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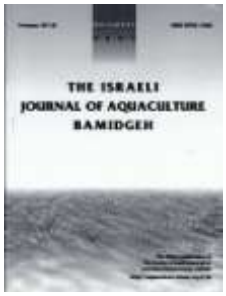

Effects of Dietary Lipid and Carbohydrate and Their Interaction on Growth Performance and Body Composition of Juvenile Blunt Snout Bream, *Megalobrama amblycephala*

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Key words: blunt snout bream, lipid, carbohydrate, growth performance, body composition

Abstract

The effects of dietary lipid and carbohydrate, and their interaction, on growth performance and body composition of juvenileblunt snout bream *Megalobrama amblycephala* were investigated. Fish were fed one of eight isonitrogenous (32% crude protein) diets containing 4% or 7% lipids and 25%, 30%, 35%, or 40% carbohydrate for nine weeks. Weight gain, feed conversion ratio, protein efficiency ratio, and nitrogen and energy retention improved significantly as the dietary lipid level increased, while there were no significant differences in these parameters within the tested range of carbohydrate levels. The interaction between the lipid and carbohydrate levels had positive effects on weight gain, feed conversion ratio, and protein efficiency ratio when fish were fed increased carbohydrates and 7% lipid. The intraperitoneal fat ratio and liver lipid content were significantly affected by the dietary carbohydrate level and reached maximum values in fish fed 40% and 30% carbohydrates, respectively. Further, the dietary lipid and carbohydrate levels significantly affected body moisture and lipid content while there were no significant differences in body protein, ash, energy, or muscle and liver glycogen contents. Results indicate that the optimal dietary carbohydrate content for juvenile *M. amblycephala* is approximately 30% when dietary lipid is 4%. However, juvenile *M. amblycephala* can efficiently utilize 40% dietary carbohydrate with a dietary lipid content of 7%.

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Introduction

Protein is the single most expensive ingredient in most fish diets. High dietary protein contents are often associated with uneconomical feed costs and negative environmental impacts due to nitrogenous loading of the aquatic environment. Therefore, reducing dietary protein levels and maximizing protein utilization are priorities from both economic and environmental perspectives. Many studies have investigated the protein-sparing potential of dietary lipids and carbohydrates in fish diets (Watanabe, 2002).

Lipids are generally the major non-protein energy-yielding molecules for fish. Carbohydrates are abundant and low cost, making their inclusion in diets attractive. In addition, carbohydrates may have beneficial effects on feed pelleting quality (Arnesen and Krogdahl, 1993) and growth performance (Peragón et al., 1999). However, dietary lipid contents must be taken into account to maximize the carbohydrate utilization of fish, since an interaction between these two nutrients may exist (Honorato et al., 2010; Vásquez-Torres and Arias-Castellanos, 2012). Further, carbohydrate utilization may be affected by species, growth stage, carbohydrate source or type, structure complexity, processing method, inclusion level, feeding frequency, nutritional status, and feeding habit (Hemre et al. 2002).

Blunt snout bream (*Megalobrama amblycephala*) is an herbivorous freshwater fish, native to China and distributed throughout North America (northern Canada to southern Mexico), Africa, and Eurasia (Li et al., 2010). The species is a good candidate for intensive culture as it is highly valued for its high larvae survival rate, fast growth, use of natural foods, tender flesh, and disease resistance (Zhou et al., 2008). Due to increasing consumer demand and relatively low production costs, aquaculture of this fish has expanded rapidly in China, reaching approximately 652,215 tons in 2010, 4.22% more than the previous year, and ranking sixth in Chinese freshwater fish production (MoA, 2011).

Due to its herbivorous feeding habits, diets formulated for blunt snout bream in China usually cost less than US$200/ton (Zhou et al., 2008). To further reduce feed costs, the use of dietary non-protein energy sources should be used. The optimal dietary lipid requirement of blunt snout bream fingerlings has been documented (Liu et al., 1992; Li et al., 2013). The present study was conducted to compare utilization efficiencies of dietary lipid and carbohydrates for energy, investigate carbohydrate utilization at two dietary lipid levels, and determine the interactive effects of dietary lipid and carbohydrate on growth performance in blunt snout bream juveniles. The results can be helpful in understanding the efficacy of non-protein energy utilization of this fish as well as other herbivorous freshwater species.

Materials and Methods

Diets. A 4 × 2 factorial design with four replicates was used. Eight isonitrogenous (32% crude protein) diets were prepared to contain 4% or 7% lipids and 25%, 30%, 35%, or 40% carbohydrates (nitrogen-free extract). Fishmeal, soybean meal, rapeseed meal, and cottonseed meal served as protein sources (Table 1). Soybean oil was the single lipid source. Dextrin white was added to achieve the desired dietary carbohydrate level. Cellulose microcrystalline was included as a filler. Dietary ingredients were finely ground, well mixed, and dry pelleted through a 3-mm dye in a laboratory pellet mill (MUZL 180, Jiangsu Muyang Group Co., Ltd., Yangzhou, China). Diets were dried in a ventilated oven and stored in plastic bags at -20°C until use.

