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Effect of different feed application rate on growth, survival and cannibalism of African catfish, *Clarias gariepinus* fingerlings

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Abstract: In aquaculture feeding rate is an important factor affecting the growth of fish, and thus determining the optimal feeding rate is important to the success of any aquaculture operation. In the present study aimed to investigate the effect of different feeding rate on the growth, survival, cannibalism and body composition of African catfish, *Clarias gariepinus* fingerlings (initial weight; 1.629± 0.016g). The commercial catfish feed was used and it consists of 38% protein, 5% lipid, 15% ash and 12% moisture. Four feeding rates were evaluated (2%, 5%, 8% and 12%), as a percentage of fish body weight, with three replicates per treatment. The fishes were fed twice per day at 08:30 and 17: 30 hr. At the beginning of the experiment and at 7-day intervals all the fish from each tank were collected, counted, individually measured (nearest mm) and weighed (nearest mg) for four weeks. After each sampling period, the amount of feed given was adjusted according to the biomass in each tank. Final weights were significantly greater ($p< 0.05$) than initial weights in all the feeding rate. At 8% and 12% feeding rate, *C. gariepinus* fingerlings were found to achieve maximum growth. The best feed conversion ratio (1.00±0.086) was observed in 8%, followed by (1.250±0.010) in 12% feeding rate. Significantly the highest specific growth rate (6.590±0.100) was obtained in 12% followed by (6.047±0.291) in 8% feeding rate. Fish survival did not increase by providing more feed. Cannibalism was also not reduced by providing commercial feed. The fish fed at 2% feeding rate had the highest ash contents but lowest lipid content, while the fish fed at 12% feeding rate had the highest lipid content than the other feeding rate. Based on the growth performance, feed efficiency data obtained in the present study suggest that the optimum feeding rate of 8% bw/day for African catfish, *C. gariepinus* fingerlings.

Key words: African catfish, *Clarias gariepinus*, feed application rate, larval rearing, nutrition

تغيير معدل تغذية اصبعيات اسماك القرموط الإفريقي وتأثيرها على درجات النمو والحياة والافتراس

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قسم التكنولوجيا الحيوية ، كلية العلوم التطبيقية ، جامعة AIMST ، باتو 31 / 2 بوكيت الجوية ناسى ، جالان سميلنك بدونق ، 08100 بدونق ، دار أمان ولاية كيدا ، ماليزيا

الملخص: يعتبر معدل التغذية من العوامل المؤثرة على نمو الأسماك وعلية فتحديد معدل التغذية الأمثل هو أساس نجاح عملية الاستزراع السمكي. وتهدف الدراسة الحالية تتبع تأثير التغيرات في معدلات تغذية اصبعيات (وزن إبتدائى 1,629 ± 0.016 جرام) اسماك القرموط الأفريقي على النمو ودرجة الافتراس والبقاء والتركيب الكلى للجسم. والعلف المستخدم في البحث هو علف اسماك القراميط التجاري ويتكون من بروتين 38% ودهن 5% ورماد 15% ورطوبة 12%. وشملت الدراسة تقييم أربعة معدلات تغذية كنسبة من وزن الجسم (2%, 5%, 8% و12%) بتكرارية ثلاثية لكل معدل. كذلك تمت تغذية الأسماك مرة في اليوم عند الساعة 8:30 و17:30. وبعد سبعة أيام من بداية التجربة ولمدة أربعة أسابيع تم جمع الأسماك وعدها وقياس أطوالها (اقرب مم) وأوزانها (اقرب مجم) وتم تعديل كمية العلف المضاف وفقا للزيادة الفعلية في الكتلة الحيوية. وأظهرت النتائج أن الوزن النهائي للأسماك زاد بالنسبة للوزن الإبتدائى في جميع المعاملات بدرجة ذات مغذى إحصائي مرتفع كما سجل اعلي نمو عند معدل التغذية 8% و12%. وكان معامل التحول الغذائي أعلى عند 8%(1,01 ± 0,086) يليه (1,25±0,01) عند 12%. كما سجل أعلى زيادة ذات مغذى إحصائي للوزن النوعي عند معدل التغذية 12% (6,59±0,1) يليه عند 8% (8,049 ± 0,291). وبالنسبة لدرجة البقاء فلما تزداد بزيادة كمية العلف المضاف. كما لم تتأثر درجة الافتراس باستخدام العلف التجاري. و فيما يخص التغيرات في نسبة الرماد فوصلت إلى أعلى مستوى في أجسام الأسماك عند 2% معدل تغذية مع اقل محتوى دهني وسجل أعلى مستوى للدهن في أجسام الأسماك عند 12%. وبناء على النتائج التي تم التوصل لها في هذا البحث فإن معدل التغذية عند 8% من وزن الأسماك هو المعدل الأمثل.

