein sources ingredients, such as shrimp meal (16.33±0.99% moisture), fish meal (57.80±1.26% crude protein), mixed dry fish (22.91±1.49% crude fiber and 31.17±1.36% ash), crab shell (40.57±1.28% nitrogen-free extract), and plant-based full-fat soybean (18.57±1.03% ether extract) comprised the considerable proportion of proximate components. For per-unit protein cost, soybean meal was a cheaper protein source followed by mustard oil cake, full-fat soybean, and sesame oil cake, while the fish meal was found as an expensive protein source ingredient. This research revealed that local ingredients could be utilized for livestock and aqua farming to produce cost-effective, high-quality feeds.

Key words: Local ingredients, proximate composition, market price, livestock and aquafeeds

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1. Introduction

The livestock and fisheries subsectors are growing at a rising pace, 9.32% and 11.05%, respectively, in the fiscal year of 2018-19, to satisfy the increasing demand for high-quality animal proteins (BBS, 2020). With the growing demand for animal protein, livestock and fish farming systems are intensifying (McDermott et al., 2010), resulting in the eventual expansion of Bangladesh's livestock and aqua feeds market. Feed accounts for the highest portion of production cost for livestock and aquafarming, about 70% and 40-60%, respectively (Thirumalaisamy et al., 2016; Agboola et al., 2019). Among all the feed ingredients utilized in feed production, protein-rich items are the most costly (Glencross et al., 2007). The utilization of exclusive protein-rich ingredients nowadays makes farming expensive and non-profitable worldwide. Utilizing local ingredients can increase economic efficiency by relieving the urge to import components, positively affecting market demand (Abbasi et al., 2015; Kasapidou et al., 2015; Stein et al., 2016).

Local low-quality agricultural products and by-products could be used as feedstuffs to produce high-quality animal protein to boost protein availability for human consumption (Henchion et al., 2017). Therefore, instead of expensive feed, it is essential to use nutrient-rich feed formulated using local ingredients to cut back expenditures in farming. Lower production expenditures, easier to satisfy protein needs, improving food security, and reducing poverty levels in developing countries will be other consequences. It is therefore essential to spot inexpensive and local feedstuffs since the long-term growth of the farming system depends on the utilization of local ingredients. Moreover, the proximate composition of used elements indicates the quality of produced feeds (Li et al., 2006; Glencross et al., 2007).

As an agriculture-based country, there are varieties of agricultural products and by-products available that are typically not used for human consumption but have a high potential for small-scale and commercial farming in Bangladesh. The existence of a good range of anti-nutritional substances often restricts the utilization of plants or plant-derived ingredients in the production of livestock and aquafeeds. However, some anti-nutritional variables are easy to get rid of through processing; others could also be harder to eliminate (Jaybhaye and Srivastav, 2015; Handa et al., 2017). Nutritionists and feed producers have based their studies so far on evaluating which of the broad range of ingredients available to the livestock and fish feed industries are often accustomed to producing low-cost diets. However, Bangladesh has inadequate data on the proximate composition of the profit-making ingredients for feed production (Kamal et al., 2020). This study investigated the proximate composition of local feed ingredients and retail prices for formulating and producing aqua and livestock feed in Bangladesh. Feed development involves evaluating the proximate composition of available ingredients and price inferences.

2. Materials and Methods

2.1. Sample collection and preparation

Total 230 samples of 18 different local feed ingredients were collected from various sources like feed ingredient suppliers, retailers, producers, and feed mills, along with retail prices from Gazipur, Mymensingh, Chuadanga, Narayanganj, Rajshahi, Natore, Bogura, Dinajpur, Kurigram, and Chattogram districts during the study period from June to November 2020. Samples were collected in bulk quantity from different lots, and the quartering method was followed for ingredient sample collection, as Jacobs (1973) and Lovell (1975) stated. The grounded samples were sieved through a 60 μm mesh size sieve following grinding by an electric grinder. Later, the samples were stored in dry and air-tight containers until analysis.

2.2. Analysis of proximate composition

For the proximate analysis viz. moisture, crude protein, ether extracts, crude fiber, total ash, and nitrogen-free extract of the ingredient samples, all the ingredients were first classified as energy sources and protein sources according to Li and Robinson (2013). They stated that ingredients containing less than 20% protein are considered energy source ingredients more willingly than protein sources. The quality control laboratory facilities of Lion Feeds Limited, Gazipur, Bangladesh, were used. The triplicate analysis in a completely randomized design (CRD) was carried out for each sample to determine the proximate compositions.

