Development of low cost formulated quality feed for growth performance and economics of *Labeo rohita* cultured in cage

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Abstract. The present study was carried out to establish an economical and effective diet for the intensive culture of *Labeo rohita* in pond cage culture system during July to November 2016. The fishes with an initial weight of 76.23±4.21 g were raised with a stocking density of 35 fishes/m^3 in each cage. Three types of diets namely handmade balls (HMB), semi-auto feed mill pellet (SAFM-pellet) and a commercial diet (CD-pellet) were evaluated for their effects on growth and economic effect in *L. rohita*. During the study period, the water quality parameters were found to be within the suitable ranges for the culture of *L. rohita*. Significantly higher ($P<0.05$) final weight, weight gain, % weight gain, average daily gain and specific growth rate were found in fishes fed with SAFM-pellet when compared to HMB and CD-pellet feed. Significantly ($P<0.05$) better food conversion ratio, higher total fish yield and economic return were also obtained from SAFM-pellet fed fishes after the culture period. Therefore, the present study recommended to using SAFM-pellet feed as an alternative of costly commercial feed for economically sound cage culture of *L. rohita*.
Key Words: Formulated feed, *Labeo rohita*, semi-auto feed pellet, handmade balls.

Introduction. Cage culture in ponds has great potential to increase fisheries production in Bangladesh as it provides an opportunity for small-scale farmers to use their limited resources and to include high-valued species in their ponds to generate more income and improve their livelihood. Cage culture can be considered as an intensive culture system of fishes, as it provides the opportunity of higher biomass production and intensive technology to be applied. One of the challenges faced by cage culturist is the need to obtain a balance between a rapid growth and optimum use of the supplied feed. Nevertheless, for the cage fish culture to be continued an important role is played by the increasing of animal protein demands for large number of population, thus this sub-sector needs to develop (Iliyasu et al 2014). The success of intensive fish culture depends on the formulation of a fish feed that contains an optimum level of protein and energy necessary for the growth of fish, but also to be cheap. In order to make the intensive monoculture of major carps successful, it is indispensable to prepare specific feed for each species (Muzammel et al 2003) as because feed represent 40-50% of production costs (Craig & Helfrish 2002). In countries like Bangladesh, commercial feed is simply beyond the reach of most marginal and landless farmers, limiting their ability to intensify aquaculture production. However, if fish feed ingredients are locally available, and labor can be drawn from the household at low opportunity cost, production costs can be reduced and profit margins can be increased. Therefore, the choice of feed is a determining factor for successful cage farming. Dependency on fishmeal is a severe constraint to fish farming in Bangladesh. High cost and short supply of fishmeal have necessitated its substitution with cheaper plant protein sources. Though there is a tendency to use alternative plant and animal proteins, as a low cost substitute for fish meal, such alternatives are known to have lower nutritional value than fish meal, resulting in lower growth rates or a reduced performance of the cultured animals (Pai et al 2016). Singh et al (2005) opined that optimum protein requirements vary with the protein sources and feed ingredients that are locally available and cheap ingredients should be used to develop a suitable feed for carp. Now-a-days, the most important barrier towards fish feed development in Bangladesh is lack of simple technology for developing feed from locally available ingredients. Therefore, the present study was to evaluate the performance of two locally formulated feeds as possible replacements for a costly commercial feed commonly used on rearing of *L. rohita*.

Material and Methods

Experimental site. The present experiment was conducted in a pond for a period of five months (150 days) from July 2016 to November 2016 in Tungipara of Gopalgonj district. The size of pond was 2 ha.

Cage construction and installation. 9 floating net cages each having an area of 14 m^3 and made of synthetic nylon net (mesh size of 1.1 cm) were installed in the pond. Each cage was tied and hanged with bamboo pole frame. Empty plastic drum of 250 liters size was used as cage float. Each cage was covered at the top with another piece of net to prevent escape of fish by jumping and predation of birds. Feeding tray was installed inside each cage for feeding of experimental fishes.

Fish collection and stocking. Fishes with average initial weight of 76.23±4.21 g were collected from farmer's pond and kept in three net cages for 24 h for acclimation with the pond environment. Finally the cages were randomly stocked with a stocking density of 35 fishes/m^3 and such individual cage contained 490 fishes.