Fish and feeding trial. Juvenile blunt snout bream were obtained from the Fish Hatchery of Songjiang (Shanghai, China). After acclimation, fish of similar sizes (11.42±0.17 g) were randomly distributed into 32 floating cages (2 × 1 × 1 m) at 80 juveniles per cage. Cages were anchored in an outdoor concrete pond (100 × 50 m), with an average water depth of 2 m and held under natural photoperiod conditions. Water temperature ranged 23-32°C, pH fluctuated 7.2-7.5, and dissolved oxygen was maintained above 5.0 mg/l. Cages were randomly assigned one of the eight experimental diets. Fish were hand-fed to apparent satiation three times daily (07:30, 11:30, 16:30) for nine weeks. Feed consumption was recorded and dead fish, if any, were removed and weighed daily.

Sample collection. At the end of nine weeks, the fish were starved for 24 h, harvested, and anesthetized in diluted MS-222 (Sigma, Saint Louis, Missouri, USA) at 100 mg/l. The total number and weight of fish in each cage was determined. A sample of 30 fish at the beginning and 12 fish per cage at the end of the feeding trial were collected and stored at -22°C for body composition analysis. Twenty fish were randomly sampled from each cage to analyze the intra-peritoneal fat ratio and hepatosomatic index. Livers and dorsal white muscles were quickly sampled and stored at -22°C for further analysis.

Table 1. Formulation and proximate composition of diets for juvenile blunt snout bream, *Megalobrama amblycephala*.

	Diet (% lipid/% carbohydrate)							
Ingredient (%)	*4/25*	*4/30*	*4/35*	*4/40*	*7/25*	*7/30*	*7/35*	*7/40*
Soybean meal[1]	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0
Rapeseed meal[2]	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Cottonseed meal[3]	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Fishmeal[4]	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
α-Starch[5]	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Cellulose microcrystalline[5]	18.9	13.9	8.9	3.9	15.9	10.9	5.9	0.9
Soybean oil[6]	2.0	2.0	2.0	2.0	5.0	5.0	5.0	5.0
Calcium biphosphate[5]	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Vitamin/mineral premix[7]	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Dextrin white[8]	0.2	5.2	10.2	15.2	0.2	5.2	10.2	15.2
Proximate composition (%)								
Dry matter	89.6	91.2	90.7	89.4	90.8	92.1	89.9	90.9
Crude protein	31.4	31.5	32.0	31.5	31.9	31.9	31.9	31.0
Crude lipid	4.2	3.9	4.0	3.9	7.3	7.2	6.9	7.2
Crude fiber	21.5	16.9	11.6	6.0	19.4	13.9	8.4	5.0
Ash	7.9	7.7	7.7	7.5	7.4	7.7	7.8	7.7
Nitrogen-free extract[9]	24.7	31.2	35.5	40.6	24.8	31.5	34.9	40.2
Gross energy (MJ/kg)	13.3	14.4	15.3	16.0	14.7	15.8	16.3	17.1

[1] 44.5% crude protein, 1.79% crude lipid; Zhengchang Feed Industry Co., Ltd., Huaian, China
[2] 34.6% crude protein, 3.10% crude lipid; Zhengchang Feed Industry Co., Ltd., Huaian, China
[3] 38.0% crude protein, 1.48% crude lipid; Col and Feed Industry Co., Ltd., Wuhan, China
[4] 63.3% crude protein, 8.64% crude lipid; Zhengchang Feed Industry Co., Ltd., Huaian, China
[5] Lanping Industry Co., Ltd., Shanghai, China
[6] Col and Feed Industry Co., Ltd., Wuhan, China
[7] per kg: $CuSO_4 \cdot 5H_2O$ 2.0 g; $FeSO_4 \cdot 7H_2O$ 25 g; $ZnSO_4 \cdot 7H_2O$ 22 g; $MnSO_4 \cdot 4H_2O$ 7 g; Na_2SeO_3 0.04 g; KI 0.026 g; $CoCl_2 \cdot 6H_2O$ 0.1 g; vitamin A 900,000 IU; vitamin D 200000 IU; vitamin E 4500 mg; vitamin K3 220 mg; vitamin B1 320 mg; vitamin B2 1090 mg; niacin 2800 mg; vitamin B5 2000 mg; vitamin B6 500 mg; vitamin B12 1.6 mg; vitamin C 5000 mg; pantothenate 1000 mg; folic acid 165 mg; choline 60,000 mg
[8] Henan Golden Corn Co., Ltd., Jiaozuo, China
[9] Dry matter - crude protein - crude lipid - ash - crude fiber