Moisture (M): The oven method (Shreve et al., 2006) was followed for the moisture content determination of the ingredient samples. All the samples were dried at 105 °C for 3 h. The moisture content was calculated as:

$$\text{Moisture (\%)} = \frac{\text{weight of fresh sample - the weight of the dried sample}}{\text{weight of the fresh sample}} \times 100$$

Crude protein (CP): The Micro Kjeldahl (AOAC, 2005) method was used to determine the Nitrogen (N) of the ingredient samples. The following equation determines n content of ingredients:

$$\text{N (\%)} = \frac{\text{the volume of sulphuric acid (ml)} \times \text{normality of sulphuric acid} \times 14.007 \times 100}{\text{weight of the sample (g)}}$$

Later, the protein factor was multiplied with N to calculate crude protein content. The protein factor for ingredients was 6.25 except 5.70 for wheat.

Ether extracts (EE): The soxhlet extraction technique was adapted by using the solvent "Hexane" (65-70 °C) to determine the ether extract content of ingredient samples (Jacobs, 1973). The following equation was used to calculate the ether extract content:

$$\text{Ether extract (\%)} = \frac{\text{weight of fat}}{\text{weight of sample}} \times 100$$

Crude fiber (CF): Crude fiber content was quantified by following AOAC (2005) method. The CF content was calculated as:

$$\text{Crude fiber (\%)} = \frac{\text{weight of sample residue - the weight of ash}}{\text{weight of sample}} \times 100$$

Total ash (Ash): Total ash content was quantified by the incineration method (AOAC, 2005). The ash content was determined using the equation as follow:

$$\text{Ash (\%)} = \frac{\text{weight of ash}}{\text{weight of sample}} \times 100$$

Nitrogen-free extract (NFE): The nitrogen-free extract content of ingredient samples was resolute by difference, that is, the summation of moisture, crude protein, total ash, ether extract, and crude fiber was subtracted from 100 (Ali and Hoq, 2010). The NFE content was determined using the equation as follow:

$$\text{NFE (\%)} = 100 - (\text{moisture} + \text{crude protein} + \text{ether extract} + \text{crude fiber} + \text{total ash})$$

2.3. Statistical analysis

All the data of proximate composition were analyzed for one-way analysis of variance (ANOVA) and post hoc Duncan's multiple range test to know the differences among the treatment means at a 5% level of significance by using IBM SPSS Statistics 26.

3. Results and Discussion

3.1. Analysis of proximate composition

All the local ingredients commonly used to prepare livestock and aqua feeds were categorized into energy and protein source feed ingredients.

Energy source ingredients: Proximate compositions of local energy source ingredients are presented in Table 1. The moisture content of the assessed ingredients was significantly different (P≤0.05) and ranged from 7.77±1.68% (sun-dried rice polish) to 12.54±0.63% (maize). However, the moisture content of wheat (12.50±0.23%) was found nearly similar to maize. Moisture content is a crucial factor to consider when choosing ingredients, as greater than 12% moistness accelerates decomposition during storage (Akiyama, 1988). Maize, wheat, wheat bran, sun-dried rice polish, and boiled rice polish comprised the moisture contents with in or slightly above the standard limit set by Bangladesh's national livestock feed ingredients standards (MoFL, 2013). In contrast, B grade rice polish and de-oiled rice bran adhered to Bangladesh's national fish feed ingredients standards (MoFL, 2011). The value for broken rice was nearly identical to the NRC standard (1994), and the moisture content of wheat flour was consistent with the study of Ali and Hoq (2010).

Protein is one of the essential components of animal tissues, constituting 45% to 47% of dry tissue matter (Murai, 1985). Hence, it is a necessary supplement for body support and development. Energy sources ingredients are generally high in calorie or fat content but lower in crude protein content. In this study, the crude protein content of wheat, wheat bran, sun-dried rice polish, and boiled rice polish followed Bangladesh's national livestock feed ingredients standards (MoFL, 2013). Among the assessed ingredients, crude protein content was found significantly (P≤0.05) higher in de-oiled rice bran (18.14±0.57%) followed by wheat bran (15.38±0.15%), while lower in maize (8.25±0.12%). This variation happened due to the different cultivar and crop species (Islam et al., 2021; Islam et al., 2022).