Preparation of experimental diets and feeding. The experimental fishes were feed with handmade balls (HMB), semi-auto feed mill pellets (SAFM-pellet) and commercial diet (CD-pellet) in the amount of 5% of body weight for first two months and 3% of body weight for last three months of culture period. HMB and SAFM-pellets were prepared using locally available feed ingredients and using a local feed manufacturing method. The required amount of different ingredients was mixed with a blander to prepare the experimental diets. The different ingredients and their amounts to prepare experimental diets are shown in Table 1. The CD-pellet is a commercial feed and it was bought from the local market.

Table 1

Ingredients used for preparation of experimental diets and feed costs

Ingredients (%)	*Handmade balls*	*SAFM-pellet*	*CD-pellet*
Rice bran (Gr-A)	40	42	Commercial diet feed
Mastered oil cake	45	20	
Soybean oil cake	-	10.8	
Wheat flour	-	10	
Dry fish	-	15	
Wheat bran	15	-	
Vitamins & minerals	-	0.2	
Salt	-	0.5	
Binder	-	0.5	
Limestone (powder)	-	1	
Total	100	100	
Feed cost (BDT/kg)	20	23	28

Gr-A = Grade A, 1 USD = 84.53 Bangladeshi Taka (BDT). HMB = Handmade balls, SAFM-Pellet = Semi-auto feed mill pellet, CD-Pellet = Commercial diet pellet.

Fish sampling, growth parameters and yield analysis. Fish sampling was carried out in the morning between 7:00 and 9:00 AM using a scoop net. Around 10% of fishes from each feed types were sampled monthly in order to determine the weight of fishes. At the final harvest, all fishes were weighed, measured and the survival rate were determined. To determine the growth response of fish, the following parameters were calculated according to Panase & Mengumphan (2015):

Mean weight gain (g) = Mean final weight (g) – Mean initial weight (g)

Average daily weight gain (ADG) = $\frac{\text{Final weight} - \text{Initial weight}}{\text{Culture period}}$

SGR (% day^{-1}) = $\frac{\ln[\text{Final weight}] - \ln[\text{Initial weight}]}{\text{Culture period}} \times 100$

Survival rate (%) = $\frac{\text{No. of fish harvested}}{\text{No. of fish stock}} \times 100$

Feed conversion ratio = $\frac{\text{Weight of feed fed}}{\text{Fish weight gain}}$

Fish yield (kg cage^{-1} 150 days^{-1}) = Fish biomass at harvest −fish biomass at stock.

Water quality monitoring. Water samples were collected fortnightly (twice in a month) between 10:00 and 11:00 for analysis of various physico-chemical parameters using dark bottles. Water temperature and transparency were measured using a Celsius thermometer and a black and white standard color coded Secchi disc of 30 cm diameter. Water pH was measured using an electronic pH meter (Jenwary 3020) and dissolved oxygen (DO) was measured directly with a DO meter (Lutron DO-5509). Total dissolved solids (TDS) were measured by a TDS meter (Adwa AD31 water prove EC/TDS tester) and ammonia was determined using a HACH water analysis kit (Model FF-2, USA).

Proximate composition analysis. Proximate composition analyses of experimental diet and whole fish body were performed by the standard methods of Association of Official Analytical Chemists (AOAC 1995). After the completion of experiment, five fishes from each treatment were collected for further analyses of body carcass composition. For determining moisture content, samples of diets and wet fishes were dried at 135°C for 2 h. Crude lipid content was determined by the Soxhlet apparatus using Soxtec system 1046 (Foss, Hoganas, Sweden) and crude protein content by Kjeldahl method (N × 6.25) after acid digestion, distillation and titration of samples. Ash content was determined by using a muffle furnace (600 °C for 4 h). Carbohydrate was analyzed by acid method (Miller et al 1972). The samples were analyzed in the Fish Nutrition Laboratory, Department of Aquaculture, Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh, Bangladesh.

Economic analysis. At the end of the experiment, an economic analysis was performed to estimate the net return and benefit-cost of the experimental diets used for *L. rohita* reared in cages. The following simple equation was used according to Asaduzzaman et al (2010): R = I - (FC + VC + Ii),

Where: *R* = net return, *I* = incomes from *L. rohita* sale, *FC* = fixed/common costs, *VC* = variable costs and *Ii* = interest on inputs.

