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Growth Performance and Postprandial Metabolic Responses of Southern Catfish (*Silurus meridionalis* Chen) Fed Formulated Feed and Loach Flesh

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Abstract: Growth and postprandial metabolic responses of juvenile Southern catfish, *Silurus meridionalis* Chen fed either formulated feed or loach flesh were investigated at 27.5°C. The feeding rate of loach flesh was significantly lower ($p<0.05$) but the specific growth rate was significantly higher than that of formulated feed. Both feed efficiency and protein efficiency ratio of loach fresh were significantly higher than those of formulated feed. The specific dynamic action duration and coefficient of loach flesh were significantly smaller than those of formulated feed. The results suggested that Southern catfish was more adaptive to loach flesh. The postprandial metabolic response might partly explain the observed differences in nutrient utilization between the two foods.

Key words: Formulated diet, growth performance, *Silurus meridionalis* chen, specific dynamic action

INTRODUCTION

The Southern catfish, *Silurus meridionalis* Chen is the most widely cultured carnivorous catfish in China. Nutritional requirements of juvenile Southern catfish have been studied in recently years which provide useful information for commercial diets (Fu and Xie, 2005; Fu, 2005; Fu and Cao, 2006) and formulated feed is available, but farmers also use low-cost fish flesh as feed. No comparative data for catfish fed formulated feed and fish flesh are available.

Metabolic rate increases in response to feeding, a phenomenon commonly referred to as specific dynamic action (SDA). SDA represents the summed energy expended on the ingestion, digestion, absorption and biochemical processing of a meal (Jobling, 1981; Beamish and Trippel, 1990; Brown and Cameron, 1991; Lyndon *et al*., 1992), which represent a large portion of the energy budget of Southern catfish (Fu *et al*., 2005), so measures of postprandial metabolic responses would be useful data in comparative studies of fish fed formulated feed or fish flesh.

Southern catfish were given either formulated feed or loach flesh and measurement of food consumption, nutrient utilization, growth performance and postprandial metabolic responses were then undertaken with the aim of exploring the two foods on ingestive, post-ingestive and performance-related responses.

MATERIALS AND METHODS

Experimental Diet

The feed was formulated based upon results of previous studies (Fu and Xie, 2005). Fishmeal was used as the protein source, corn oil as supplemental fat and precooked cornstarch (15 min at 120°C)

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Table 1: Formulation and proximate composition of the feeds used in experiment (% Dry weight).

Ingredients	Formulated feed	Loach flesh
Fish meal[1]	56.20	
Corn starch[1]	15.00	
Corn oil	6.06	
Micro-crystal cellulose	15.74	
Mineral and vitamin mix[2]	5.00	
Carboxymethyl cellulose	1.50	
Moisture	39.99	78.20
Protein	40.13	72.08
Lipid	10.50	14.53
Digestible carbohydrate	15.72	0.30
Ash	12.63	10.76
Energy (kJ g^{-1})[3]	17.75	22.75
P: E (mg kJ^{-1})	22.61	31.68

[1]Fish meal: commercially available, moisture, 6.68%; crude protein, 71.10% dry matter; crude lipid, 8.66% dry matter. Corn starch: commercially available, moisture, 12.03%; carbohydrate, 98.19% dry matter, crude protein, 0.28% dry matter, crude lipid, 0.75% dry matter.

[2]Mineral premix (mg kg^{-1} diet): NaF, 2 mg; KI, 0.08 mg; $CoCl_2.6H_2O$, 1 mg; $CuSO_4.5H_2O$, 10 mg; $FeSO_4.H_2O$, 74 mg; $ZnSO_4.H_2O$, 50 mg; $MnSO_4H_2O$, 60 mg; $MgSO_4 7H_2O$, 1000 mg; $K_2HPO_3 3H_2O$, 6000 mg; $NaH_2PO_3 2H_2O$, 5000 mg; NaCl, 100 mg; $CaCO_3$, 4 g; Vitamin premix (mg or IU kg^{-1} diet): B_1, 20 mg; B_2, 40 mg; B_6, 20 mg; B_{12}, 0.1 mg; K_3, 10 mg; inositol, 1000 mg; pantothenic acid, 60 mg; niacin acid, 200 mg; H, 1.23 mg; A, 25000IU; D, 2500IU; E, 1200 mg; C, 2112 mg; choline chloride, 2500 mg.