According to NRC (1994), the ether extract content of wheat bran and rice polish was 4% and 14.5%, respectively, which were close to the present findings. Ether extract content differed significantly (P≤0.05) in boiled rice polish (20.02±0.87%) in comparison with wheat flour (0.45±0.08%), and similar trends was also observed in crude fiber content that ranged between 0.47±0.07% (wheat flour) to 20.12±2.26% (B grade rice polish). Again, B grade rice polish comprised maximum ash content (18.76±1.27%) than other energy source local ingredients. Fats provide about twice as much energy as proteins and carbohydrates through the oxidation of triglycerides (Baião and Lara, 2005) and constitute the primary energy source for livestock and fish, having the uppermost caloric value among all the nutritional components. Essential fatty acids are supplied by fats, which often serve as carriers for fat-soluble vitamins (Kono and Arai, 2015).

Table 1. Proximate composition of local energy source feed ingredients (dry matter basis).

Ingredients	N	% M	% CP	% EE	% CF	% Ash	% NFE
Plant-based							
Maize	15	12.54±0.63[a]	8.25±0.12[e]	3.22±0.09[d]	2.00±0.08[d]	1.23±0.15[de]	72.76±0.73[ab]
Wheat	10	12.50±0.23[a]	11.50±0.10[cd]	1.59±0.12[de]	2.78±0.20[d]	2.26±0.19[d]	69.37±0.46[b]
Wheat bran	10	11.70±0.26[ab]	15.38±0.15[b]	3.19±0.14[d]	11.32±0.16[b]	5.63±0.25[cd]	52.79±0.33[bc]
Wheat flour	15	11.75±0.48[ab]	12.10±0.21[c]	0.45±0.08[e]	0.47±0.07[e]	0.54±0.05[e]	74.68±0.58[ab]
Broken rice	10	11.56±0.22[ab]	8.43±0.09[e]	1.22±0.06[de]	0.64±0.12[e]	0.92±0.04[e]	77.23±0.23[a]
Sun-dried rice polish	15	7.77±1.68[d]	12.21±0.10[c]	14.82±1.40[b]	7.94±0.87[c]	7.56±0.78[c]	49.70±2.78[bc]
Boiled rice polish	15	9.19±0.61[bc]	12.12±0.09[c]	20.02±0.87[a]	10.35±0.38[bc]	10.39±0.73[bc]	37.93±0.55[cd]
B grade rice polish	10	8.81±0.87[c]	10.67±0.71[d]	10.43±0.52[c]	20.12±2.26[a]	18.76±1.27[a]	31.20±2.52[d]
De-oiled rice bran	15	10.92±0.78[b]	18.14±0.57[a]	0.92±0.32[e]	10.74±0.59[bc]	12.33±1.17[b]	46.95±2.34[c]

All data are presented in Table 1 as mean ± standard deviation. N= number of samples, M= moisture, CP= crude protein, EE= ether extract, CF= crude fiber, NFE= nitrogen-free extract. Values with different superscripts in each column are significant (P≤0.05).

Moreover, the ether extract content of de-oiled rice bran found in this study was nearly similar to Bangladesh's national fish feed ingredients standards (MoFL, 2011). Total crude fiber content is a rough approximation of the incomprehensible portion of the ingredient when it is included in the feed. This component gives the digestive tract its bulk, which is crucial for the correct peristaltic motion required for adequate digestion (Mateos et al., 2012). In this study, wheat, wheat bran, sun-dried, and boiled rice polish comprised crude fiber content that was found according to Bangladesh's national livestock feed ingredients standards (MoFL, 2013). In contrast, the value of de-oiled rice bran followed Bangladesh's national fish feed ingredients standards (MoFL, 2011). Ash contains minerals present in the ingredient of compound feed (Dawodu et al., 2012), which is required to determine to know about the different mineral content of any ingredient or meal. Al Mahmud et al. (2012) found ash content of rice polish 18.84%, which was more or less similar to our findings. Ash content of wheat bran, rice polishes (all grades), and de-oiled rice bran found in this study followed Bangladesh's national fish feed ingredients standards (MoFL, 2011).

