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Alternate feeding strategies for optimum nutrient utilization and reducing feed cost for semi-intensive practices in aquaculture system-A review

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ABSTRACT

In aquaculture system, 40-60% cost comes from the production of fish regarding feed. Hence, there is a need in future to further reduce the cost of the feed and its utilization in aquaculture with low input for growth and high survival of fish. Concerning the former the most obvious approach to reducing the cost of feed is to decrease the amount of the most expensive ingredient in the feed i.e. fishmeal, through substitution with a suitable low-cost alternative ingredients, while ensuring that such substitution will not compromise the growth and quality of the cultured stock. Previously, few attempts have been made on the mixed feeding schedule in carps and other species in aquaculture. There is a need to undertake the effect of mixed feeding schedule with suitable feeding strategies i.e. alternate feeding strategies with the different combination of protein variation in the diet. This study will throw light in the low cost feed formulation, feeding strategies, reduction in pollution load in pond and minimize the cost of fish production in aquaculture of Indian major carps and other cultured species in the country and it will improve the economic status and benefits of farmers in the generation of income and employment opportunities.

Key words: Alternate feeding strategies, Body composition, Growth performance.

Aquaculture is the fastest growing food sector in recent decades. In developing countries, pond-based or open-water extensive, improved extensive and semi-intensive practices using polyculture farming technologies have been widely accepted. Comparatively, the higher amount of freshwater and marine carnivorous finfish in developed countries is produced by intensive farming systems using high-cost nutrient inputs in the form of "nutritionally-complete formulated diets". In most of developing countries like Asia and Africa, global aquaculture production can be achieved through the advancement of semi-intensive, small-scale pond farming. Hence, nutrition and feeding strategies will play an immense role in sustaining the aquaculture development. Therefore, sustainable aquaculture management should address allocation of inputs based on local circumstances, and balance maximizing profitability with social and environmental costs (Hasan, 2001).

Feed accounts substantially to the cost of commercial fish production which makes the difference between profitable and unprofitable culture enterprises (Boliver *et al*., 2006). The determination of aquaculture feeding strategies based on mathematical, economic, and nutritional models can be rather complex. Some feeding restriction strategies help in lowering the feed costs without a net reduction in crop yields, but it is not known whether these result in more efficient feed consumption, better feed utilization or both (Boliver *et al*., 2006). Furthermore, it has been revealed that on the basis of water quality concerns that optimal feeding levels should be below the level that supports maximal growth. It has been seen in regular feeding of fish to the point of satiation increases the risk of waste, feed decomposition, and affect fish health.

Apart from the cost factor other issues related to use of fish meal and trash fish in aquaculture, impacts on overall sustainability of the sector. Though, fish meal replacement studies have generally been the main emphasis for reducing feed costs in aquaculture. This article attempts to show that in semi-intensive, small scale aquaculture practices feed costs can be significantly reduced by adoption of varying feed management practices, and may be more suited currently for small scale practices in the tropics (De Silva, 1985).

Formulated diets : In general prepared or formulated diets may be either complete or supplemental. Complete diets supply all the ingredients (protein, carbohydrates, fats, vitamins, and minerals) necessary for the optimal growth and health of the fish in semi-intensive practices. Most fish farmers use complete diets, those containing all the required protein (18-50%), lipid (10-25%), carbohydrate (15-20%), ash (< 8.5%), phosphorus (< 1.5%) and trace amounts of

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vitamins, and minerals (Lovell, 1989). When fish are reared in high density indoor systems or confined in cages and cannot forage freely on natural feeds, they must be provided a complete diet. In contrast, supplemental diets are intended only to support the natural food (insects, algae, small fish) normally available to fish in ponds or outdoor raceways. Supplemental diets do not contain a full complement of vitamins or minerals, but are used to help fortify the naturally available diet with extra protein, carbohydrate and lipid. Fish, especially when reared in high densities, require a high-quality, nutritionally complete, balanced diet to grow rapidly and remain healthy.