[3]The dietary energy was calculated on the basis of 23.6, 39.5 and 17.2 kJ g^{-1} of protein, lipid and digestible carbohydrate

as the carbohydrate source. Before each feeding, moisture feeds were made into soft pellets with the same weight (0.35±0.02 g) by a special apparatus (Fu and Xie, 2005). Small pieces (1.00±0.02 g) of flesh of loach, *Misgurnus anguillicaudatus* purchased from a local market were used as the other feed. The ingredients and proximate compositions of the formulated feed and loach flesh are listed in Table 1.

Animals and Acclimation

Juvenile catfish, obtained from local farmers, were acclimatized for two weeks, during which they were fed to satiation on either formulated feed or loach flesh every other day. Feeding experiment was carried out in a rearing system in which dechlorinated freshwater from a holding tank was recirculated through biological filters. The system had 60 round 5 L plastic tanks. Water flow rate through each tank was about 0.5 L min^{-1}. Continuous aeration was supplied to each tank through air stones attached to an air blower. The water temperature was maintained at 27.5±0.2°C, oxygen content was kept above 5 mg L^{-1}, the pH ranged from 6.5 to 7.3 and ammonia-N ranged from 0.005 to 0.025 mg L^{-1} during the experiment period. A 14L: 10D photoperiod was used to simulate natural light cycle.

Growth Experiment

Thirty fish were randomly selected for each treatment and fed to satiation with each diet once daily (18:00) individually. According to composition of diet and loach flesh and the pellet numbers ingested by tested fish, feed intake was estimated. The flesh but not whole fish was used because it was easy to be quantified. The feeding trial lasted for eight weeks. Fish were weighed after 24 h starvation at the end of experiment. The samples of feed was hold below -20°C before proximate analysis. Analyses of chemical composition were carried out as standard method (AOAC, 1995).

Respirometer and Measure of Metabolic Rate

Oxygen consumption of individual fish fed either formulated feed or flesh for four weeks was measured by using an 11-chamber (0.4 L), continuous flow respirometer (Fu *et al*., 2005). A feeding tube was mounted at the front of the chamber to allow feeding of the fish in the chamber. The feces were discharged by a tube mounted at the rear of the chamber. Up to eight fish were studied at any given time and one chamber without fish acted as a control for background O_2 consumption. The following formula was used to calculate oxygen consumption (X_m, mg O_2 h^{-1}) of individual fish (Fu *et al*., 2005):

$$X_m = \Delta O_2 \times v \quad (1)$$

where, ΔO_2 is the difference (mg O_2 L^{-1}) in oxygen concentration between an experimental chamber and the control chamber, v is the velocity of water flow in a chamber (L h^{-1}). Oxygen consumption was adjusted to a standard body mass of 1 kg using a mass exponent of 0.75. Standardized value of metabolic rate was calculated by the following formula (Fu and Xie, 2004):

$$X_s = (1/m)^{0.75} X_m \quad (2)$$

where, X_s is the standardized oxygen consumption rate, X_m is the measured oxygen consumption per fish (mg O_2 h^{-1}) calculated by Eq. (1) and m is the body mass of the fish (kg).

Dissolved oxygen concentration was measured at the outlet of the chamber by an oxymeter (HQ20, Hach Company, Loveland, Colorado, USA). The flow rate of water through the chamber was measured by collecting the water outflow over a 2-min period and flow was adjusted to assure at least 70% oxygen saturation in the outlet water. Lights were on for the duration of the experiment period.