The proportion of nitrogen-free extract (NFE) from 77.23±0.23% (broken rice) to 31.20±2.52% (B grade rice polish) for overall proximate composition was varied greatly in all energy source ingredients (Table 1). Nitrogen-free extract (NFE) content is considered the cheapest dietary energy source in livestock and aqua feeds, which is more available than proteins (Sultana et al., 2016; Azaza et al., 2020). NFE is broken down into simple sugars in the digestive tract, the potential energy source for animals (Nunes et al., 2013). The NFE content of maize and wheat flour were ranged 65-70% and 75-80%, respectively (Ali and Hoq, 2010), and were more or less similar to the findings of this study.

Protein source ingredients: Table 2 represents the proximate compositions of protein source local ingredients. The results showed that the moisture content of animal-based ingredients except for fish meals (9.39±0.75%) was higher than plant-based ingredients. Conversely, fish meal comprised significantly (P≤0.05) crude protein content (57.80±1.26%) than other protein source local ingredients. However, the crab shell's minimum crude protein content was observed (25.09±2.95%). Moisture contents of soybean meal, mustard oil cake, fish meal, and sesame oil cake were found within the standard limit or slightly higher according to both of national livestock feed ingredients standards of Bangladesh (MoFL, 2013) and national fish feed ingredients standards of Bangladesh (MoFL, 2011). Mixed dry fish comprised the moisture content found in this study was consistent with the findings of Ali and Hoq (2010). For full-fat soybean and crab shells, the values were nearly similar or slightly higher than the standard of NRC (1994).

Fish meal is an imperative and foremost source of animal protein in livestock and fish feeds. When utilized in feed formulation, fish meal leads to a rise in the budget of feed and farming (Ekelemu, 2010; Monebi and Ugwumba, 2013). However, the elevated price of fish meals could be a significant limitation to use in different feed formulations. Different oil cakes are considered excellent and cheap protein sources for aquafeeds, mainly available in large quantities as by-products of the edible oil industry. Nowadays, oil cakes are being incorporated in livestock and aqua feeds to replace a fish meal (Jahan et al., 2013). However, utilization of these ingredients is not up to expectation due to the presence of protease inhibitors, phytates, lectins, tannins, and other anti-nutritional factors (Francis et al., 2001). However, the crude protein content of soybean meal, mustard oil cake, and sesame oil cake in this study was followed the national livestock feed ingredients standards of Bangladesh (MoFL, 2013).

Table 2. Proximate composition of local protein source feed ingredients (dry matter basis).

Ingredients	N	% M	% CP	% EE	% CF	% Ash	% NFE
Plant-based							
Soybean meal*	15	12.05±0.29^{b}	46.75±0.43^{ab}	0.89±0.07^{e}	5.98±0.17^{cd}	6.15±0.30^{de}	28.18±0.74^{bc}
Mustard oil cake	15	12.20±0.17^{b}	32.17±0.23^{c}	6.40±0.18^{c}	6.37±0.21^{c}	7.05±0.42^{de}	35.80±0.56^{ab}
Full-fat soybean	15	12.31±0.58^{b}	36.29±1.23^{bc}	18.57±1.03^{a}	6.05±0.47^{c}	5.28±0.68^{e}	21.50±0.76^{c}
Sesame oil cake	10	10.25±0.61^{bc}	28.15±0.48^{cd}	7.42±0.36^{bc}	13.91±0.35^{b}	7.58±0.33^{d}	32.69±0.77^{b}
Animal-based							
Mixed dry fish	15	13.73±1.76^{ab}	29.53±1.88^{cd}	2.53±0.72^{d}	22.91±1.49^{a}	31.17±1.36^{a}	0.13±0.12^{e}
Fish meal	15	9.39±0.75^{c}	57.80±1.26^{a}	6.69±1.18^{c}	5.62±1.40^{cd}	19.97±1.70^{c}	0.54±0.52^{e}
Crab shell	10	13.89±2.41^{ab}	25.09±2.95^{d}	4.39±0.29^{cd}	9.08±0.73^{bc}	6.98±1.76^{de}	40.57±1.28^{a}
Shrimp meal	10	16.33±0.99^{a}	41.35±0.80^{b}	7.49±0.75^{bc}	3.98±0.59^{d}	26.22±0.67^{b}	4.65±1.20^{d}
Shrimp shell	10	13.23±0.15^{ab}	31.29±0.14^{c}	9.78±0.65^{b}	12.69±1.20^{b}	29.53±0.49^{ab}	3.48±1.37^{d}