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Introduction

Over the years with the increasing popularity of aquaculture, feed has become one of the most expensive elements. Feed management in terms of optimization of feeding rate is essential in culture of marine and freshwater fishes and it has become one of the crucial areas of research in the field of aquaculture. Hence, to reduce excessive expenses, numerous studies have been focused on the feeding rate of fish species (Qin and Fast, 1996; Dong-Fang et al., 2003). Feeding rates vary across species and at each developmental stage and this has driven research to be focused on these areas. Overfeeding and waste food disrupts the water quality (Ng et al., 2000) while inadequate food supply has direct impact on production cost (Mihelakakis et al., 2002). Several factors influence the feeding rate in culture system. These include fish size, species and rearing systems (Cho et al., 2003). Feeding rate is also influenced by the presence of the nutrients in the feed (Mihelakakis et al., 2002). By controlling the feeding rates, farmers can successfully reduce cost; maximize growth whilst managing other factors such as individual size variation and water quality which are deemed important in rearing of fish in culture conditions (FAO, 1999). Feeding rate is an important factor affecting the growth of fish, and thus determining the optimal feeding rate is imperative to the success of any aquaculture operation. Therefore, this study has been conducted to assess the effect of feeding rate on the growth, survival, cannibalism and body composition of African catfish, *Clarias gariepinus* fingerlings.

The African catfish (*Clarias gariepinus*) is locally known as Ikan keli and belongs to the family Clariidae. It is a native fish species in African countries and it has been introduced and commercially cultured in several countries in Europe (Netherlands, Germany, Belgium) and Asian countries (Indonesia, Thailand, Malaysia) and South America (Brazil). It is one among the highly demanded freshwater food fish and cultivable species in Malaysia and elsewhere because of its resistance to diseases, ability to tolerate a wide range of environmental parameters and high stocking densities under culture conditions, relative fast growth rate, and good quality meat (Hogendoorn, 1980; Huisman and Richter, 1987; Haylor, 1991; Goos and Richter, 1996). The African catfish inhabits in a wide range of water bodies like swamps, lakes and rivers. They are hardy and are able to thrive in harsh environmental conditions in muddy, turbid and oxygen depleted water bodies with the help of their accessory air-breathing organ (labyrinth organ) that allows them to breathe atmospheric oxygen. Generally, they are omnivores feeding nature. They feed on insects, plankton, snails, plant matter in the natural water bodies (Bruton, 1979; Uys, 1989). However, this species is highly cannibalistic when substantial differences in size occur (Baras and Jobling, 2002). In Malaysia, however its full aquaculture potential has not yet been realized. The objective of the study was to evaluate the effects of different feeding rates on growth performance, food conversion and survival, cannibalism, of *C. gariepinus* fingerlings which would lead to better larval rearing management during the critical period of larval phase.