The benefit-cost ratio was determined as:

Benefit cost ratio (BCR) = Total net return/Total input costs.

Statistical analysis. Water quality, fish growth and yield parameters, proximate composition and economic performance were analyzed by one-way ANOVA. When a mean effect was significant, the ANOVA was followed by Duncan New Multiple Range Test (Duncan 1955) at 5% level of significance (Gomez & Gomez 1984). As percentages and ratio data did not show a normal distribution by Kolmogorov-Smirnov test (P>0.05) they were analyzed using arcsine transformed data. All analyses were performed using SPSS (Statistical Package for Social Science) version 20.0 (IBM Corporation, Armonk, NY, USA).

Results and discussion

Water quality parameters. Mean values (mean±SD) and ranges (parentheses) of water quality parameters measured in the cages during the experimental period are shown in Table 2. There were no significant differences (P>0.05) among the treatments in all the parameters. During the study period water temperature ranged from 30.00 to 33.20ºC, water transparency ranged between 25.00 to 43.00 cm, pH ranged between 6.50 to 7.40, DO varied between 5.80 to 7.40 mg L^{-1}, TDS ranged from 116.00 to 132.00 mg L^{-1} and Un-ionized ammonia (NH_3) varied from 0.000 to 0.008 mg L^{-1} inside all of the experimental cages. To obtain better growth performance in fishes under cage culture system, the water quality parameters has great importance. However, during the study period, all the water quality parameters were in suitable ranges for fish culture in cage according to Abid & Ahmed (2009), Ali et al (2000), Boyd (1982) and Jobling (1994).

Table 2

Mean values and ranges (parentheses) of water quality parameters during the study period

Parameters	*Treatments*		
	Handmade balls	*SAFM-pellet*	*CD-pellet*
Water temperature (°C)	31.06±1.09^a (30.00-33.00)	31.11±1.09^a (30.00-33.20)	31.10±1.02^a (30.10-33.10)
Transparency (cm)	34.28±6.62^a (25.00-43.00)	33.83±6.52^a (25.00-43.00)	34.01±6.36^a (25.00-42.00)
pH	6.97±0.23^a (6.50-7.30)	7.06±0.24^a (6.70-7.40)	6.99±0.27^a (6.50-7.40)
DO (mg L^{-1})	6.68±0.43^a (5.90-7.20)	6.78±0.46^a (5.90-7.40)	6.71±0.46^a (5.80-7.30)
TDS (mg L^{-1})	121.36±2.87^a (117.00-126.00)	124.64±4.40^a (118.00-133.00)	123.50±5.14^a (116.00-132.00)
Un-ionized ammonia (mg L^{-1})	0.002±0.001^a (0.001-0.003)	0.001±0.000^a (0.001-0.002)	0.002±0.001^a (0.00-0.008)

Values in each same row having the same superscripts are not significantly different (P>0.05).
DO = Dissolved oxygen, TDS = Total dissolved solids. HMB= Handmade balls, SAFM-Pellet = Semi-auto feed mill pellet, CD-Pellet = Commercial diet pellet.

Growth and yield parameters. During the experimental period, growths of *L. rohita* at monthly interval are shown in Figure 1. During the study period, the final weight of *L. rohita* was significantly (P<0.05) higher for fishes fed with SAFM-pellets (463.67±8.72 g) and CD-pellets (432.43±4.49 g) when compared to HMB (262.31±4.10 g). Growths towards the growing phase of the fish fed with SAFM-pellet indicate the ability to utilize formulated feed more effectively than commercial feed. The growth performance, survival, feed utilization and yield of *L. rohita* in three treatments after 150 days of rearing are presented in Table 3. Similar to the final weight, weight gain, % weight gain and ADG were also significantly higher (P<0.05) for the fishes fed with SAFM-pellets feed compared to other two types of feeds. The overall SGR value of the fishes fed SAFM-pellets was significantly (P<0.05) higher (3.25±0.01% day^{-1}) compared to the fishes fed CD-pellets (3.18±0.02% day^{-1}) and HMB (0.82±0.01% day^{-1}). The significantly higher