* Local high protein soybean meal. All data are presented in Table 2 as mean ± standard deviation. N= number of samples, M= moisture, CP= crude protein, EE= ether extract, CF= crude fiber, NFE= nitrogen-free extract. Values with different superscripts in each column are significant (P≤0.05). It indicated that both the maximum and minimum ether extract and crude fiber content were found from plant-based and animal-based ingredients, respectively.

Ether extract content ranged from 0.89±0.07% (soybean meal) to 18.57±1.03% (full-fat soybean) among the assessed ingredients was significantly different (P≤0.05). Alternatively, crude fiber content was ranged between 3.98±0.59% (shrimp meal) to 22.91±1.49% (mixed dry fish). Except for crab shells (6.98±1.76), the ash content of all animal-based ingredients was significantly (P≤0.05) higher in comparison to plant-based ingredients. Although crab shell comprised the higher nitrogen-free extract (NFE) content (40.57±1.28%), however, the other animal-based ingredients comprised noticeably lower NFE as of 0.13±0.12% (mixed dry fish) to 4.65±1.20% (shrimp meal), whereas plant-based NFE was found from 21.50±0.76% (full-fat soybean) to 35.80±0.56% (mustard oil cake).

In the present study, ether extract content of sesame oil cake was found 7% that followed the standard of NRC (1994). Likewise, the ether extract content of soybean meal, mustard oil cake, and the fish meal was found nearly similar to Bangladesh's national fish feed ingredients standards (MoFL, 2011). This study also found crude fiber contents of different oil cakes according to Bangladesh's national livestock feed ingredients standards (MoFL, 2013). However, the crude fiber content of full-fat soybean was found slightly higher (1.05%) following NRC (1994). In contrast, the ash content of soybean meal, mustard oil cake, and fish meal followed Bangladesh's national fish feed ingredients standards (MoFL, 2011). Nitrogen free extract (NFE) content of soybean meal, mustard oil cake, sesame oil cake, and shrimp meal found in this study were nearly similar to the findings of Ali and Hoq (2010), revealed the NFE content of 30-35%, 30-40%, 30-35%, and 2-4% respectively. Furthermore, the NFE content of crab shells in our study was consistent with the NFE of 40.82±1.28% reported by Bhuiyan et al. (2016).

3.2. Evaluation of market price

The market price is one of the dynamic criteria for selecting an ingredient to be incorporated in the formulation and production of feed. The prices were collected while sample collection for this study from different sources. The average market prices of all the studied ingredients are presented in Figure 1.

The energy source is the highest volume used in feed formulation, followed by protein sources. Among energy sources, the maximum price was observed for wheat bran (0.38 USD/Kg) and the minimum for B grade rice polish (0.18 USD/Kg). Fish meal (1.59 USD/Kg) was the most expensive animal-based protein source, while crab shell was the cheapest (0.41 USD/Kg). The soybean meal price was higher (0.47 USD/Kg) than mustard oil cake (0.35 USD/Kg) among plant-based protein sources. These findings indicate that energy source ingredients are cheaper than protein sources.