Materials and methods

The feeding trial was performed at AIMST University, Malaysia. Brood fishes were obtained from a private fish farm, Sungai Petani, Malaysia. Ripe females and males with an average weight of (750 ± 75g) were selected based on the method of Viveen et al. (1985) for induced breeding. Larvae were fed exclusively on unhatched, decysted *Artemia* for a period of 5 days from 48 h after hatching, and then weaned gradually by supplementing the *Artemia* with a commercial diet. The following 2 weeks the larvae were fed with commercial diet (38% protein, 5% lipid, 15% ash and 12% moisture). Two weeks prior to the start of the feeding trials, 120 fish were selected and acclimated to 12 experimental plastic tanks (25 L capacity) at 10 fish per/tank. During the acclimation period the fishes were fed with the same commercial diet twice daily fed *ad libitum*. De-chlorinated municipal tap water was used throughout the experiments. Each

tank was supplied with air stone to maintain supplemental aeration. At the start of feeding trial the acclimated fish were deprived of feed for 24 hrs, pooled, and 12 groups each of 10 fish with the initial mean weight of 1.629± 0.016 g (mean ± SD) were randomly stocked into 12 experimental tanks. Four feeding rates (2%, 5%, 8% and 12% of body weight) with three replicates per treatment were tested. The fishes were fed twice per day on a daily basis at 08:30 and 17: 30 hr.

At the beginning of the experiment and at 7-day intervals all the fish from each tank were collected, counted, individually measured (nearest mm) and weighed (nearest mg) for four weeks. Approximately 80% of the water of each tank was exchanged with freshwater two times daily, in the morning (08.00 hrs) and in the evening (16.30 hrs). Leftover feed and waste excreta were also removed twice a day by siphon pipe with minimal disturbance to the fish. After each sampling period, the amount of feed given was adjusted according to the biomass in each tank. In order to quantify cannibalism, all fish from each tank were removed at 7-day intervals and counted before being returned to the tank. Cannibalism was calculated by recording the difference in fish numbers between each count, reduced by the recorded natural mortality (Qin and Fast, 1996). Dead fish in each tank were recorded daily. Dead or eaten fish were not replaced during the experiment.

The water quality parameters like pH, water temperature and dissolved oxygen (DO) level were measured weekly once. At the end of four weeks feeding trials, fish were deprived of feed for 24 hr, captured and bulk weighed individually in all the treatments. Five fishes were sampled from each group for the determination of whole body composition. The sampled fish were frozen at −20°C until analysis. The crude protein, lipid, and ash contents of experimental fishes were determined by standard methods (AOAC, 1984). Mean wet weight gain, specific growth rate (SGR) [(ln final weight)-(ln initial weight)/Number of days] X100; and feed conversion ratio (FCR) [dry feed fed (g)/wet weight gain (g)] were estimated followed by Lee et al (2000). All experimental data like final mean weight, survival and SGR, FCR were analysed using one way analysis of variance to determine the significant difference among the feed application rate. Differences between mean values were assessed by Duncan's multiple range tests using SPSS package version 11. Effects with a probability of ($P< 0.05$) were considered significant (Lee et al., 2000).

Results

Water quality parameters such as temperature, pH and dissolved oxygen were given in Table 1. Mean temperature and pH, were found to be not affected by feed application rates during the four weeks feeding trial. However dissolved oxygen levels decreased significantly with increasing feed application rate (Table 1).

Table 1. Water quality parameters (temperature, pH and dissolved oxygen) at different feeding rates.

	Feeding rate			
Parameters	**2%**	**5%**	**8%**	**12%**
Temperature (^{0}C)	27.38±0.08	27.13±0.03	27.29±0.02	27.36±0.02
pH	6.32±0.03	6.31±0.08	6.24±0.03	6.22±0.02
Dissolved Oxygen (mg/L)	4.64±0.28	3.89±0.44	2.35±0.34	2.24±0.20