After 24 h fasting, the fish (48.5±1.1 g, mean±SE) were placed in the metabolic chambers and allowed to acclimatize for 48 h. Metabolic rate was then measured four times at 2 h intervals and that was taken as resting metabolic rate (Rs). Then either formulated feed or loach flesh with same energy (about 0.3 kJ g^{-1}) was offered to the fish. The chambers were closed immediately after the fish finished the meal and the metabolic rate was monitored for 48 h. This was determined in a pilot experiment that showed postprandial metabolic rate returned to pre-fed levels within this time period.

Three variables were quantified as described by Jobling (1981): (1) Peak metabolic rate (Rp), the observed maximum O_2 uptake rate in SDA process; (2) Duration, calculated as the time from feeding to when metabolic rate returned to within one standard error of standard metabolic rate of a given fish; (3) SDA coefficient (%), energy expended on SDA quantified as a percentage of the energy content of the meal. The oxygen consumption was converted to energy by using a conversion factor of 13.84 J mg O_2^{-1} (Guinea and Fernandez, 1997).

Data Processing and Analysis

The STATISTICA 4.5 (StatSoft Inc.) was used for t-test for independent sample. A p-value lowers than 0.05 was considered statistically significant and all data were presented as means±S.E. The variables of growth experiment were calculated as following:

Specific growth rate (SGR, % day^{-1}) = [Ln(final wet body mass)-ln(initial wet body mass)]× 100%/duration of experimental days

Feeding rate of dry matter (FR_d, % $g^{-1}day^{-1}$) = Dry diet intake× 100%/(mean wet body mass × duration of experimental days)

Feeding rate of protein (FR_p, % $g^{-1}day^{-1}$) = Protein intake/(mean wet body mass × duration of experimental days)

Feeding rate of energy (FR_e, J $g^{-1}day^{-1}$) = Energy intake/(mean wet body mass × duration of experimental days)

Feed Efficiency (FE) = Wet weight increment/dry feed consumed

Protein Efficiency Ratio (PER) = Wet weight gain/protein consumed

RESULTS

There were no significant differences in initial body mass ($t = -1.810$, $p = 0.076$) and final body mass ($t = 1.551$, $p = 0.127$) (Table 2) between the two treatment groups. The feeding rate of dry matter (0.71±0.01 vs. 1.62±0.04% day^{-1}, $t = -17.496$, $p<0.001$), protein (0.52±0.00 vs. 0.65±0.02% day^{-1}, $t = -6.149$, $p<0.001$) and energy (164±1 vs. 220±5 J g^{-1} day^{-1}, $t = -7.944$, $p<0.001$) of fish fed loach flesh were significantly lower than those fed formulated feed. But specific growth rate of fish fed loach was significantly higher than those fed formulated feed (3.04±0.11 vs. 2.63±0.09% day^{-1}, $t = 2.738$, $p = 0.008$). Feed efficiency was significantly lower, 1.30±0.06 vs. 2.84±0.04%, in formulated diet group compared to those fed loach flesh ($t = -16.705$, $p<0.001$). Protein efficiency ratio of fish fed loach flesh was also significantly higher than those fed formulated feed (3.91±0.06 vs. 3.14±0.09, $t = 5.867$, $p<0.001$).

For a given diet oxygen consumption rate increased significantly 2 h after feeding, peaking at 2 to 12 h postfeeding and gradually decreased to fasting level (Fig. 1). There was no significant difference in body mass between two experimental groups ($t = 1.473$ $p = 0.163$), but resting

Table 2: The growth performance and nutrient utilization of Southern catfish fed with formulated feed and loach flesh (Mean±SE, n = 30)

