A Technical Overview Of Feeding Management In Epinephelinae Groupers Grow-Out Farming

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Abstract

Epinephelinae groupers are aquaculture species with high commercial value in Asian countries, including Malaysia. However, feed cost in the grow-out farming of groupers is very high (the latest report in 2020 was 86% of the total production cost) hence appropriate feeding management is necessary to minimize feed wastage and to promote fish optimum growth. This study reviewed the information available on the conventional feeding management practiced in groupers' grow-out farming (feeding frequency, food ration, and the best timing for feeding based on groupers' feeding rhythm), and potential improvement was recommended. In brief, it was found that daily frequent feeding (at least once daily), appropriate daily food ration estimation, and the best feeding timing at dusk and dawn (outside of human's routine working hours) are the challenges in the feeding management of groupers' grow-out farming. To overcome these challenges, the development and application of demand feeder in groupers' grow-out farming have been recommended.

Keywords: Feeding frequency, food rations, feeding rhythm, demand feeder

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Introduction

Mariculture of grouper is a global industry, and it is particularly important to Asian countries, including Malaysia (Rimmer and Glamuzina, 2019). In 2015, the global grouper aquaculture production was 155000 tonnes, worth a total value of USD 630 million (FAO, 2017). The techniques of grouper broodstock conditioning (*e.g.* Mustafa et al., 2015; Ranjan et al., 2017), artificial breeding (*e.g.* Mat Ali, 1996; Senoo et al., 2004; He et al., 2008), larval rearing (Sugama et al., 2012; Ma et al., 2013), nursery, and grow-out farming (SEAFDEC, 2001; Ismi et al., 2012) have been well-developed. Also, knowledge of the nutritional requirements of groupers has been well studied (Luo et al., 2005; Williams, 2009; Shapawi et al., 2019; Nankervis et al., 2022), and the formulated diets for its farming are available commercially (Shapawi et al., 2011; Bunlipatanon et al., 2014). Nevertheless, feed cost has been reported as the largest cost in grouper production (Afero et al., 2010; Petersen et al., 2013; Huang et al. 2014). Although many previous studies have been conducted to reduce the feed cost by replacing the expensive fish meal and fish oil with plants originated protein and lipid sources and discovering feeding stimulants to overcome groupers' poor feed intake on plant-based diets (Lim et al., 2014; 2015a, 2015b; 2016, 2017; Jamil et al., 2019), the issue of expensive feed cost in groupers grow-out farming is still difficult to be resolved. Recently, Dennis et al. (2020) have evidenced that the feed cost of hybrid grouper (*Epinephelus fuscoguttatus* × *E. lanceolatus*) production in Vietnam can be as high as 86% of the total production cost. Therefore, the practice of appropriate feeding management in grouper grow-out farms is necessary to avoid over-feeding, minimize feed wastage, and promote optimum growth in cultured fish. Up-to-date, studies have been conducted to determine the optimal feeding frequency, feeding level, and feeding timing for groupers. Nevertheless, these works have never been reviewed to synthesize information that is potentially useful in the field. This paper reviewed the feeding management in groupers' grow-out farming as reported in previous studies, and the potential way for improvement was discussed. Although feed type (low value fish and commercial diet or formulated feed) is also an important part of feeding management, previous studies have discussed the pros and cons of using these feeds (Sim et al., 2005; Shapawi et al., 2011; Chor et al., 2020). The feed type topic hence was not included in the present study. In the following sections, the species of groupers are mentioned only by their scientific names. Therefore, the common names of these groupers are listed in **Table 1** for reference.

Table 1. The common names of the grouper species that have been mentioned in this study.

Common names	Scientific names
Greasy grouper	*Epinephelus tauvina*
Malabar grouper	*Epinephelus malabaricus*
Mouse grouper/ humpback grouper	*Cromileptes altivelis*
Red spotted grouper/ Hong Kong grouper	*Epinephelus akaara*
Blacktip grouper/ redbanded grouper	*Epinephelus fasciatus*
Orange-spotted grouper	*Epinephelus coioides*
Malabar grouper	*Epinephelus salmoides* *(synonym to E. malabaricus)*
Sevenband grouper	*Epinephelus septemfasciatus*
Dusky grouper	*Epinephelus marginatus*

Feeding Frequency

In fish farming, it is very difficult to determine the cultured fish's appetite or hunger level. Generally, frequent feeding is necessary to ensure cultured fish satiation and optimum growth. Nevertheless, such practice can easily lead to over-feeding, causing high feed waste and water quality deterioration (Sim et al., 2005), especially when the feeding is conducted by inexperienced farm workers. Therefore, knowledge of the appropriate feeding frequency is necessary to minimize such problems. In previous studies, the feeding frequencies for groupers cultured under various conditions have been reported, and this information has been summarized in **Table 2**.