Growth performance of African catfish fingerlings fed with different feed application rate was presented in Table 2. Initially *C. gariepinus* fingerlings, had similar weight, and exhibited no significant difference among the treatment ($p< 0.05$). After, 28 days of feeding trial, final fish weight and growth generally showed a linear increase with increasing feeding rate (Figure 1). The highest growth (8.716±0.356) was observed in fish fed with 12% followed by (7.250±0.686) at 8% whereas, the lowest value (0.787±0.055) was

found in 2% feeding rate. Daily specific fish growth rates for feeding rate at 2%, 5%, 8% and 12 % of body weight were 1.417±0.091, 3.393±0.170, 6.047±0.291 and 6.590±0.100 respectively. Significantly highest specific growth rate was observed in 12% feeding rate fed groups ($p< 0.05$). Significantly the best FCR (1.00 ±0.086) was also observed in the 8% feed application rate fed groups whereas no difference was noticed in all the remaining treatments. Significantly highest survival was recorded in 2% and 5% feed application rate fed groups. No natural mortalities were observed in all the experimental groups and it was noticed that all the mortalities is due to cannibalism. There was no significant difference in survival rate among the fish fed at different feed application rate ($P<0.05$). The cannibalism was noticed in all the feeding groups and the cannibalism rate was not reduced by increasing the feed application to fishes. Size variation in fish length was observed in all the treatments except 2% feed application rate fed groups. At all feeding rate, most small fingerlings were cannibalized and all treatments had a few large individuals at the end of feeding trail. No significant differences in protein content were observed in fish fed with 5%, 8% and 12% feed application rate whereas lowest protein content was observed in 2% feed application rate. Significantly linear increase in lipid content was observed in increase in feed application rate ($P<0.05$). The highest lipid content was reordered in fish fed at 12% followed by 8% body weight per day ($P>0.05$, Table 3). The fish fed at 2 and 5% body weight per day had lower lipid content ($P<0.05$).

Table 2. Effect of different feeding rate on growth performance and survival of *C. gariepinus* fingerlings.

Feeding rate	Initial weight (g)	Final weight (g)	Growth (g)	SGR* (%/day)	FCR**	Survival Rate (%)	Cannibalism Rate (%)
2%	$1.613±0.019^{b}$	$2.397±0.040^{d}$	$0.787±0.055^{d}$	$1.417±0.091^{d}$	$1.343±0.108^{b}$	$96.67±5.77^{a}$	$6.6±5.77^{a}$
5%	$1.641±0.012^{a}$	$4.247±0.192^{c}$	$2.607±0.195^{c}$	$3.393±0.170^{c}$	$1.347±0.077^{b}$	$86.67±5.77^{ab}$	$13.33±5.77^{a}$
8%	$1.631±0.08^{ab}$	$8.883±0.681^{b}$	$7.250±0.686^{b}$	$6.047±0.291^{b}$	$1.00±0.086^{a}$	$80.00±10^{b}$	$20.00±10.00^{a}$
12%	$1.634±0.014^{ab}$	$10.350±0.367^{a}$	$8.716±0.356^{a}$	$6.590±0.100^{a}$	$1.250±0.010^{b}$	$86.67±5.77^{ab}$	$13.337±5.77^{a}$

Mean values given in the same column having the similar superscript are not significantly different at ($p<0.05$). Each value is the mean of three replicates and standard deviation. SGR* - specific growth rate; FCR**- Food conversion ratio.

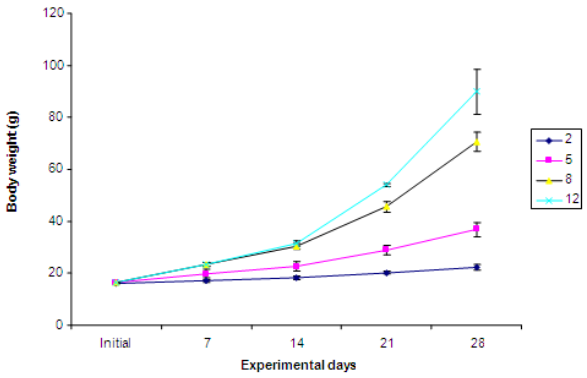

Figure 1. Effect of different feeding rate on the weight increment of *C. gariepinus* fingerlings fed with 4 weeks.