Parameters	Loach flesh	Formulated diet	t-value	p-value
Initial mass (g, WW)	15.80±0.70	17.40±0.50	-1.810	0.076
Final mass (g, WW)	87.30±4.10	77.50±4.10	1.551	0.127
Specific growth rate (SGR, % day^{-1})	3.04±0.11	2.63±0.09	2.738	0.008
Feeding rate of dry matter (FR_d, % day^{-1})	0.71±0.01	1.62±0.04	-17.496	<0.001
Feeding rate of protein (FR_p, % day^{-1})	0.52±0.00	0.65±0.02	-6.149	<0.001
Feeding rate of energy (FR_e, J g^{-1} day^{-1})	164.00±1.00	220.00±5.00	-7.944	<0.001
Feed Efficiency (FE)	2.84±0.04	1.30±0.06	16.705	<0.001
Protein Efficiency Ratio (PER)	3.91±0.06	3.14±0.09	5.867	<0.001

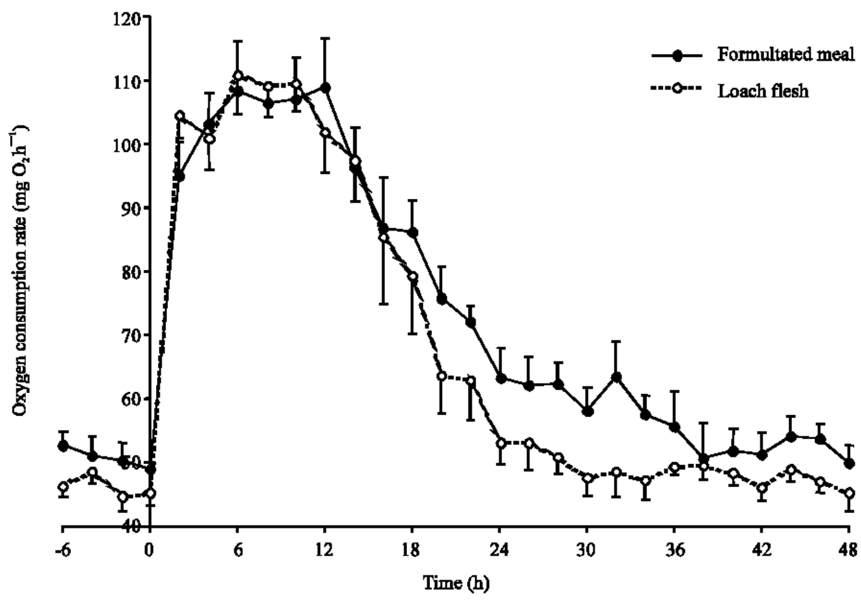

Fig. 1: The postprandial metabolic rate in Southern catfish fed with formulated feed (0.27 kJ g^{-1}) and loach flesh (0.28 kJ g^{-1}). (Feeding was completed at 0 h, Data is expressed as mean±SEM, n = 8. Water temperature was maintained at 27.5°C)

Table 3: The postprandial metabolic responses of Southern catfish fed with formulated feed and loach flesh (Mean±SE, n = 8)

Parameters	Loach flesh	Formulated diet	t-value	p-value
Body mass (g)	48.50±4.4	41.70±1.5	1.473	0.163
Resting metabolic rate (mg O_2 kg^{-1})	46.30±1.2	50.80±1.5	-2.419	0.030
Energy intake (kJ g^{-1})	0.28±0.03	0.27±0.01	0.191	0.851
Protein ingested (mg g^{-1})	8.55±0.21	7.68±0.14	3.640	0.002
Peak metabolic rate (mg O_2 kg^{-1})	119.30±3.5	121.70±3.0	-0.517	0.613
Duration (h)	26.30±1.7	33.00±2.3	-2.316	0.036
SDA coefficient (%)	11.00±0.2	13.30±0.9	-2.454	0.027

metabolic rate of fish fed loach flesh was significantly lower than those fed formulated feed ($t = -2.419$, $p = 0.030$) (Table 3). Even though the energy ingested did not differ significantly between two experimental groups ($t = 0.191$, $p = 0.851$), the SDA duration (26.3±1.7 vs. 33.0±2.3 h, $t = -2.316$, $p = 0.036$) and coefficient (11.0±0.2 vs. 13.3±0.9%, $t = -2.454$ $p = 0.027$) were significantly lower for the catfish given the loach flesh feed. There was no significantly difference between peak metabolic rate of experimental groups (119.3±3.5 vs.121.7±3.0 mgO_2. kg^{-1}, $t = -0.517$, $p = 0.613$).