Reducing feeding cost as major challenge in semi-intensive aquaculture : In semi-intensive culture systems, economic return of fish production can be achieved by reducing the feeding cost. Since natural food is the main energy input in fish ponds, excessive supplemental feeding may result in a considerable economic loss, in addition to a severe environmental impact, while partial reduction of feeding level may improve economic return. Protein sparing effect of lipid and carbohydrate in the diet to utilize high enrgy can be results in an overall reduction in feed costs. Most suited examples in this regard are salmonids diets which have over the year have resulted in a significant lowering in the protein component and a corresponding increase in the dietary lipid level to almost 30% or more, and a significantly better food conversion ratio (FCR). Moreover, Lin and Yi (2003) reported that Nile tilapia reared in fertilized ponds and fed supplemental diets at 50%, 75%, and 100% satiation, produced comparable yields, but the 50% level achieved considerable reduction in production costs and in nutrient loading. This means that farmers who adopt this feeding level can save about 50% of the feed without reducing their yield. Similarly, the highest production and net income of Nile tilapia polyculture with common carp and silver carp in fertilized ponds and fed 0, 1%, 3%, 5% biomass and to apparent satiation were achieved at 2.67% of fish biomass day^{-1} (equivalent to apparent satiation). It is clear, thus, that adoption of an optimal feeding regime will reduce both feed costs and nutrient loading in the ponds, and in turn, reduce environmental impacts of aquaculture practices.

Alternate feeding strategies: Mixed feeding schedules : De Silva (1985) proposed concept of "mixed feeding schedules". It was primarily based on the observations on the daily variation in apparent dry matter and protein digestibility of feed in the Asian chromid *Etroplus suratensis* (Bloch) and *Oreochromis niloticus* (De Silva and Perera, 1984). De Silva (1985) hypothesized that when the fish are provided a high protein diet throughout the rearing period it might not be able to utilize the feed effectively to the same degree, day after day. Similar kind of this hypothesis was also reported on young *O. niloticus* through the use of mixed feeding schedules where a high-protein diet (a diet containing the optimal protein requirement) was alternated with a low-protein diet (a diet containing approximately 10% less than the optimal requirement), each of these diets being fed alternately over a pre-determined number of days. The experimental results supported the findings that when fish maintained on certain mixed feeding schedules performed better or equally well as those fish maintained regularly on a high protein diet. Results showed that growth performance parameters, such as specific growth rate (% SGR), percent gain, and weight gain were significantly higher ($P < 0.05$) for fish maintained on the feeding schedule of 3A/3B (A & B representing different level of protein level).

The replacement of fishmeal by cheaper protein ingredients (Tacon and Jackson, 1985; Kaushik, 2000) to reduce feed costs has been adopted as general approach. Based on the observation that the dry matter and protein digestibility varies from day to day in a certain rhythmic fashion in green chromide, *Etroplus suratensis*, (De Silva and Perera, 1983) and Nile tilapia, *Oreochromis niloticus* (De Silva and Perera, 1984), De Silva, 1985 postulated that the application of mixed feeding schedules where a high-protein diet was alternated with a low-protein diet could result in improved nutrient utilization. The applicability of mixed feeding schedules in reducing feed costs and improving nutrient utilization has been demonstrated in Indian carps, *Catla catla* and *Labeo rohita* (Nandeesha *et al.,* 1993, 1994); common carp, *Cyprinus carpio* (Srikanth *et al*., 1989; Nandeesha *et al*., 1995, 2002); Nile tilapia, *Oreochromis niloticus* (Patel and Yakupitiyage, 2003); sutchi catfish, *Pangasius hypophthalmus*; and silver carp, *Hypophthalmichthys molitrix* (Ali *et al*., 2005).

The potential of mixed feeding schedules in reducing feed costs and improving nutrient utilization has also been pointed out for species such as *Channa striata* (Hashim, 1994) and *Labeo rohita* (Saha and Ray, 1998) under laboratory conditions, and Indian major carps (Nandeesha *et al.,* 1994), common carp (Nandeesha *et al.,*1995) and tilapia under pond culture system (Patel and Yakupitiyage, 2003).In essence, a mixed feeding schedule is a strategy in which one deviates from feeding the same feed, approximately in same amount, through the growth cycle. Use of mixed feeding schedules using two diets differing in protein content have been proven to be useful for many other cultured species such as the cyprinids common carp *Cyprinus carpio* (Sreekanth *et al.,* 1989), catla, *Catla catla*, rohu, *Labeo rohita* and common carp, (Nandeesha *et al.,* 1993, 1994, 1995, 2002), Nile tilapia (Santiago and Laron, 2002; Patel and Yakupitiyage, 2003), *Channa striata* (Hashim *et al*., 1994), and on tilapia on-farm trials (Bolivar *et al.,* 2006).