Table 2. The recommended feeding frequencies in groupers grow-out farming from previous studies

Species	Initial size (TL = total length) (BW = body weight)	Culture system (water temperature)	Feed type	Feeding duration	Experimental treatments (feeding frequencies)	Outcomes	References
Epinephelus tauvina	TL 16.2 - 16.9 cm	Floating net cages (29.2 - 31.5 °C)	Low value fishes	3 months	- Once in 5 days - Once in 4 days - Once in 3 days - Once in 2 days - Once per day - Twice per day - Thrice per day	Feeding once in 2 days provided the optimal growth, good conversion ratio and higher fish survival rate	Chua and Teng (1978)
E. malabaricus	BW 110 - 130 g	Net cages in the earthen ponds (27.5 - 31.5 °C)	Low value fish	12 weeks	- Once in 3 days - Once in 2 days - Once per day - Twice per day	Feeding once per day gave the best growth and relatively good feed conversion ratio than the other treatments	Kohno et al. (1989)
E. akaara	TL 3.41 cm	Floating net cages (27.2 - 21.4 °C)	Composed diet (CP 55 %; CL 10 %)	40 days	- Once in 2 days - Once per day - Twice per day - Four times per day - Eight times per day	The highest weight gain, good feed conversion efficiency, and also the higher survival were obtained in the “four times per day” treatment. Minimum 2 or 4 times per day was recommended.	Kayano et al. (1990)
	TL 4.7 cm	Floating net cages in indoor ponds (28.2 - 22.2 °C)	Formulated diet (CP 51.6 %; CL 12.6 %)	40 days	- Once per day - Twice per day - Four times per day - Six times per day - Eight times per day	High feeding frequencies resulted in higher weight gain, feed conversion efficiency and survival rate but the highest muscle mass and protein were obtained in the “six times per day” treatment. Feeding 4 to 6 times a day was recommended.	Kayano et al. (1993)
Cromileptes altivelis	TL 7 cm/ BW 10 g TL 12 cm/ BW 50 g	Floating net cages (28 - 31 °C)	Commercial diet (CP 53.7 - 55.22 %; CL 10.42 - 10.70 %)	90 days 120 days	- Once in 2 days - Once per day - Twice per day - Thrice per day	Twice or thrice per day gave significantly higher growth rates and lower feed conversion rates. Feeding twice a day was recommended.	Sutarmat et al. (2004)
	TL 18 cm/ BW 150 g			180 days	- Once in 3 days - Once in 2 days - Once per day - Twice per day	Twice or once per day gave significantly higher growth rates and lower feed conversion rates. Feeding once a day was recommended.	

E. fasciatus	TL 5.60 cm	FRP tanks (27.6 ± 0.6 °C)	Commercial diet (CP 48 %; CL 8 %)	33 days	- Once in 2 days - Once per day - Twice per day - Thrice per day - Four times per day - Five times per day	Feeding twice or more per day resulted in a higher growth rate. No significant difference survival rate among all treatments	Kawabe and Kohno (2014)
	TL 8.94 cm	FRP tanks (27.7 ± 0.4 °C)		38 days	- Once in 4 days - Once in 3 days - Once in 2 days - Once per day - Twice per day - Thrice per day	Feeding once or more per day resulted in a higher survival and daily growth rates	
E. coioides	BW 29.33 ± 1.08 g	Glass tanks with recirculating water (28 - 29 °C)	Formulated diet (CP 48.6 %; CL 6.9 %)	8 weeks	- Once per day - Twice per day - Thrice per day	Feeding thrice per day gave the higher weight gain but it was not significantly different with those fed once or twice per day. Feeding thrice per day increased water ammonia level hence feeding once a day to satiation was recommended	Mouhamadou Amadou et al. (2019)
E. marginatus	TL 5.0 ± 0.6 cm/ BW 1.96 ± 0.43 g	150 L circular tanks (27.9 ± 1.1 °C)	Commercial feed (CP 41.8%; CL 8.75%)	60 days	- Once per day - Thrice per day - Six times per day	Feeding 6 times per day provided the significantly higher final weight, final biomass, specific growth rate than the other treatments	de Sousa et al. (2019)
	TL 7.1±0.6 cm/ BW 6.34 ± 1.55 g			60 days	- Six times per day - Twelve times per day - Eighteen times per day	Feeding 12 times per day provided superior results for final weight, final biomass, specific growth rate, and daily weight gain than the other treatments	

