Available online at www.sciencedirect.com
SCIENCE DIRECT
Comparative Biochemistry and Physiology, Part A 144 (2006) 41 – 47
CBP
www.elsevier.com/locate/cbpa

Effects of dietary soybean protein levels on metabolic response of the southern catfish, *Silurus meridionalis*

Qinghui Ai [a,b,*], Xiaojun Xie [a]

[a] *Institute of Fisheries Science, Southwest China Normal University, Chongqing 400715, PR China*
[b] *The Key Laboratory of Mariculture (Ministry of Education), Ocean University of China, Qingdao 266003, PR China*

Received 2 October 2005; received in revised form 21 January 2006; accepted 22 January 2006
Available online 9 March 2006

Abstract

A closed respirometer was used to measure oxygen consumption of the southern catfish *Silurus meridionalis* fed with six isonitrogenous (48% crude protein) diets replacing 0%, 13%, 26%, 39%, 52% and 65% fish meal (FM) protein by soybean meal (SBM) protein, in order to investigate the effects of dietary soybean protein level (SPL) (replacing FM) on metabolic rates of the southern catfish. The results showed that there were no significant differences in routine metabolism among dietary treatments. Either the total metabolic rate or specific dynamic action (SDA) was positively correlated with assimilated food energy at each diet, respectively ($P<0.05$). The SDA coefficient (means the energy spent in metabolism per unit of assimilated dietary energy) significantly increased with increasing dietary SPL ($P<0.05$). Fish fed the diet with 13% SPL had a significantly lower SDA coefficient (0.1528) than fish fed the diet with 52% or 65% SPL (0.1826 or 0.1932) ($P<0.05$). However, there were no significant differences in SDA coefficient among fish fed the diets with 13%, 26% and 39% SPL ($P>0.05$). Results of the present study suggested that an imbalance of essential amino acids at higher dietary SPL resulted in more energy channeled into metabolism, and subsequently increased the SDA coefficient.

Keywords: The southern catfish; *Silurus meridionalis*; Soybean protein level; Metabolic rate; Routine metabolism; Specific dynamic action; Respirometer; Fish nutritional energetics

1. Introduction

A major proportion of the energy consumed by fish is channeled into metabolism and lost as heat (Brett and Groves, 1979; Brafield, 1985). In a generalized energy budget, energy channeled into metabolism can be divided into three components: standard metabolic rate (R_s), active metabolic rate (R_a) and specific dynamic action (SDA) (Warren and Davies, 1967; Brett and Groves, 1979). R_s is defined as the metabolic rate for unfed and rested fish. Since it is difficult to keep fish at rest absolutely, the measured value was often an approximation and several terms were used to describe R_s, such as resting metabolic rate, fasting metabolic rate and routine metabolic rate. SDA can be taken to comprise all the energy expenditure resulting from the nutritive process, but also may include components relating to energy requirements for muscular activity of the gut, digestive enzyme formation and release, the processes of digestion and absorption (Jobling, 1983; Mommsen, 2001). SDA has been defined in a variety of ways. Some authors called the process "apparent SDA" (Beamish, 1974) or apparent heat increment (Beamish and Trippel, 1990). Feeding metabolism has been used to describe the overall increase in metabolic rate which accompanies feeding because SDA and R_a related to ingestion and digestion are usually difficult to separate experimentally (Cui and Wootton, 1988; Cui and Liu, 1990).

Many studies have focused on the effects of feeding level, temperature and body size on SDA (Muir and Niimi, 1972; Beamish, 1974; Brett, 1976; Hamada et al., 1985; Xie et al., 1997; Liu et al., 2000). Only a few studies reported the effects of food on SDA (Tandler and Beamish, 1980; Jobling and Davies, 1980; Ross et al., 1992; Francis et al., 2002; Fu and Xie, 2004). To our knowledge, no information was available on the effects of different dietary protein sources on metabolic rates and SDA.

* Corresponding author. The Key Laboratory of Mariculture (Ministry of Education), Ocean University of China, Qingdao 266003, PR China. Tel./fax: +86 532 82032495.
E-mail address: qinghuiai@yahoo.com (Q. Ai).

1095-6433/$ - see front matter © 2006 Elsevier Inc. All rights reserved.
doi:10.1016/j.cbpa.2006.01.030

Reducing feeding cost and tropic levels in aquaculture has long been one of the goals for fish nutritionist. One approach is to replace increasingly expensive fish meal (FM), a major protein source in aquatic feed, with less expensive and readily available plant proteins. Of plant proteins, soybean meal (SBM) is a promising candidate because of high protein level and better amino acid profile. A lot of studies have reported the utilization of dietary SBM in fish (Kikuchi, 1999; Cheng and Hardy, 2003; Chou et al., 2004; Ai and Xie, 2005). However, no study was related to the effects of dietary SBM on metabolic rates and SDA in fish.

The southern catfish *Silurus meridionalis*, a piscivore endemic to China, is widely cultured in Yangtze and Zhujiang Rivers. A series of studies were reported about the energetics of this fish (Xie and Sun, 1990, 1992, 1993; Xie et al., 1998). Fu and Xie (2004) investigated the effects of dietary carbohydrate on routine metabolism and SDA of this catfish. A previous growth experiment on this catfish showed that different ratios of SBM to FM in diets had a significant effect on growth. When replacing FM protein more than 39%, the growth response was significantly lower than the control and other groups (Ai and Xie, 2005). The purpose of the present study was to investigate the effects of dietary SBM protein to FM protein ratios on routine metabolism and SDA in the southern catfish, and present new data for identifying the effects of dietary plant protein sources on growth in relation to energy allocation.

