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Demand Feeding System Using an Infrared Light Sensor for Brown-marbled Grouper Juveniles, *Epinephelus fuscoguttatus*

(Penggunaan Sensor Cahaya Inframerah dalam Sistem Suapan Permintaan untuk Juvana Kerapu Harimau, *Epinephelus fuscoguttatus*)

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ABSTRACT

In general, demand feeding devices are equipped with a mechanical trigger switch. Such a switch is not suitable for juvenile fish with a small body size, because the body weight is insufficient to trigger the feeder. An infrared light sensor that does not require the fish to push a feeder switch is more suitable for small fish. The brown-marbled grouper Epinephelus fuscoguttatus *is an important fish species in Southeast Asia. The purpose of this study was to compare the growth rates (GRs) of brown-marbled grouper juveniles reared using customised demand feeding devices with an infrared light sensor (the infrared light demand feeder (IRDF) group) and automatic feeding devices (the automatic feeder (AF) group). The results indicated that GRs of standard lengths and body weights showed no significant differences using one-way analysis of variance; however, the standard length of the IRDF group showed a tendency of a higher GR than the AF group. Although the feed conversion ratio (FCR) also showed no significant difference, the FCR of the IRDF group was more efficient, indicating that the IRDF group yielded a more desirable FCR. These results indicate that IRDF can be used in the culture of brown-marbled grouper juveniles. In view of the working schedule of the fish farm staff, IRDF are superior to other feeding devices, because they are less labour-intensive than usual tasks. We conclude that IRDF is a useful feeding system for aquaculture.*

Keywords: Brown-marbled grouper; Epinephelus fuscoguttatus*; demand feeding; infrared light sensor*

ABSTRAK

Secara umum, peranti suapan permintaan dilengkapi dengan suis pencetus mekanikal. Suis berkenaan tidak sesuai untuk ikan juvana bersaiz badan kecil kerana berat badan mereka tidak mencukupi untuk mengaktifkan peranti suapan. Sensor cahaya inframerah yang tidak memerlukan ikan untuk menolak suis peranti suapan adalah lebih sesuai untuk ikan bersaiz kecil. Kerapu harimau Epinephelus fuscoguttatus *merupakan spesies ikan yang penting di Asia Tenggara. Tujuan kajian ini adalah untuk membandingkan kadar pertumbuhan (GRs) juvana kerapu harimau yang diternak menggunakan peranti suapan permintaan yang diterapkan dengan sensor cahaya inframerah (kumpulan suapan permintaan inframerah (IRDF)) dan peranti suapan automatik (kumpulan suapan automatik (AF)). Hasil kajian menunjukkan bahawa tiada perbezaan yang signifikan dalam GRs panjang piawai dan berat badan melalui analisis varians sehala; walau bagaimanapun, panjang piawai kumpulan IRDF menunjukkan adanya kecenderungan peningkatan GR berbanding kumpulan AF. Walaupun tiada perbezaan yang signifikan pada nisbah penukaran makanan (FCR), FCR kumpulan IRDF adalah lebih efisien dan ini menunjukkan bahawa kumpulan IRDF menghasilkan FCR yang lebih wajar. Hasil kajian ini menunjukkan bahawa IRDF boleh digunakan dalam penternakan juvana kerapu harimau. Apabila jadual kerja pekerja penternakan ikan diambil kira, IRDF adalah lebih baik berbanding peranti suapan yang lain kerana ia tidak memerlukan tenaga kerja yang ramai. Kami menyimpulkan bahawa IRDF adalah satu sistem suapan yang berguna untuk akuakultur.*

Kata kunci: Epinephelus fuscoguttatus*; Kerapu harimau; sensor cahaya inframerah; suapan permintaan*