According to Chua and Teng (1978), feeding low value fish once in 2 days to the floating cage cultured *E. tauvina* (TL 16.2 - 16.9 cm) was the most appropriate feeding frequency, as such practice produced the fish with optimal growth, low or good feed conversion ratio (FCR), and high survival. Similarly, Kohno et al. (1989) also reported that feeding low value fish once per day to the *E. malabaricus* (BW 110 - 130 g) cultured in earthen ponds provided the highest fish growth and the relatively better FCR than the other feeding frequencies tested. In addition, Sutarmat et al (2004) reported that feeding the commercial diet once a day was recommended for the *Cromileptes altivelis* (TL 18 cm/ BW 150 g) cultured in floating cages, to achieve the high fish growth rate and low FCR. Apparently, feeding once in a day or two, regardless of the feed type (either the low value fish or commercial diets), is the best feeding frequency for the groupers (with sizes of at least TL 16.2 cm or BW 110 g), cultured in floating cages or earthen ponds. However, the smaller sizes of groupers appear to require a higher frequency of feeding to

achieve optimal growth. Kayano et al. (1990, 1993) have demonstrated that feeding 2 - 4 times and 4 - 6 times were necessary to promote high weight gain and survival in the *E. akaara* with TL 3.41 cm and 4.7 cm, respectively. Sutarmat et al. (2004) also recommended that feeding twice per day was the best feeding frequency to promote the significantly high growth rate and low FCR in the *C. altivelis* (TL 7 cm/ BW 10 g and TL 12cm/ BW 50 g). In fact, similar results (feeding at least once a day) were also reported in the *E. fasciatus (*TL 5.60 cm and 8.94 cm) (Kawabe and Kohno, 2014), *E. coioides* (BW 29.33 g) (Mouhamadou Amadou et al., 2019), and *E. marginatus* (TL 5.0 cm/ BW 1.96 g and TL 7.1 cm/ BW 6.34 g) (de Sousa et al., 2019). Indeed, through a 60-day feeding trial, Spandri et al. (2021) recently demonstrated that the *E. marginatus* growth in the "feeding 5 days and fasting 2 days" treatment was about 15% lower significantly than those in the "feeding daily" treatment, although the former had the significantly higher feed intake than the latter. These findings were aligned with the feeding frequencies recommended for practical use in farms as reported by Sim et al. (2005), which was the reduced feeding frequency for the larger sizes (BW > 100 g) but a high feeding frequency for the smaller sizes (BW < 100 g) of groupers (as shown in **Table 3**).

Table 3. Daily feeding frequency and food rations as recommended by Sim et al. (2005).

	Daily feeding level (%ABW)	**Feeding frequency/ day**
Fish size (g)	*Low Value Fish*	
5-10	15-20	3-4
10-50	10-15	2-3
50-150	8-10	1-2
150-300	6-8	1
300-600	4-6	1
	Commercial Diet	
1-5	4.0-10.0	3-5
5-20	2.0-4.0	2-3
20-100	1.5-2.0	2
100-200	1.2-1.5	1-2
200-300	1.0-1.2	1
> 300	0.8-1.0	1

Food Ration or Feeding Level

Besides feeding frequency, food ration or feeding level is also an important criterion to ensure fish optimum feeding and growth. Chua and Teng (1982) have examined the effects of food ration on the growth performances of the *E. salmoides*, cultured in floating net cages. By feeding the low value fishes (consisting of anchovy, *Engraulis* spp., sciaenids, *Pseudosciaena* spp., and small carangids, *Selaroides* spp.) once every 2 days to the *E. salmoides* (with TL and BW approximately at 23.13 cm and 193.15 g, respectively) through an 84-day feeding trial, it was concluded that the food rations to maintain (keeping alive), optimum, and maximum food rations were 1.41%, 5.75%, and 9.0% of the fish body weight (wet), respectively. As the difference in yield between the 2% and 5% food ration treatments was much higher than that between the 5% and 9% treatments, 5% was recommended as the optimum food ration for the *E. salmoides* culture. On the other hand, Luo et al. (2006) examined the growth performances of the *E. coioides* cultured in net cages, and fed with different feeding levels. During the feeding trial that lasted for 8 weeks, the fish (initial mean weight, 10.31 ± 60.36 g) were fed with the formulated diet at the feeding levels of 0% (starvation), 0.5%, 1.0%, 1.5%, 2.0%, 2.5%, 3.0%, and 3.5% fish body weight per day (bw/d). The fish in the 0.5% treatment was fed only once a day,