Discussion

In the present study the increased rate of feed application associated with increased amount of feed offered to fishes influenced the decreased water quality with respect to dissolved oxygen, however the parameters like temperature, pH and dissolved oxygen were within the appropriate ranges for catfish culture and no apparent influence of these parameters on catfish growth was recorded. In the present study the feeding rate presented a significant effect on all the growth performance and feed efficiency indices. It is obvious that the feeding rate is one of the main limitation factors for growth of fishes. Similar results were observed for cobia (*Rachycentron canadum*) juvenile, which presented a greater SGR when fed with

7% body weight/day, rather than with 3% body weight/day (Sun et al., 2006). Other fish species like bagrid catfish juveniles (*Mystus nemurus*), European sea bass (*Dicentrarchus labrax*) Channel catfish (*Ictalurus punctatus*) and Pacu (*Piaractus mesopotamicus*) also presented greater growth when fed with higher feeding rates rather than smaller (Borghetti and Canzi, 1993; Robinson and Li, 1999; Ng et al., 2000; Eroldogan et al., 2004). The fish fed at 8% body weight per day exhibited the best FCR among the feed application rate fed groups ($P<0.05$), while there were no significant differences in FCR among the fish fed at 2, 5, and 12% body weight per day ($P>0.05$). Feed ration greater than optimum feed level would increase the waste food, increase the feed conversion ratio and also deteriorate water quality (Marian et al., 1982, Anderson and Fast, 1991).

Table 3. Carcass composition of African catfish *C. gariepinus* fingerlings fed with different feeding rate (mean ±SD) mean with three replicates.

Carcass composition (on a dry weight basis)	Different feed application rate				
	Initial	2%	5%	8%	12%
Protein (%)	53.87±0.82^{ab}	52.72±0.63^{b}	54.82±0.75^{a}	53.76±0.68^{ab}	54.74 ±0.65^{a}
Lipid (%)	7.16±0.15^{d}	4.56±0.26^{e}	8.33±0.31^{c}	8.33±0.12^{b}	12.86±0.16^{a}
Ash (%)	14.12±0.16^{d}	20.26±0.65^{a}	17.85±0.78^{b}	15.79±0.70^{c}	14.51±0.72^{d}

Values in same row with different superscripts are statistically different ($P<0.05$)

In the present study, different feed application rate did not significantly affect body composition especially protein content of African catfish fingerlings, whereas body lipid content of the fish fed at 12 and 8% body weight per day was higher than that of the fish fed at 2 and 5% body weight per day fed groups. It has been demonstrated that, low body lipid content of fish resulted from fish fed with less than optimum feed application rate (Chua and Teng, 1982, Fiogbe and Kestemont, 2003, Van Ham et al., 2003, Puvanendran et al., 2003, Bureau et al., 2006) and declined feeding frequency (Andrews and Page, 1975; Chua and Teng 1978; Kayano et al., 1993; Ruohonen et al., 1998; Wang et al., 1998; Lee et al., 2000 and Dwyer et al., 2002).

Daily feed application rate of 8% body weight may be optimum rate for the fingerlings of African catfish *C. gariepinus*, since with our investigation below this level of feeding rate reduced the growth and feed efficiency indices. In general, food conversion ratio increases with increased feed application rates above the optimal rate. Earlier authors have also reported different optimal feeding rate in different fish species. Optimum feed application rate of other fish species *Channa striatus* (5% body weight), *Clarias fuscus* (6% body weight) tambaqui, *Colossoma macropomum* (10%) (Qin and Fast, 1996; Andreson and Fast, 1991; Silva et al., 2007). Hogendoorn (1981) and Hogendoorn et al. (1983) reported that a daily ratio of 10% body weight was optimum for 0.5 g juvenile *C. gariepinus*. Qin and Fast (1996) found that feed application rate greater than 5% per day with juvenile snakehead could even reduce growth, apparently due to increased surfacing and swimming activities. In several fish species, including *C. gariepinus*, a decrease in cannibalism has been reported with increased food availability (Fox, 1975; Polis, 1981; Hecht and Pienaar, 1993). In the present study our initial assumption was that increased feed application rate could reduce the cannibalism and increase the survival rate of carnivorous cannibalistic fishes. Contrast we found that, increase the feed application rate did not reduce cannibalism and increase the survival rate. The substantial size differences in fish existed in all the feeding rate fed groups except 2% feed application rate fed groups. According to Grobler et al. (1992) and Van der Waal (1998) a considerable growth variation has been exhibited in African catfish both in aquaculture and in nature. The heterogeneity in size often leads to social dominance, which results in aggressive behaviour and