(P<0.05) SGR of fishes fed SAFM-pellets might be due to the fact that this feed was more palatable than other feed types. The present findings were also similar to Dars et al (2010) and Nekoubin & Sudagar (2012) who also found higher SGR in formulated feed compared to commercial feed for the species *Catla catla* and *Ctenopharyngodon idella*. Therefore, the present study demonstrates that increasing dietary protein level (Table 4) by using cheap and easily available feed ingredients has positive effect on growth of *L. rohita* in cage culture. In the present study, lower FCR was found in fishes fed SAFM-pellets (2.97±0.09), which may be due to the reason that commercial feed may contain pollutants such as heavy metal (Kundu et al 2017) due to the use of higher amount of fish meal, which reduce digestibility and feed quality, finally poor FCR. Better FCR in formulated feed was also obtained by Haque & Mazid (2005). However, lower performance in HMB might be due to lower food value of plant ingredients. As reported by Inayat & Selim (2005), the growth and FCR are good tools to compute the acceptability of feed in fish feeding experiments, a low FCR value obtained for SAFM-pellet indicates better feed utilization efficiency. During the study period, the different feed types did not show any significant differences (P>0.05) in the survival rate of *L. rohita*. Survival rate was 85.10±6.93, 92.15±3.03 and 89.29±4.83% in HMB, SAFM-pellet and CD-pellet fed fishes, respectively. The total fish yield were significantly different (P<0.05) among the different feed groups during the study period. The total yield was found higher for SAFM-pellet fed fishes (209.29±2.95 kg cage^{-1}) followed by CD-pellet and HMB feed fed fishes. This finding is in accordance with the results of Ahmed et al (1996) who also reported highest net yield for fishes feed formulated feed compared to commercial feed.

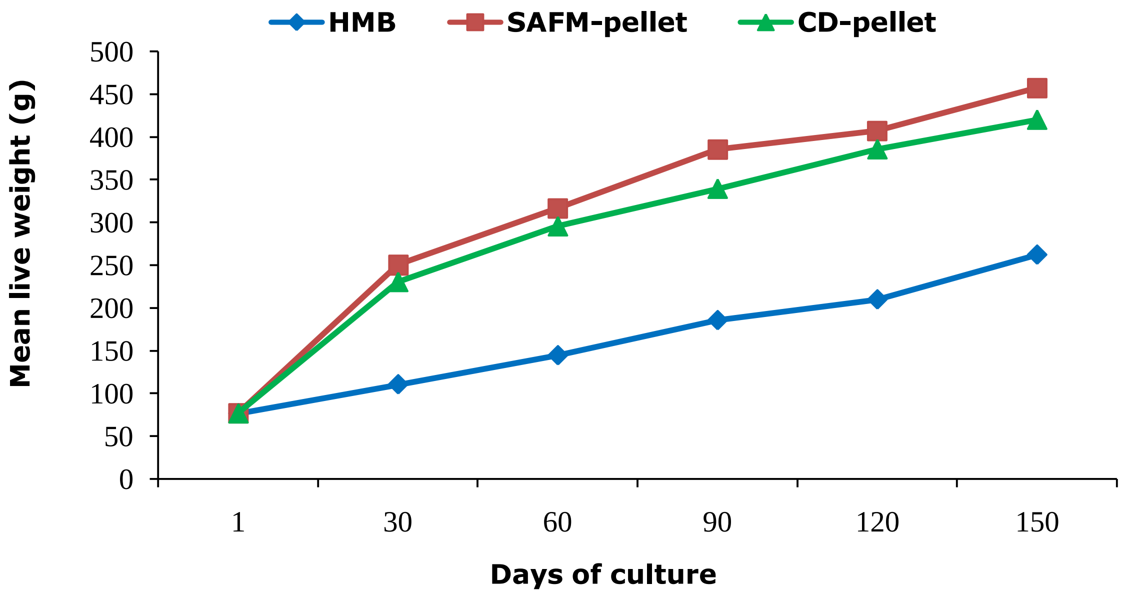

Figure 1. Mean live weight gain at different sampling dates over 150 days of cage culture system of *Labeo rohita.*

Proximate composition of feed and fish. The proximate compositions of three feed types (HMB, SAFM-pellet and CD-pellet) are shown in Table 4. In case of diet, the percentage (%) of crude lipid, crude protein and crude ash were significantly different (P<0.05) and higher in CD-pellet (7.76±0.60, 24.88±0.02 and 12.29±0.01% respectively) than SAFM-pellet (7.30±0.03, 24.68±0.03 and 11.53±0.02% respectively) and HMB (6.48±0.08, 22.60±0.10 and 6.35±0.01% respectively).