Previous studies on alternate feeding strategies in aquaculture : Experiment on evaluation of mixed feeding schedules in two Indian major carps, catla (*Catla catla*) and

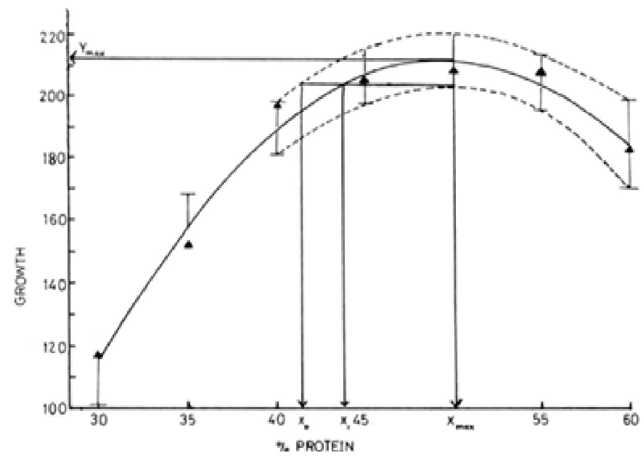

Figure 1: The second order polynomial relation (solid curve) of percent weight gain and dietary protein level, with 95% confi dence limits (dotted curves). X_0 and X_1 are the approximate protein levels which minimize cost while maintaining an adequate growth. X_{max} is the level supporting highest growth.

rohu (*Labeo rohita*), by Nandeesha *et al.* (1994) reported that growth and feed conversion efficiency indicators like specific growth rate, feed conversion rate, protein efficiency ratio, protein retention, biomass production and energy content of fish indicated feeding for 1 or 2 days with low protein diet followed by 3 days of high protein diet is the best schedule for catla. In rohu, feeding alternately with low and high protein diet or 1 or 2 days of low protein diet followed by 2 or 3 days of high protein diet were the most suitable feeding schedules.

Furthermore, Osama M, El Husseiny *et al.* (2008) observed, effect of mixed protein schedules combined with choline and betaine on the growth performance of Nile tilapia (*Oreochromis niloticus*). In this experiment, four mixed protein schedules were achieved by alternating diet (A; 31 %CP) and diet (B; 24%CP) as follows: (6 days-A), (5 days-A/1 day-B), (4 days-A/2 days-B) and (3 days-A/3 days-B).results showed that, fish fed on the 4A/2B or 3A/3B schedules utilized protein more efficiently than fish fed on the (6A) schedule. Fish fed diets supplemented with betaine (b) only showed the highest energy retention. The lowest feed cost was recorded for fish fed on (3A/3B) in the presence of betaine 0.5% and choline 0.3% in fish diet.

Wee and Wang (1987) and Hassan *et al.* (1997) observed relatively good growth in fishes feeding with 'subabul' leaf meal involving water soaking treatment (to remove mimosine) as compared to sundried and commercially processed meals. The plant protein diet was low in overall crude protein content (23.76%) than the fish meal based diet (34.42%). Feeding fish continuously with fish meal diet (schedule F) or one day with 'subabul' leaf meal diet followed by three days of fish meal diet (schedule 1S/3F) proved equally effective and better than rearing fish on schedules S and 2S/3F. Similarly, schedule 1S/3F promote better growth of fish than schedule F, in terms of average live weight gain (205.1 and 169.6% respectively) and SGR (1.39 and 1.23%/day respectively). FCR was found better with schedule 1S/3F than schedule F. However no mortality was recorded in any of these two groups of fish. Another experiment conducted by Nandeesha, M. C. *et al.* 1995 on use of mixed feeding schedules in fish culture: performance of common carp, *Cyprinus carpio* on plant and animal based protein diets, recorded that fish grown on diet A, grow the least, while there was no significant between those fed on diet B or C. Of the three mixed schedule, 2A/2C produced highest growth which has better performance as compare to control diets. Similarly Corazon B Santiago and Manule A Laron (2002) find out that Tilapia fingerlings on the 25% protein diet (H) throughout the feeding period and 2H-1L feeding schedule had the highest growth after week 7. Several studies have been carried out on the adoption of mixed feeding schedules with a number of fish species which include, catla, *Catla catla;* rohu, *Labeo rohita* and common carp, *Cyprinus carpio*