cannibalistic responses (Hecht and Appelbaum, 1988). Diana and Fast (1989) and Anderson and Fast (1991) reported strongly size-dependent mortality in *C. fuscus* whereby most of the mortality occurred in fish weighing 5.4–26.9g. Qin and Fast (1996) reported that in snakehead *C. striatus*, large variation in fish size in the stocked individuals may not only increase the cannibalism but can also increase other mortalities due to injuries. Size variation in fishes caused by either genotype differences or inadequate food supply has already been found to be a major cause of cannibalism (Hecht and Appelbaum, 1988). Further, De Angelis et al. (1979) reported that minimizing the size variation could be more important than the availability of food for controlling cannibalism. Conversely another study by Martins et al. (2005) reported that size variation had no significant effect on the growth performance of African catfish.

In the present study, it appears that the daily feed application rate of 8% body weight was near to optimum when the fish grew from 1.6 to 10.3g. The results suggest that, although a feeding rate of 12% gave the highest growth performance, *C. gariepinus* should be fed at the rate of 8% body weight per day, considering feed conversion efficiency, muscle quality and growth performance into account.

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References

Anderson, M. J. and A. W. Fast. 1991. Temperature and feed rate effects on Chinese catfish, *Clarias fuscus* (Lacepede), growth. Aquacul. Res. 22:443–445.

Andrews, J. W. and J. W. Page. 1975. The effect of frequency of feeding on culture of catfish. Transact. Am. Fish. Soc. 105:317–321.

Association of Official Analytical Chemists (AOAC) 1984. In: Official methods of Analysis. 13th edition, Arlington, Virginia, USA.

Baras, E. and M. Jobling. 2002. Dynamics of intracohort cannibalism in cultured fish. Aquacul. Res. 33:461– 479.

Borghetti, J. R. and C. Canzi. 1993. The effect of water temperature and feeding rate on the growth rate of pacu (*Piaractus mesopotamicus*) raised in cages. Aquacult. 114:93-101.

Charles, P. M., S. M. Sebastain, M. C. V. Raj and M. P. Marian. 1984. Effect of feeding frequency on growth and food conversion of *Cyprinus carpio* Fry. Aquacult. 40:293-300.

Bruton, M. N. 1979. The food and feeding behaviour of *Clarias gariepinus* (Pisces; Clariidae) in Lake Sibaya, South Africa, with emphasis on its role as a predator of cichlids. Tratis. Zool. Soc. London. 35:47-1 14.

Bureau, D. P., K. Hua and C. Y. Cho. 2006. Effect of feeding level on growth and nutrient deposition in rainbow trout (*Oncorhynchus mykiss* Walbaum) growing from 150 to 600g. Aquacult. Res. 37:1090–1098.

Cho, S. H., Y. S. Lim, J. H. Lee and S. Park. 2003. Effect of feeding rate and feeding frequency on survival, growth, and body composition of ayu post-larvae *Plecoglossus altivelis*. J. World Aquacult. Soc. 34**:**85–91.

Chua, T. and S. Teng. 1978. Effect of feeding frequency on the growth of young estuary grouper, *Epinephelus tauvina* (Forskal), cultured in floating net-cages. Aquacult. 14**:**31–47.

Chua, T. and S. Teng. 1982. Effects of food ration on growth, condition factor, food conversion efficiency, and net yield of estuary grouper, *Epinephelus salmoides* maxwell, cultured in floating net-cages. Aquacult. 27:273–283.