Table 3

Growth performance, survival rate and feed utilization of *L. rohita* yield in cages system over 150 days of culture periods

Parameters	*Treatments*		
	HMB	*SAFM-pellet*	*CD-pellet*
Initial weight (g)	76.36±0.50^{a}	76.93±1.31^{a}	76.86±1.21^{a}
Final weight (g)	262.31±4.10^{c}	463.67±8.72^{a}	432.43±4.49^{b}
Weight gain (g)	185.96±4.60^{c}	386.75±7.42^{a}	355.57±5.70^{b}
% weight gain	243.57±7.63^{c}	502.75±1.06^{a}	462.77±14.70^{b}
ADG (g)	1.24±0.03^{c}	2.58±0.05^{a}	2.37±0.04^{b}
SGR (% day^{-1})	0.82±0.01^{c}	3.25±0.01^{a}	3.18±0.02^{b}
FCR	4.15±0.05^{a}	2.97±0.09^{b}	3.14±0.02^{b}
Survival rate (%)	85.10±6.93^{a}	92.15±3.03^{a}	89.29±4.83^{a}
Fish yield (kg cage^{-1} 150 days^{-1})	109.32±7.19^{c}	209.29±2.95^{a}	189.15±4.45^{b}

Values in each same row having different superscripts are significantly different (P<0.05). ADG = Average daily gain, SGR = Specific growth rate, FCR = Feed conversion ratio, HMB= Handmade balls, SAFM-Pellet = Semi-auto feed mill pellet, CD-Pellet = Commercial diet pellet.

The final carcass composition of fish fed on different types of feed after 150 days of rearing are also shown in Table 4. The percentage of crude protein and lipid in muscle of *L. rohita* were significantly different (P<0.05) among the different feed types and it was the highest for fishes fed with SAFM-pellet (20.77±0.02 and 8.00±0.02%) followed by CD-pellet (19.48±0.02 and 6.95±0.02%) and HMB (18.80±0.15 and 3.25±0.02%). Although the crude protein content of CD-pellet was significantly higher than SAFM-pellet, higher assimilation of protein was found in fishes fed SAFM-pellet. On the contrary, lower protein assimilation occurred in CD-pellet which might be due to the use of fish meal as main protein source in this diet. According to Mohanty (2006), optimal protein requirement of *L. rohita* is 25-30% under pond conditions. Therefore, only SAFM-pellet and CD-pellet diets showed more or less similar protein content to optimal range, while protein content of HMB was far below from this optimum level. This might be responsible for lower growth and muscle crude protein content of fishes which were fed HMB diets. Mohanty (2006) considered a range of 7–9% dietary lipid to be optimum for Indian major carps including rohu and in the present study, except for HMB, lipid content of other two types of diets (SAFM-pellet and CD-pellet) was within this range. There were also significant differences in the moisture (%) content of muscle of three feeding group of fishes and it was lower in SAFM-pellet fed fish (70.10±0.02%) than CD-pellet fed fish (72.15±0.03%) and HMB fed fish (77.80±0.57%) respectively (Table 4).