INTRODUCTION

A demand feeding system in aquaculture requires the fish to push a feeder switch in order to gain access to food (Alanärä 1996; Kohbara et al. 2003; Paspatis & Boujard 1996). This system is intended to decrease feed loss and water pollution from fish farms (Alanärä 1996; Kohbara et al. 2003). Many studies have been conducted to develop a demand feeding system for important aquaculture species, including the Atlantic salmon *Salmo salar* (Paspatis & Boujard 1996), the rainbow trout *Oncorhynchus mykiss* (Sánchez-Vázquez & Tabata 1998), the European seabass *Dicentrarchus labrax* (Covès et al. 2006, 1998; Rubio et al. 2004), the yellowtail *Seriola quinqueradiata* (Kohbara et al. 2003) and the barfin flounder *Verasper moseri* (Sunuma et al. 2007).

D. labrax fed using demand feeding systems has been reported to show considerably higher total weight gain than that fed using automatic feeding systems (Azzaydi et al. 1998). The gilthead sea bream *Sparus aurata* fed using demand feeding systems have been reported to show better feed conversion ratio (FCR) than that fed by hand (Sánchez-Muros et al. 2003). Other studies also showed that lower feed loss with demand feeding than with regular feeding systems, indicating that demand feeding systems are useful for aquaculture (Alanärä 1996; Kohbara et al. 2003).

However, demand feeding systems present several problems. For example, in the case of *D. labrax*, limited numbers of fish occupy the trigger, wherein one or two individuals shared most of the actuation number of demand feeders (Covès et al. 2006). Other problems include the quantity of food that should be provided after a fish triggers the feeder (Alanärä 1996) and appropriate time-lapse setting for the feeder.

In general, demand feeding devices have a physical trigger switch. Such a switch is not suitable for small-sized juvenile fish, because their body weight is insufficient to trigger the feeder. A light sensor that does not require the fish to push the sensor of a demand feeder offers advantages for small-sized fish. Till date, several types of demand feeders equipped with a light sensor have been developed (Amano et al. 2007; Sánchez-Vázquez et al. 1996). In this study, a demand feeding system with an infrared light sensor was developed for juvenile fish.

The brown-marbled grouper *Epinephelus fuscoguttatus* is an important species in Southeast Asia. This fish is in high demand in the market and the supply of juvenile seed fish is limited. The juvenile rearing technique of this species needs improvement. It is a demersal species that waits motionless on the tank bottom until a disturbance on the water surface signals feeding. When hungry, they swim to the surface in search of food; however, when not hungry, they do not move. Thus, this species is suitable for the demand feeding system. The purpose of the present study was to compare the growth rates (GRs) of brown-marbled grouper juveniles reared using a custom-developed demand feeding device with an infrared light sensor with those juveniles reared using an automatic feeding device.

MATERIALS AND METHODS

Brown-marbled grouper juveniles were purchased from a private fish farm. Juvenile rearing experiments were conducted in the hatchery at the Kulliyyah of Science, International Islamic University Malaysia. Fish rearing experiments were conducted using an automatic feeder (AF) and infrared light demand feeder (IRDF) in triplicates. Juveniles were distributed into six 500 L round polyethylene tanks (water volume 380 L) at a stocking density of 10 juveniles per tank. About 90% of water in each tank was exchanged every morning. Throughout the experiment, the fish were exposed to a natural photoperiod. The initial standard length (mean ± SD) of the juveniles was 105.3 ± 6.4 mm and the initial body weight was 35.1 ± 7.0 g. The water temperature was 28.0-31.5°C and salinity was 27-28 ppt.