DISCUSSION

Like other fish species, Protein Efficiency Ratio (PER) was usually negative related with dietary protein level when fed formulated feed (Fu, 2005). But PER of fish fed loach flesh was significantly higher than those fed formulated feed even the flesh contained 80% more protein than formulated feed (Table 1). The Feed Efficiency (FE) of fish fed loach flesh was also 118% higher than that of formulated feed group. These results suggested flesh were better used by Southern catfish than formulated feed. SGR of fish fed flesh was only 16% higher than that of formulated feed group since the feed rate of fish fed flesh was much lower (less than half of formulated feed). A previous study found Southern catfish might regulate the feed intake and maintain a potential inherent growth rate (Fu and Cao, 2006). This experiment is in agreement with that.

The protein source used in formulated diet was high quality fish meal, which account for 56% of all feed material, but FE of formulated feed was only 46% of flesh. It suggests the nutritional value was greatly decreased even not consider the additional feed material such as fat and carbohydrate. The digestibility was not determined in this study. The digestibility of energy and protein of this formulated feed and loach flesh were similar according to previous study (90-93%, Fu and Xie, 2005). So it must be some pre-digestive (mechanical breakdown cost and secretion of enzyme) or post-digestive (deposition of assimilated nutrient) mechanisms leading to the difference of nutrient utilization and growth performance between two groups. The metabolic response curve of fish fed formulated feed and flesh discuss below might give us further information on this.

The resting metabolic rate was significantly lower in fish fed loach flesh. This could partly explain the difference of feed efficiency of fish fed two experimental feeds. The resting metabolic rates of carnivorous fish usually lower than herbivorous fish. Present results may give some interesting information about this phenomenon. The underlying mechanism is unclear. A previous work on this catfish found the resting metabolic rate was increased with increased dietary carbohydrate. We suggested the assimilated carbohydrate caused futile substrate cycle in carbohydrate intermediary metabolism of carnivorous fish (Fu and Xie, 2004). This might cause the higher resting metabolic rate of fish fed formulated feed in this study.

SDA coefficient ranged from 11.0 to 13.3% in this study, which was similar to the results of other fishes (10-19%, Jobling, 1981). The energy expended on SDA of formulated feed was higher than that of loach flesh even the ingested energy was similar. The increased energy expenditure could partly explain the observed difference in food utilization between two feeds. Energy costs of ingestion, digestion, absorption and biochemical transformation of absorbed food constitute total energy expenditure during digestive process (Beamish and Trippel, 1990; Brown and Cameron, 1991; Lyndon *et al*., 1992). Previous research has suggested that the protein of a meal is a primary determinant of energy expended on SDA in fish species (Jobling, 1981; Ross *et al*., 1992). It also suggested that protein synthesis was the mainly energy expenditure during SDA (Houlihan *et al*., 1995), hence SDA coefficient should increase with increased feed efficiency (and growth rate). As expected based on protein content of feed and growth performance of fish fed different feeds, the SDA coefficient of fish fed flesh would much higher than those fed formulated feed if ingested energy was similar. But it is interesting to fid that SDA response was much profound in fish fed formulated feed. It suggested that protein content is not the sole factor influencing the magnitude of SDA in Southern catfish as demonstrated in a horned frog (*Ceratophrys cranwelli*) recently (Grayson *et al*., 2005). It also suggested the energy expenditure on unit deposition of body tissue in fish fed loach flesh was lower. It perhaps due to the energy cost for other part of SDA such as secretion of enzymes, transport of nutrient or intermediary metabolism in Southern catfish fed with formulated feed might higher. It is interesting that the postprandial metabolic curves of the first several hours after feeding (0 to 16 h) between two experimental groups were similar, but metabolic rate of fish fed formulated feed was a little higher in posterior phase. So the increased energy expenditure of fish fed formulated feed was mainly produced at last phase of SDA.