Table 4

Proximate composition of experimental diets and muscle of *Labeo rohita*

Proximate (%)	*HMB*	*SAFM-pellet*	*CD-pellet*
Diets			
Moisture	15.67±0.02^{a}	12.16±0.01^{b}	11.95±0.01^{c}
Crude lipid	6.48±0.08^{b}	7.30±0.03^{a}	7.76±0.60^{a}
Crude protein	22.60±0.10^{b}	24.68±0.03^{a}	24.88±0.02^{a}
Crude ash	6.35±0.01^{c}	11.53±0.02^{b}	12.29±0.01^{a}
Crude fiber	6.96±0.01^{a}	6.77±0.03^{b}	5.89±0.01^{c}
Carbohydrate	41.95±0.01^{a}	38.20±0.04^{b}	37.23±0.02^{c}
Fish muscle			
Crude protein	18.80±0.15^{c}	20.77±0.02^{a}	19.48±0.01^{b}
Crude lipid	3.25±0.02^{c}	8.00±0.02^{a}	6.95±0.02^{b}
Moisture	77.80±0.57^{a}	70.10±0.02^{c}	72.15±0.03^{b}

Values in each same row having different superscripts are significantly different (P<0.05). HMB = Handmade balls, SAFM-Pellet = Semi-auto feed mill pellet, CD-Pellet = Commercial diet pellet.

Economic analysis. Comparison of economic return among the treatments with different feed types is shown in Table 5. The mean total inputs including 10% annual interest per 14 m^3 of cage was significantly (P<0.05) higher for CD-pellet (198.79 USD) followed by SAFM-pellet (179.06 USD) and HMB (108.54 USD). The cost of input was lowest in HMB because of the lowest formulation cost of this diet compared to other two types of diets. There were significant differences (P<0.05) in the mean values of financial return as fish sale and higher total net return was obtained from SAFM-pellet fed fishes (192.06 USD and 354.05 USD) followed by CD-pellet fed fishes (319.99 USD and 136.58 USD) and HMB fed fishes (165.33 USD and 59.42 USD), respectively. The benefit-cost ratio (BCR) was also significantly (P<0.05) higher in SAFM-pellet (1.07) followed by CD-pellet (0.69) and HMB (0.55) respectively. According to Yakubu et al (2014) cost-benefit ratio is viable when it is >1. Therefore, in the present study, viability in BCR was only achieved for SAFM-pellet diet, which might be attributed to better growth performance of fishes.

Table 5

Cost-benefit analysis of *Labeo rohita* growth in different feed types from single unit of cage (14 m^3) after 150 days

Variables	*Price rate (USD)*	*Treatments*		
		HMB	*SAFM-pellet*	*CD-pellet*
Fixed cost				
Net cage (14 m^3)	26.58 USD $unit^{-1}$	26.58	26.58	26.58
Plastic drum (250 L)	4.73 USD $unit^{-1}$	10.87	10.87	10.87
Other materials cost for cage supporting (bamboo, rope, anchor, brick)	1.77 USD $unit^{-1}$	1.77	1.77	1.77
Sub total		**39.22**	**39.22**	**39.22**
Cost in one cycle		**6.54**	**6.54**	**6.54**
Variable costs				
Fish fingerling		26.05	26.05	26.05
Feed cost	T_1 = 0.24 USD kg^{-1} T_2 = 0.27 USD kg^{-1} T_3 = 0.33 USD kg^{-1}	70.43	138.13	157.07
Labour cost		0.59	0.59	0.59
Fish harvesting & marketing cost		0.59	0.59	0.59
Sub total		**97.66**	**165.35**	**184.30**
Total (Fixed + variable costs)		**104.19^c**	**171.89^b**	**190.84^a**
Interest on inputs (5 months)	10% annually	4.34	7.17	7.95
Total inputs		**108.54^c**	**179.06^b**	**198.79^a**
Financial return				
Fish sale as total return	T_1 =1.54 USD kg^{-1} T_2 =1.77 USD kg^{-1} T_3 =1.77 USD kg^{-1}	165.29^c	353.54^a	319.53^b
Total net return		**59.34^c**	**191.78^a**	**136.38^b**
BCR		**0.55^c**	**1.07^a**	**0.69^b**

Values in each same row having different superscripts are significantly different (P<0.05). 1 USD = 84.53 Bangladeshi Taka (BDT), HMB = Handmade balls, SAFM-Pellet = Semi-auto feed mill pellet, CD-Pellet = Commercial diet pellet, BCR = benefit-cost ratio.

Conclusions. It can be concluded that, on the basis of water quality, growth performance, total yield and economic return, SAFM-Pellet feed could be recommended for the successful cage culture of *L. rohita* that gives better FCR, BCR and more sustainability in aquaculture business.

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