2. Materials and methods

2.1. Experimental fish

Experimental fish (29.8–79.2 g) were obtained from a local hatchery and acclimated to the experimental diets in a rearing system for at least 56 days prior to the metabolic rate experiment. During this period, the fish were fed to satiation every other day with each diet, respectively. The water temperature was maintained at 27.5±0.2 °C, oxygen content was kept above 5 mg L^{-1}, pH ranged from 6.6 to 7.3 and ammonia-N was below 0.02 mg L^{-1}. The photoperiod (14 L:10 D) in the present study was controlled by artificial lighting with the light period from 07:00 to 21:00. During the dark period, the room was lit with a dim red light to facilitate the operation.

2.2. Experimental diets

Using fish meal (FM) as the animal protein source, soybean meal (SBM) as the plant protein source (commercially available from Beijing Friendship Feed Corp. in China), and α-starch as supplemental energy for balance, six isonitrogenous (48% crude protein) and isoenergetic (20 kJ g^{-1} gross energy) diets were formulated to contain 0.0%, 11.6%, 23.1%, 34.7%, 46.3% and 57.9% SBM as replacement of 0% (the control), 13%, 26%, 39%, 52% and 65% protein from FM (referred to as Diet 1, Diet 2, Diet 3, Diet 4, Diet 5 and Diet 6) (Table 1, Table 2), respectively. The digestibilities of dietary nutrients and energy have been determined using 0.1% Cr_2O_3 as an indicator in a previous growth experiment (Ai and Xie, 2005).

Table 1
Formulation and proximate composition of experimental diets (% dry weight)

Ingredient %	SPL[1] (% dietary protein) (Diets)					
	0% (Diet 1)	13% (Diet 2)	26% (Diet 3)	39% (Diet 4)	52% (Diet 5)	65% (Diet 6)
Fish meal	57.0	49.6	42.2	34.8	27.4	19.9
Soybean meal	0.0	11.6	23.1	34.7	46.3	57.9
Fish oil	0.3	1.5	2.6	3.7	4.8	6.0
Soybean oil	2.0	1.8	1.6	1.4	1.1	0.9
α-starch	25.8	20.6	15.5	10.5	5.5	0.4
Mineral premix[2]	2.00	2.00	2.00	2.00	2.00	2.00
Vitamin premix[3]	2.00	2.00	2.00	2.00	2.00	2.00
Sodium alginate	1.50	1.50	1.50	1.50	1.50	1.50
Ox liver[2]	8.40	8.40	8.40	8.40	8.40	8.40
Cr_2O_3	1.00	1.00	1.00	1.00	1.00	1.00
Proximate composition						
Crude protein %	47.9	47.8	48.2	47.8	47.9	48.7
Crude lipid %	11.4	11.9	12.1	12.1	12.1	12.1
Ash %	10.6	10.5	10.4	10.1	9.9	9.7
Gross energy kJ g^{-1}	19.9	19.9	20.1	20.3	20.1	20.2
Assimilated energy kJ g^{-1}	17.2	17.0	16.5	15.7	15.5	13.1
Digestible protein %	41.3	41.0	39.5	37.1	36.8	31.6

Assimilated energy was calculated by dietary energy and digestibility of dietary energy and protein determined by a previous experiment. [1]SPL = soybean protein level; [2]Mineral premix (mg/kg diet): NaF, 2 mg; KI, 0.08 mg; $CoCl_2 \cdot 6H_2O$, 1; $CuSO_4 \cdot 5H_2O$, 10 mg; $FeSO_4 \cdot H_2O$, 74 mg; $ZnSO_4 \cdot H_2O$, 50 mg; $MnSO_4 \cdot H_2O$, 60 mg; $MgSO_4 \cdot 7H_2O$, 1000 mg; $K_2HPO_3 \cdot 3H_2O$, 6000 mg; $NaH_2PO_3 \cdot 2H_2O$, 5000 mg; NaCl, 100 mg; $CaCO_3$, 4 g; [3]Vitamin premix (mg or IU/kg 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, 25,000 IU; D, 2500 IU; E, 1200 mg; C, 2112 mg; choline chloride, 2500 mg.

2.3. Experimental facilities

Oxygen consumption was measured in closed respirometers (Fu and Xie, 2004). Fish were held individually in respirometers. Each respirometer was about 100 L in volume (barrel, diameter: 43 cm, height: 62 cm) with a tight-fitting, transparent lid of heavy plastic. The flow of fresh water was recirulated using a pump. The oxygen concentration was measured by means of oxymeter (YSI 52, Yellow Springs Instruments, Yellow Springs, OH, USA). The following formula was used to calculate the absolute O_2 consumption rate (mg O_2 kg^{-1} h^{-1}) from oxygen concentration (Alsop and Wood, 1997).

$$\text{Metabolic rate} = \Delta O_2 v/(mt) \tag{1}$$

where ΔO_2 is the measured change in oxygen concentration (mg O_2 L^{-1}) values between the beginning and end of each test period, v is the volume (L) of water in chamber tank, t is the duration of test period, and m is body mass (kg) of the test fish. Oxygen concentration was never below 70% saturated dissolved oxygen level, thus avoiding the stress on physiological process (Beamish, 1974). Usually a 4-h test period and a 10-min recirculated period comprise a measure cycle. The metabolic rate in recirculated period was estimated as an average value of two close cycles.