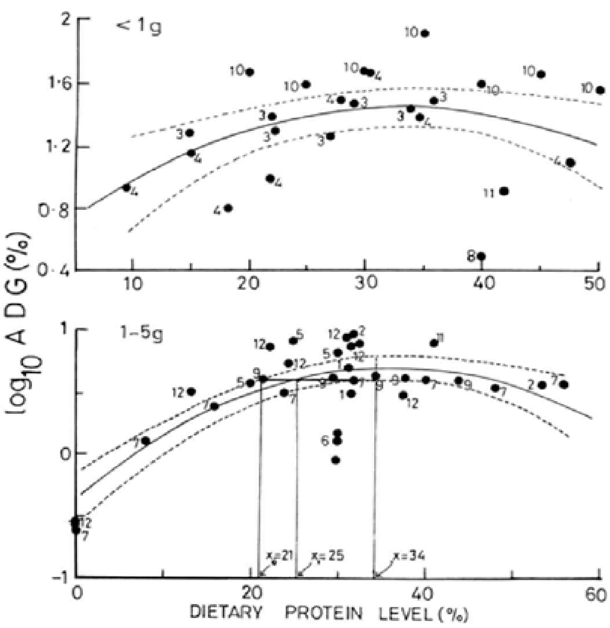

Figure 2: Relationships of % ADG of tilapias, of <1g and 1-5g body weight, to dietary protein content. Nos. 1-11 refer to the sources of information: 1, Appler (1985); 2, Appler and Jauncey (1983); 3, Davis and Stickney (1978); 4, De Silva and Perera (1985); 5, De Silva and Gunasekera (1989); 6, Jackson et al. (1982); 7, Jauncey (1982); 8, Martinez-Palacios et al. (1988); 9, Mazid et al. (1979); 10, Santiago et al. (1982); 11, Tacon et al. (1983). X, X_0 and X_1 refer to the same parameters as in figure 1.

Table 1: Previous studies on mixed feeding schedules in fish (HP - high protein, LP - Low protein)