In the AF group, the juveniles were fed using an automatic feeder (WT-180, Warmtone). About 150-170 pieces of pellets (OTOHIME EP3, Marubeni Nisshin Feed Co. Ltd., Tokyo; 3.1 mm in size, 48% crude proteins and 12% crude fats) were set to be dispensed at 0800 and 1600 daily. The amount of the pellets was decided to be enough for the fish in preliminary study. In the infrared light demand feeder group, the juveniles were fed using an IRDF. The feeder comprised an infrared light sensor (950 nm, ML5-8-430/00/115, Pepperl + Fuchs GmbH) ending in a red pellet-like knob (the target), a 360° rotating food container driven by a stepper motor and a control unit with a microcomputer. The infrared light sensor was located 20 mm below the water surface and the target was located a further 10 mm below the infrared light sensor. The demand feeder was set to dispense 10-15 pellets over a localised area. When the fish attacked the target knob, they pass across the infrared light beam and the infrared light was reflected on the sensor (Figure 1). After 3 s, IRDF began dispensing pellets under the control of the microcomputer. We established the position of the target knob by studying the visual axis of juveniles of the brown-marbled grouper (Tan et al. 2013); the results of the study showed that this axis is directed forward. Considering this visual axis and their searching posture on the tank bottom, we selected the position for the target knob at 30 mm below the water surface. In order to ensure that all pellets were eaten by the juveniles at each food delivery, there was a 3 s pause after the release of each pellet.

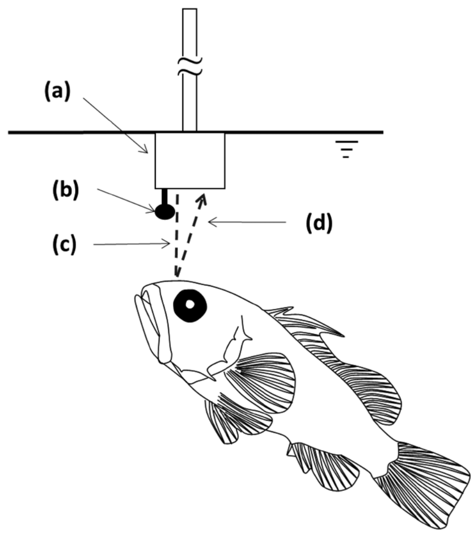

FIGURE 1. Infrared light emitted from the infrared light sensor hit the juveniles and the light was reflected back to the receiver of the sensor (a) infrared light sensor, (b) pellet-like knob, (c) emitted infrared light and (d) reflected infrared light

When the fish rearing experiments were started, the fish were trained to obtain pellets through a demand feeding system. For the first 3 days, 10–15 pellets were manually thrown to the target point several times. During these 3 days, the fish learned the position of the target point in order to obtain pellets.

In order to calculate FCR, uneaten pellets were counted before cleaning the bottom of the tank and recorded each day for 25 days. The remaining pellets in each feeder were removed, weighed and recorded. The food containers for both the experimental groups were daily re-filled to ensure freshness of the dispensed pellets.

At the beginning and end of the experiment (25 days later), all juveniles were anesthetised with Transmore® (Nika Trading Co., Malaysia) and the standard lengths and body weights were measured. GRs were calculated using the average values of the standard length and body weight in each tank.

GR for standard length (GR_{SL}), GR for body weight (GR_{BW}) and FCR were calculated at the end of the experiment (Cotton & Walker 2004; Lopez & Castello-Orvay 1995):

$$GR_{SL} = \frac{SL_f - SL_i}{SL_i} \times 100\%,$$

where GR_{SL} is the growth rate for standard length (%); SL_i is the initial standard length (mm) of the juveniles; and SL_f is the final standard length (mm) of the juveniles.

$$GR_{BW} = \frac{BW_f - BW_i}{BW_i} \times 100\%,$$

where GR_{BW} is the growth rate for body weight (%); BW_i is the initial body weight (g) of the juveniles; and BW_f is the final body weight (g) of the juveniles.

$$FCR_{adj} = \frac{W_{tp} - W_{up}}{W_f - (n \times W_t)},$$

where FCR_{adj} is the adjusted feed conversion ratio; W_{tp} is total weight of pellet given (g); W_{up} is total weight of uneaten pellet (g); W_i is the initial mean weight (g) of the fish; W_f is the final total weight (g) of the fish; and n is the number of fish remaining at the end of the experiment. FCR_{adj} was calculated to account for weight loss attributed to mortality during the experiment (Cotton & Walker 2004).