while those in the others (1.0 - 3.5%) were fed twice (equal portions) a day. At the end of the experiment, it was concluded that the optimum and maintenance feeding levels for the *E. coioides* were 2.5% bw/d and 0.25% bw/d, respectively. The findings from Chua and Teng (1982) and Luo et al. (2006) were very close but slightly lower than the recommendations provided by Sim et al. (2005) for the practical feeding of groupers on a farm (**Table 2**).

Feeding Rhythms and the Optimum Timing to Feed

Circadian rhythms or the biological clocks are the physical, mental, and behavioural changes in an organism that follow a 24-hour cycle, responding primarily to ambient lightness and darkness (National Institute of General Medical Sciences, 2020). Fish possesses circadian rhythms hence it also has feeding rhythms (López-Olmeda and Sánchez-Vázquez, 2010). Knowledge of fish feeding rhythms is essential to farmers to identify the best timing for feeding and consequently, to promote optimum growth in fish farming (Noeske and Spieler, 1984; Solovyev and Gisbert, 2022). According to Mukai et al. (2013; 2016), the feeding peaks of the *E. fuscoguttatus* and *E. coioides* juveniles were observed at 08:00 h, and between 16:00 h and 17:00 h, through a study using demand feeders. On the other hand, Kohbara et al. (2014) investigated the diel-feeding rhythms of the *E. septemfasciatus*, cultured in indoor tanks and outdoor net pen, using a self-feeding device. The fish also was found to show the feeding peaks at dawn (between 06:00 h and 07:00 h) and/ or dusk (between 18:00 h and 19:00 h).

Discussion and Recommendation

Based on the literature, groupers juveniles (BW < 100 g) in grow-out farming should be fed at least once a day, but frequent feeding daily is recommended (Sim et al., 2005) for the fish to achieve optimum growth. In addition, the daily food rations for groupers juveniles can be ranged from 8 % - 20 % (fed with low value fish) or 2 % to 10 % (commercial diets) of their body weight, according to their sizes (Sim et al., 2005). Other than that, grouper juveniles' feeding rhythm was peak during the dawn and dusk hours. Apparently, these feeding requirements can be very challenging to the farmers when they are relying solely on the conventional manual (hand) feeding method by labour. Indeed, frequent feeding daily will require extra manpower when the farm is operating on a large scale. On the other hand, the variants of daily food rations for grouper juveniles according to their sizes can be easily confused or calculated wrongly by inexperience farm workers, and consequently lead to under or overfeeding (*e.g.* should the designed amount of feed be fully given to the fish when they show less excitement during feeding? Should extra feed be given when the fish are still very excited after the designed amount of feed was fully given?). In fact, environmental factors, especially water temperature (Leung et al., 1999; Jeon et al., 2020; Das et al., 2021; Thalib et al., 2021), are reported to be capable of affecting groupers' juveniles' feed intake or appetite and growth. This situation no doubt can further confuse the farmers to decide the right feed amount for feeding. On top of that, feeding groupers' juveniles outside human's routine working hours (dusk and dawn) to suit their feeding rhythm is definitely a burden to the farm management as extra labour costs could be required for this feeding operation. After considering the requirements, a machinery system that can facilitate fish demand feeding is apparently needed in the grow-out farming of groupers. A demand feeder is defined as a system that will give out food when it is triggered by cultured animals (including fish), based on their demands (Tanveer et al., 2018). With the aid of a demand feeder, it is highly possible to feed the fish frequently without extra labour costs, minimize the errors in food rations estimation, and conduct feeding outside the routine working hours of humans. In addition, the development of intelligent feeding control methods in aquaculture is now a new advancement to further ease feeding management in aquaculture (Zhou et al., 2018). Therefore, the development and application of demand feeder in grouper's grow-out farming are recommended.

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Conflict of Interests
The authors declare no conflicts of interest in this work.

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