Species	Rearing conditions	Feeding habit	Weight (g)	Feed used (%protein)	Best schedule	Authors
Catla catla	Outdoor cement tanks	Omnivore	0.5	15.9 (LP), 31.8 (HP)	1LP/3HP	Nandeesha *et al.* (1993)
C. catla	Earthen ponds	Omnivore	2.2	9.5 (LP), 42.6 (HP)	1HP/1LP	Nandeesha *et al.* (1994)
Channa striata	Indoor fibre glass tanks	Carnivore	0.6-1.0	33.5 (A), 35.1 (B), 46.7 (C)	1A/2C	Hashim (1994)
C. carpio	Earthen ponds	Omnivore	1.1-5.1	9.5 (LP), 42.6 (HP)	1HP/1LP	Nandeesha *et al.* (1994)
C. carpio	Outdoor cement tank	Omnivore	0.53	16.0 (A), 26.2 (B), 31.7 (C)	2A/2C	Nandeesha *et al.* (1995)
C. carpio	Outdoor cement tanks	Omnivore	0.3	16.7 (A), 19.7 (B), 25.6 (C), 30.9 (D)	2A/2D	Nandeesha *et al.* (2002)
Labeo rohita	Outdoor cement tank	Omnivore	0.8	15.9 (LP), 31.8 (HP)	1HP/1LP	Nandeesha *et al.* (1993)
L. rohita	Indoor plastic tanks	Omnivore	3.1-4.1	18.4 (LP), 38.9 (HP)	2LP/3HP	Mohanty & Samal (1994)
L. rohita	Earthen pond	Omnivore	2.7-20.6	9.5 (LP), 42.6 (HP)	1HP/1LP	Nandeesha *et al.* (1994)
L. rohita	Indoor plastic tanks	Omnivore	7.51	S, F, 1S/3F, 2S/3F (S/F - protein source)	1S/3F	A.K. Saha & A.K. Ray (1998)
M. peelii peelii	Indoor glass fibre tanks	Carnivore	22.8	40.6 (LP), 50.0 (HP)	1HP/1LP	Unpublished (Wu et al.)
O. niloticus	Indoor glass fibre tanks	Omnivore	0.2-1.1	18.2 (LP), 30.4 (HP)	2LP/3HP	De Silva (1985)
O. *niloticus*	Indoor glass fibre tank	Omnivore	1.9	18.0 (LP), 25.0 (HP)	1LP/2HP & 1LP/ 3HP	Santiago & Laron (2002)
O. niloticus	Earthen pond	Omnivore	0.5-1.4	33% (A), 22% (B),	2H/3L	Patel *et al.* (2003)
O. mossambicus & *O. niloticus*,	Indoor glass fibre tank	Omnivore	16.4-17.3	25% (A), 35% (B)	3A/3B	Nurulhuda Ahmad Fatan *et al.* (2005)
Oncorhynchus mykiss	Indoor glass fibre tanks	Carnivore	35.0	28.1% (A), 49% (B)	2A/2B	Sevgili H. *et al.* (2006)
O. niloticus	Earthen pond	Omnivore	0.19	36 (A), 34 (B), 31(C), 29(D)	-	Boliver *et al.* (2006)
P. hypopthalamus & *H. molitrix*	Earthen pond	Omnivore	4.9/12	1LP/1HP, 7LP/7H, 14LP/14HP	1LP/1HP	Md Zilfikar(2005)
C. mrigala	Indoor glass fibre tanks	Omnivore	2.84	20.29% (LP), 40.12% (HP)	1L/3H	R.P. Saroha & S.K. Garg (2007)
Clarias gariepinus	Indoor plastic tanks	Carnivore	1.24	25 (A), 30 (B), 35 (C)	HP	M.A. Adewolu and A. J. Adoti (2010)
L. rohita	Indoor plastic tanks	Omnivore	1.87-2.26	30 (A), 25 (B), 20 (C)	1A/1B	Pankaj Kumar *et al.* (2011)

(Nandeesha *et al.,* 2002); Nile tilapia (Santiago and Laron, 2002; Patel and Yakupitiyage, 2003; Bolivar *et al.,* 2006).

Effect of alternate feeding strategies on growth performances in fishes : Dietary formulations of solely based on plant protein ingredients have not yielded considerable results as compared to those of fish meal (Mazid *et al.,* 1979; Jackson *et al.,* 1982; Jauncey and Ross, 1982). Moreover, replacement of fish meal with plant proteins, derived from *Leucaena* leaf meal, in the diets of *O. nilolicus* (Wee and Wang, 1987), female brood *O. niloticus* (Santiago *et al.,* 1988) and *L rohita* (cf. Hasan *et al.,* 1997) also failed to yield comparable growth of fish than the respective controls.

Nandeesha *et al.,* 1993 opined that daily variation in digestibility of dry matter and protein was more pronounced in rohu as compared to *catla*, the variation in the two species also did not appear to follow a well de-fined pattern, similar to the observations made in cichlids (De Silva and Perera, 1983, 1984) and common carp (Srikanth *et al.,* 1989). The results of feeding trial in farmers' ponds clearly demonstrated that the mixed feeding schedule of a LP alternated with a HP (1LP/1HP) resulted in the best growth, feed utilization and production compared with feeding sutchi catfish and silver carp with a HP continuously. This was considered as a possible way of reducing feed cost (Srikanth *et al.,* 1989; Nandeesha *et al.,* 2002).