In conclusion, the growth performance of fish fed with loach fresh was significantly higher than that of formulated feed, the postprandial metabolic response of fish fed with loach fresh was smaller than those of formulated feed, the postprandial metabolic response might partly explain the observed differences in nutrient utilization between the two feeds and the Southern catfish was more adaptive to loach flesh.

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REFERENCES

AOAC., 1995. Official Methods of Analysis. 16th Edn. AOAC, Arlington, VA.

Beamish, F.W.H. and E.A. Trippel, 1990. Heat increment: A static or dynamic dimension in bioenergetics model? Trans. Am. Fish. Soc., 119 (5): 649-661.

Brown, C.R. and J.N. Cameron, 1991. The relationship between specific dynamic action (SDA) and protein synthesis rates in the channel catfish. Physiol. Zool., 64 (3): 298-309.

Fu, S.J. and X.J. Xie, 2004. Nutritional homeostasis in carnivorous Southern catfish (*Silurus meridionalis* Chen): Is there a mechanism for increased energy expenditure during carbohydrate overfeeding? Comp. Biochem. Physiol., 139 (3): 359-363.

Fu, S.J., 2005. The growth performance of Southern catfish fed diets with raw, precooked cornstarch and glucose at two levels. Aquacult. Nutr., 11 (5): 257-261.

Fu, S.J., X.J. Xie and Z.D. Cao, 2005. Effect of dietary composition on specific dynamic action in Southern catfish, *Silurus meridionalis*. Aquacult. Res., 36 (14): 1384-1390.

Fu, S.J. and X.J. Xie, 2005. Effect of dietary carbohydrate levels on growth performance in *Silurus meridionalis* Chen. Acta Hydrobiol. Sin., 29 (4): 393-398.

Fu, S.J. and Z.D. Cao, 2006. Effect of dietary protein and lipid levels on feed intake and growth performance of Southern catfish, *Silurus meridionalis*. Chen. Aquacult. Res., 37 (1): 107-110.

Grayson, K.L., L.W. Cook, M.J. Todd, D. Pierce, W.A. Hopkins, R.E. Gatten and M.E. Dorcas, 2005. Effects of prey type on specific dynamic action, growth and mass conversion efficiencies in the horned frog, *Ceratophrys cranwelli*. Comp. Biochem. Physiol., 141(2): 298-304.

Guinea, J. and F. Fernandez, 1997. Effect of feeding frequency, relative meal size and temperature on energy metabolism in *Sparus aurata*. Aquaculture, 148 (1): 125-142.

Houlihan, D.F., B.H. Pedersen, J.F. Steffensen and J. Brechin, 1995. Protein synthesis, growth and energetics in larval herring (*Clupea harengus*) at different feeding regimes. Fish Physiol. Biochem., 14 (3): 195-208.

Jobling, M., 1981. The influences of feeding on the metabolic rate of fishes: A short review. J. Fish Biol., 18 (5): 385-400.

Lyndon, A.R., D.F. Houlihan and S.J. Hall, 1992. The effect of short term fasting and a single meal on protein synthesis and oxygen consumption in cod, *Gadus morhua*. J. Comp. Physiol., 162 B (3): 209-215.

Ross, L.G., R.W. Mckinney, S.K. Cardwell, J.G. Fullarton, S.E.J. Roberts and B. Ross, 1992. The effect of dietary protein content, lipid content and ration level on oxygen consumption and specific dynamic action in *Oreochromis niloticus* L. Comp. Biochem. Physiol., 103A (4): 573-578.