De Angelis, D. L., D. K. Cox and C. C. Coutant. 1979. Cannibalism and size

dispersal in young of the year Largemouth Bass: Experiment and Model. Ecol. Model. 8:133-148.

Diana, J. S. and A. W. Fast. 1989. The effects of water exchange rate and density on the yield of the walking catfish, *Clarias fuscus*. Aquacult. 78:267–276.

Dong-Fang, D., S. Koshio, S. Yokoyama, S. C. Bai, Q. Shao, Y. Cui and S. S. O. Hung. 2003. Effects of feeding rate on growth performance of white sturgeon (*Acipenser transmontanus*) larvae. Aquacult. 217:589-598.

Dwyer, K. S., J. A. Brown, C. Parrish and S. P. Lall. 2002. Feeding frequency affects food consumption, feeding pattern and growth of juvenile yellowtail flounder (*Limanda ferruginea*). Aquacult. 213:279–292.

Eroldogan, O. T., M. Kumlu and M. Aktas. 2004. Optimum feeding rates for European sea bass *Dicentrarchus labrax* L. reared in seawater and freshwater. Aquacult. 231:501–515.

FAO (Food and Agriculture Organization) 1999. Africa Regional Aquaculture Review. Food and Agriculture Organization, Rome.

Fiogbe, E. D. and P. Kestemont. 2003. Optimum daily ration for Eurasian perch *Perca fluviatilis* L. reared at its optimum growing temperature. Aquacult. 216:243–252.

Fox, L. R. 1975. Cannibalism in natural populations. Ann. Rev. Ecol. System. 6:87–106.

Goos, H. J. T. and C. J. J. Richter. 1996. Internal and external factors controlling reproduction in the African catfish, *Clarias gariepinus*. In: M. Legendre and J. P. Proteau (Eds.), The Biology and Culture of Catfishes. Aquatic Living Resources. 9:45–58.

Grobler, J. P., H. H. Du Preez and F. H. Van der Bank. 1992. A comparison of growth performance and genetic traits between four selected groups of African catfish (*Clarias gariepinus* Burchell 1822). Comp. Biochem. Physiol. 102:373-377.

Haylor, G. S. 1991. Controlled hatchery production of *Clarias gariepinus* (Burchell 1882): growth and survival of fry at high stocking density. Aquacult. Fish. Manage. 22:405–422.

Hecht, T. and S. Appelbaum. 1988. Observations on intraspecific aggression and coeval sibling cannibalism by larval and juvenile *Clarias gariepinus* (Clariidae: Pisces) under controlled conditions. J. Zool. 214:21- 44.

Hecht, T. and A. G. Pienaar. 1993. A review of cannibalism and its implications in fish larviculture. J. World Aquacult. Soc. 24:246–261.

Hogendoorn, H. 1980. Controlled propagation of the African catfish, *Clarias lazera* (CandV), 111. Feeding and growth of fry. Aquacult. 21:233–241.

Hogendoorn, H. 1981. Controlled propagation of the African catfish, *Clarias gariepinus* (C. and V.). IV. Effect of feeding regime in fingerling culture. Aquacult. 24:123–131.

Hogendoorn, H., J. A. J. Jansen, W. J. Koops, M. A. M. Machiels, P. H. van Ewijk and J. P. van Hees. 1983. Growth and production of the African catfish, *Clarias gariepinus* (C. and V.). II. Effects of body weight, temperature and feeding level in intensive tank culture. Aquacult. 34:265–285.

Huisman, E. A. and C. J. J. Richter. 1987. Reproduction, growth, health control and aquaculture potential of the African catfish *Clarias gariepinus* (Burchell, 1822). Aquacult. 63:1–14.

Kayano, Y., S. Yao, S. Yamamoto and H. Nakagawa. 1993. Effects of feeding frequency on the growth and body constituents of young red spotted grouper, *Epinephelus akaara*. Aquacult. 110:271–278.