Statistical analysis was done on arcsine transformed data. The statistical comparison of the means between the two experimental groups was then performed by one-way ANOVA using IBM SPSS Statistics ver. 20 (IBM Corp., New York). The significance level was $P<0.05$ for all the tests performed.

RESULTS

FISH FEEDING BEHAVIOURS

Automatic feeder: Before juveniles of the brown-marbled grouper were fed the pellets from AF, they remained at the bottom of the tanks. When AF began to dispense the pellets, the juveniles rapidly swam towards them. Some juveniles ate the pellets at the surface, some ate those that were sinking in the middle and the others ate those that sank to the bottom.

Infrared light demand feeder: At first, a few brown-marbled grouper juveniles searched for feed near the water surface and then some of them swam just below the infrared light sensor. Subsequently, pellets dropped out of the food container of the demand feeder and were consumed by the juveniles. At the same time, other fish swam to the water surface and ate the pellets. When they had finished feeding, they returned to the bottom and the feeding behaviour ceased.

GROWTH RATES AND FEED CONVERSION RATIO

Although GRs of standard lengths (AF, 4.2%; IRDF, 6.7%) and body weights (AF, 27.1%; IRDF, 26.4%) showed no significant difference by one-way ANOVA (Figures 2 & 3), the standard length has higher tendency in the IRDF group

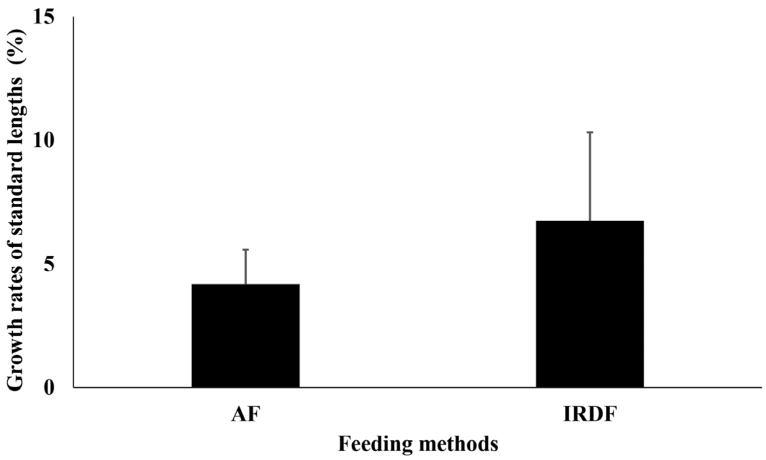

FIGURE 2. Growth rates for standard length (mean ± standard deviation) of brown-marbled grouper, *Epinephelus fuscoguttatus*, juveniles reared using an automatic feeder (AF) and an infrared light demand feeder (IRDF)

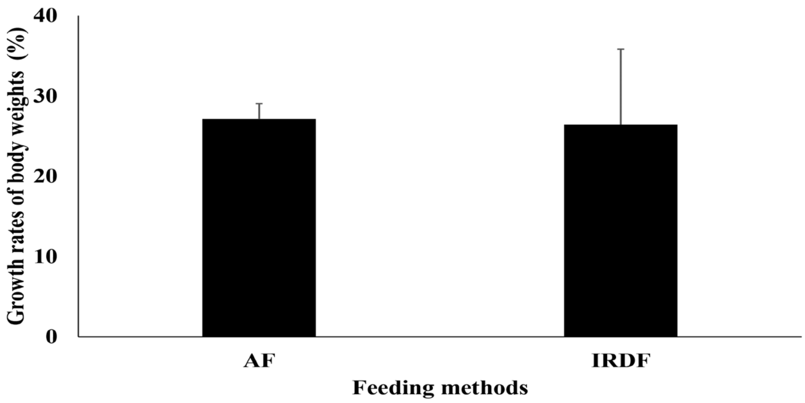

FIGURE 3. Growth rates for body weight (mean ± standard deviation) of brown-marbled grouper, *Epinephelus fuscoguttatus*, juveniles reared using an automatic feeder (AF) and an infrared light demand feeder (IRDF)