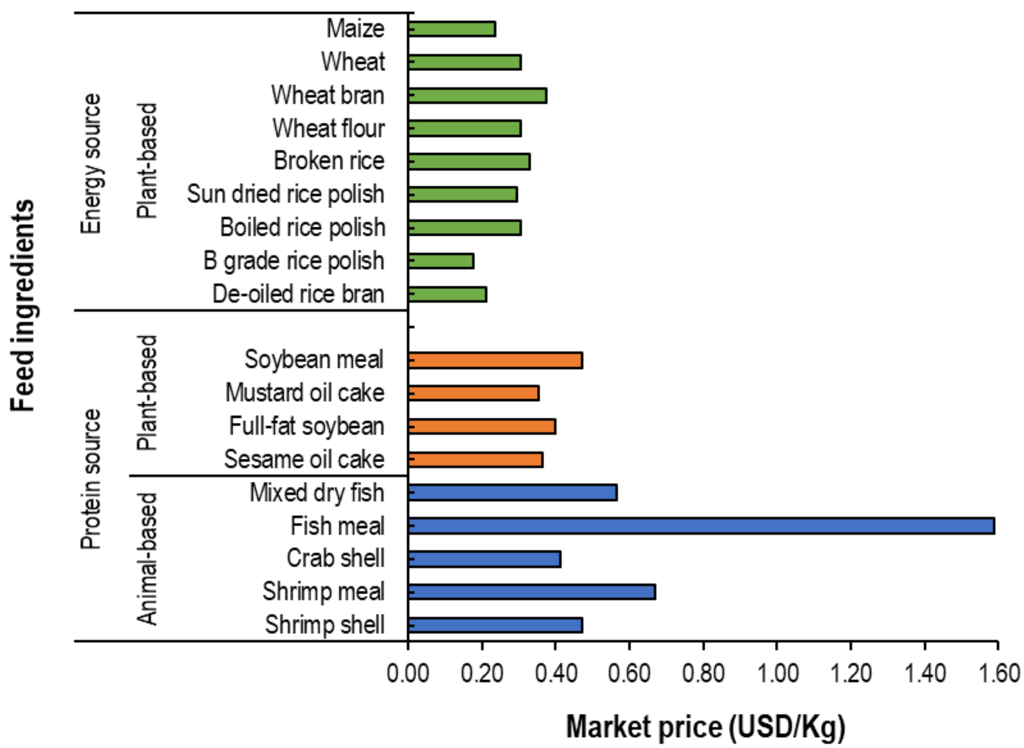

Figure 1. The average market price of studied local ingredients (1 USD = 85 BDT).

Moreover, protein source accounts for the highest part of the cost in feed. Fish meal is mainly used in aquafeeds and partially in livestock feeds production due to the higher digestibility of protein, essential amino acids, fat, vitamins, and minerals (Hardy, 2010; Udo et al., 2012), which was found highest in crude protein content as well as price among all the studied protein sources. From the results of this study, we found soybean meal as the cheapest protein source in terms of per unit protein cost, followed by mustard oil cake, full-fat soybean, and sesame oil cake (Table 3).

Table 3. Cost for per unit protein from local protein source feed ingredients.

Protein source ingredients	**Cost for per unit protein (USD)***
Plant-based	
Soybean meal	1.007
Mustard oil cake	1.097
Full-fat soybean	1.102
Sesame oil cake	1.296
Animal-based	
Mixed dry fish	1.912
Fish meal	2.748
Crab shell	1.641
Shrimp meal	1.622
Shrimp shell	1.504

*Per unit= equivalent to 1 Kg

The findings of this study indicated that animal-based protein sources ingredients are more costly than plant-based. However, soybean meal and shrimp shell are the cheapest, whereas sesame oil cake and fish meal are the expensive sources among plant-based and animal-based sources, respectively, in terms of per unit protein cost. The cost per unit protein from different plant-based and animal-based protein sources is presented in Table 3.

As the profitability depends mostly on feed cost in the case of both livestock and aquafarming, it is the prime concern of nutritionists, feed manufacturers, and farmers to use economic but good quality protein sources in feed. The fish meal contained high prices and variable quality. Some studies were conducted to replace a fish meal with soybean meal (Frempong et al., 2019) and shrimp meal (Aktar et al., 2011) in broiler diets, while some researches were conducted to replace fish meal in aquafeeds with soybean meal (Sharda et al., 2017; Bae et al., 2020), soybean meal and sesame oil cake (Latif et al., 2008) or full-fat soybean (Abdel-Warith et al., 2020). All of the attempts were successful, indicating that the costly fish meal can be replaced in livestock and aqua feeds using the studied ingredients in the present research without compromising growth traits, which will reduce costs for protein source ingredients.

4. Conclusion

This research focused on proximate composition and future cost of different energy and protein sources local ingredients incorporated in livestock and aquafeeds. This information will support nutritionists, feed manufacturers, and farmers to formulate and produce nutritionally balanced and cost-effective feeds by reducing dependency on imported feed ingredients in Bangladesh.

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Conflict of interest

We declare that we have no conflict of interest.

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