Compared with continuous feeding of the HP, the mixed feeding schedule of 1LP/1HP resulted in the highest fish production, net profit and protein saving. Feeding of fish with alternate day of LP and HP (1LP/ 1HP) shows that production (kg ha^{-1}) was higher in1LP/ 1HP and consequently, the net profit was reported to be much higher in this feeding schedule. Higher survival of fish with 1LP/ 1HP schedule also influenced net profit. Mixed feeding schedules also helped to reduce the nitrogen input substantially compared with continuous feeding of the HP (Nandeesha *et al.,* 1995, 2002).

Effect of alternate feeding strategies on body composition: Srikanth *et al.* (1989) reported that common carp maintained on the 1A/3B schedule, displayed better growth rate and body composition. Similarly, Nandeesha *et al.* (1994) fed Indian major carps with rice bran (low-protein diet) and a mixture of rice-bran-groundnut meal cake (high-protein diet) using mixed feeding schedules and found that fish reared on the 1A/3B schedule performed comparable growth with those fed continuously high-protein diet. It was reported that mixed feeding schedules using diets containing low and high-protein results in an increased and decreased N retention and loss, respectively, in tilapia and carps (De Silva, 1985; Nandeesha *et al*., 1993, 1994, 1995; Ali *et al*., 2005). Therefore the existence of rhythmic metabolic activities in fish indicates that they may not require a similar amount of nutrient intake daily.

In a similar study, Santiago and Laron, 2002 fed Nile tilapia fingerlings high protein (HP; 25%) or low protein (LP; 18%) diets at different feeding schedules. Weight gain was highest in fish fed the HP or LP for 23-days followed by LP for one day (2-3 HP-1LP). When the brood stock was fed HP (40%) or LP (25%), fry production was not affected by feeding schedules. However, when reproductive performance and economic evaluation were considered, brood stock on 1HP-1LP and 3HP-2LP gave the best overall performance. All these studies confirm that mixed-feeding schedule presents a viable alternative to a continuous feeding of one dietary protein level in enhancing growth and feed utilization in tilapia. Studies with snakehead, *Channa striata* fry showed higher overall growth performance and nutrient retention with the continuous 35% dietary protein feeding as compared to mixed-feeding schedules.

Thus mixed-feeding trials revealed that for several important cultured species such as carp and tilapia, it is not necessary to continuously provide an optimum dietary protein level to obtain good growth. This feeding concept thus presents new options for farmers in particular for the culture more expensive carnivorous fish which tend to require a higher protein input.

Effect of alternate feeding strategies on nutrient digestibility: De Silva (2007) defined mixed feeding schedules as feeding the fish on a high protein diet alternatively with a low protein diet, over a predetermined period of time. This concept was based on the observation that the digestibility of feed varies from day to day, following an apparent cyclic pattern (Ali *et al.,* 2005). The use of mixed feeding schedules have been proved effective as means of reducing feed cost and nitrogenous input into aquaculture systems (Nandeesha *et al*., 2002). In support to the effective use of mixed feeding, El-Sayed, 2008 reported that mixed feeding resulted in significant improvements in protein utilization efficiency, without any significant decline in growth rate of Nile tilapia. Existence of rhythmicity in digestibility of protein has been reported in *Etroplus suratensis* (De Silva and Perera, 1983) and *Oreochromis niloticus* (De Silva and Perera, 1984). Alternate admini-stration of high and low protein diet influences the growth performances of fish independ-ently of the mean dietary protein input, which is due to rhythm in certain basic metabolic activities (De Silva, 1985). Table 1 shows the previous studies on mixed feeding schedules in fish using HP - high protein, LP - Low protein in the diet.

CONCLUSION

Over the last decade, aquaculture sector has taken spectacular growth in many developing countries. As aquaculture practices have been proved to produce comparable results against food security and poverty alleviation. In this regard, global aquaculture production will continue to increase and further contribute to these needs. It has been seen that aquaculture production in most of developing countries could be achieved via extension and enlargement of semi-intensive, small-scale pond farming practices. Hence, feed and fertilizer resource availability, as well as cost, could be the major account for such development. Therefore, it can be emphasized that strategies of mixed feeding schedule lead to lower down the feed cost and also help in reducing nitrogenous and phosphorous loads into the systems. It is a strategy that does not necessarily involve a "third party" such as a feed manufacturer, and its adoption is entirely in the hands of the practitioner, which should make it so much easier to be translated into practice.

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