Lee, S. M., U. G. Hwang and S. H. Cho. 2000. Effects of feeding frequency and dietary moisture content on growth, body composition and gastric evacuation of juvenile Korean rockfish (*Sebastes schlegeli*). Aquacult. 187:399–409.

Marian, M. P., A. G. Ponniah, R. Pitchairaj and M. Narayanan. 1982. Effect of feeding frequency on surfacing activity and growth in the air breathing fish, *Heteropneustes fossilis*. Aquacult. 26:237–244.

Martins, C. I. M., M. Aanyu, J. W. Schrama and J. A. J. Verreth. 2005. Size distribution in African catfish (*Clarias gariepinus*) affects feeding behaviour but not growth. Aquacult. 250:300– 307.

Mihelakakis, A., C. Tsolkas and T. Yoshimatsu. 2002. Optimization of feeding rate for hatchery-produced juvenile gilthead sea bream *Sparus aurata*. J. World Aquacult. Soc. 33:169-175.

Ng, W. K., K. S. Lu, R. Hashim and A. Ali. 2000. Effects of feeding rate on growth, feed utilization and body composition of tropical bagrid catfish. Aquacult. Internat. 8:19–29.

Polis, G. A. 1981. The evolution and dynamics of intra-specific predation. Ann. Rev. Ecol. System. 12:225–251.

Puvanendran, V., D. L. Boyce and J. A. Brown. 2003. Food ration requirements of 0+ yellowtail flounder *Limanda ferruginea* (Storer) juveniles. Aquacult. 220:459–475.

Qin, J. and A.W. Fast. 1996. Effects of feed application rates on growth, survival, and feed conversion of juvenile snakehead (*Channa striatus*). J. World Aquacult. Soc. 27**:**52–56.

Robinson, E. H. and M. H. Li. 1999. Effect of dietary protein concentration and feeding rate on weight gain, feed efficiency, and body composition of pond-raised channel catfish *Ictalurus punctatus*. J. World Aquacult. Soc. 30:311–318.

Ruohonen, K., J. Vielma and D. J. Grove. 1998. Effects of feeding frequency on growth and food utilization of rainbow trout (*Oncorhynchus mykiss*) fed low-fat herring or dry pellets. Aquacult. 165:111–121.

Silva, C. R., L. C. Gomes and F. R. Brandao. 2007. Effect of feeding rate and frequency on tambaqui (*Colossoma macropomum*) growth, production and feeding costs during the first growth phase in cages. Aquacult. 264:135-139.

Sun, L., H. Chen, L. Huang and Z. Wang. 2006. Growth, faecal production, nitrogenous excretion and energy budget of juvenile cobia (*Rachycentron canadum*) relative to feed type and ration level. Aquacult. 259:211–221.

Uys, W. 1989. Aspects of the nutritional physiology and dietary requircmcnts of juvenile and adult sharptooth catfish, *Clurias gariepinus* (Pisces: Clariidae). Ph.D. Thesis, Rhodes University, South Africa.

Van der Waal, B. C. W. 1998. Survival strategies of sharptooth catfish *Clarias gariepinus* in desiccating pans in the northern Kruger National Park, Koedoe. 41:131–138.

Van Ham, E. H., M. H. G. Berntssen, A. K. Imsland, A. C. Parpoura, S. E. Wendelaar Bonga and S. O. Stefansson. 2003. The influence of temperature and ration on growth, feed conversion, body composition and nutrient retention of juvenile turbot (*Scophthalmus maximus*). Aquacult. 217:547–558.

Viveen, W. J. A. R., C. J. J. Richter, P. G. W. J. van Oordt, J. A. L. Janssen and E. A. Huisman. 1985. Practical manual for the culture of African catfish *Clarias gariepinus*. The Netherlands Ministry for Development Co-operation, Section for Research and Technology. The Hague, The Netherlands. pp.122.

Wang, N., R. S. Hayward and D. B. Noltie. 1998. Effect of feeding frequency on food consumption, growth, size variation, and feeding pattern of age-0 hybrid sunfish. Aquacult. 165:261–267.