TABLE 1. Body weights, standard lengths, the adjusted feed conversion ratios (FCRadj) and mortality rates of brown-marbled grouper *Epinephelus fuscoguttatus* juveniles fed by automatic feeder (AF) and infrared light demand feeder (IRDF)

	Feeding methods	
	AF	IRDF
Final body weight (g)	42.7 ± 7.6	46.0 ± 9.3
Initial body weight (g)	33.6 ± 7.2	36.7 ± 6.4
Final standard length (mm)	110.2 ± 6.7	111.4 ± 7.4
Initial standard length (mm)	105.8 ± 5.1	104.8 ± 7.4
FCRadj	1.2695	1.2379
Mortality (%)	0	16.7

than in the AF group. Although FCR showed no significant difference, FCR of the IRDF group was more efficient, indicating that the IRDF group had a better FCR (Table 1).

DISCUSSION

IRDF group showed higher tendency in growth rate of standard length without significant differences. In addition, FCR was better in the IRDF group. Although these results suggested that our experimental conditions did not produce maximal growth, it can be inferred that IRDF can be used to rear brown-marbled grouper juveniles. In view of the working schedule of fish farm staff, demand feeders are more preferable than other feeding systems, because they relieve the staff from early morning or midnight feeding, as required by the fish. Thus, IRDF is a useful feeding system for aquaculture practices.

Only this previous study (Sánchez-Vázquez et al. 1996) used infrared light sensors as a part of demand feeding devices. The distinguishing point of the present study is that our demand feeding devices used an infrared light sensor to detect fish body as object to trigger the feeder. This method was effective for brown-marbled grouper juveniles. Fish do not need to come into contact with this sensor but they need to only pass across the infrared light beam to activate the feeder. Thus, small-sized fish can be reared using this type of sensor.

Brown-marbled grouper juveniles can learn to obtain pellets from the target point within 3 days. The yellowtail fish *S. quinqueradiata* (Kohbara et al. 2000) also learned to obtain pellets through the demand feeding system within 3 days; however, the training period required by the brown-marbled grouper was shorter than that required by other species; for example, 20 days by the gilthead sea bream *S. aurata* (Sánchez-Muros et al. 2003) and 35 days by the rainbow trout *O. mykiss* (Heydarnejad & Purser 2013). Brown-marbled grouper juveniles usually remain at the bottom of fish tanks. When they are hungry, they swim to the surface to search for food. After their feeding ceases, they return to the bottom of fish tanks until the time for the next feeding. It appears that this behaviour accounts for their shorter learning period, given that they usually show only feeding activities in fish tanks. Thus, the brown-marbled grouper is an optimum species for a demand feeding system. We speculate that other species of *Epinephelus* are similar to brown-marbled grouper and that this method can be used for those and other demersal fish species with a similar feeding behaviour.

In a preliminary rearing experiment using this IRDF, we did not use a target knob (the red knob) and found that the response of the fish to the IRDF was less consistent. After we equipped the device with a target knob under an infrared light sensor, the response of the fish became consistent. When the fish arrived closer to the target or bit at the target knob, the infrared light sensor detected their presence and pellets were released on the water surface in the feeding area.

In a study on the rainbow trout that compared latency times 2, 4, 15 and 60 s, latency times 2 and 4 s yielded better fish growth results than the longer latency times (Shima et al. 2003). The latency time of our IRDF was 3 s. In our preliminary experiment, we attempted feeding without a latency time; however, the feeders fed a large number of pellets to the fish. We then included a latency time of 3 s as the optimum latency time in this system. However, this time is only suitable for brown-marbled grouper juveniles and it might not be applicable to other fish species.

Although our experiments did not show considerably higher GRs for the IRDF group, the results demonstrate that IRDF are useful devices in aquaculture farm for rearing of brown-marbled grouper juveniles.

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