Proximate composition. Moisture was determined by oven drying at 105°C until constant weight. Crude protein (N × 6.25) was analyzed by the Kjeldahl method after acid digestion using an Auto Kjeldahl System (1030-Auto-analyzer, Tecator, Höganäs, Sweden), crude lipid by ether extraction in a Soxtec System (Soxtec System HT6, Tecator, Höganäs, Sweden), ash by combustion in a muffle furnace at 550°C for 4 h, and crude fiber by the fritted glass crucible method using an automatic analyzer (Fibertec, Tecator, Sweden). Gross energy was measured with an adiabatic bomb calorimeter (Parr 1281, Parr Instrument Company, Moline, IL, USA). Liver lipids were extracted as described by Folch et al. (1957). Muscle and liver glycogen were measured by the method described by Hassid and Abraham (1957).

Statistical analysis. Data were analyzed by two-way ANOVA using the SPSS General Linear Models procedure (SPSS 7.5, Michigan Avenue, Chicago, IL, USA) for significant differences among treatment means. If significant (p<0.05) differences were found, Duncan's multiple range test was used to rank the means (Duncan, 1955). Data are presented as means±SEM (standard error of the mean) of four replicates.

Results

Survival and relative feed intake did not significantly differ among treatments (Table 2). Based on two-way ANOVA analysis, weight gain, daily growth index, FCR, PER, and nitrogen and energy retention efficiencies significantly improved as the dietary lipid increased from 4% to 7% but did not significantly differ among dietary carbohydrate levels. Whole body protein, ash, and energy contents did not significantly differ among treatments but whole body lipid was significantly higher in fish fed the 7% lipid diets than in those fed the 4% lipid diets. Carcass moisture, protein, and muscle and liver glycogen

contents did not significantly differ among treatments but liver lipid content was significantly affected by the dietary carbohydrate level.

Table 2. Growth performance, feed utilization, and whole body, carcass (head and viscera removed), and liver composition of juvenile blunt snout bream, *Megalobrama amblycephala*, fed diets with different lipid and carbohydrate contents (means±SEM; n = 4), with two-way ANOVA comparison of means for lipid (I), carbohydrate (II), and the interaction between the two (III).

	Diet (% lipid/% carbohydrate)								*Two-way ANOVA*[9]		
	4/25	*4/30*	*4/35*	*4/40*	*7/25*	*7/30*	*7/35*	*7/40*	*I*	*II*	*III*
Survival (%)	98.8±0.7^{a}	99.2±0.4^{a}	99.6±0.4^{a}	93.8±6.3^{a}	99.2±0.4^{x}	98.8±0.7^{x}	99.6±0.4^{x}	96.3±3.8^{x}	Ns	Ns	Ns
Relative feed intake (% body wt/d)[1]	4.82±0.14^{a}	4.85±0.10^{a}	5.03±0.04^{a}	5.27±0.23^{a}	5.09±0.15^{x}	4.86±0.18^{x}	4.68±0.15^{x}	4.79±0.54^{x}	Ns	Ns	Ns
Wt gain (%)[2]	262±12^{a}	269±13^{a}	256±8^{a}	233±22$^{a▲}$	262±15^{x}	276±15^{x}	289±11^{x}	334±12$^{y▲}$	**	Ns	*
Daily growth index (%)[3]	2.02±0.06^{a}	2.05±0.07^{a}	1.98±0.04^{a}	1.85±0.12$^{a▲}$	2.01±0.08^{x}	2.08±0.08^{x}	2.15±0.06^{x}	2.38±0.05$^{y▲}$	**	Ns	*
Feed conversion ratio[4]	1.57±0.09^{a}	1.68±0.08^{a}	1.91±0.14^{ab}	2.18±0.10$^{b▲}$	1.89±0.10^{y}	1.71±0.14^{xy}	1.54±0.19^{xy}	1.38±0.06$^{x▲}$	*	Ns	**
Protein efficiency ratio[5]	1.84±0.07^{a}	1.83±0.05^{a}	1.72±0.01^{a}	1.65±0.10$^{a▲}$	1.72±0.07^{x}	1.82±0.08^{x}	1.89±0.08^{xy}	2.10±0.09$^{y▲}$	*	Ns	**
Nitrogen retention (%)[6]	29.1±0.6^{a}	29.0±0.9^{a}	27.1±1.1^{a}	26.7±1.7^{a}	28.3±1.3^{x}	29.0±0.8^{x}	30.4±1.7^{x}	31.9±0.8^{x}	*	Ns	Ns
Energy retention (%)[6]	22.7±1.2^{a}	22.1±1.2^{a}	22.4±0.6^{a}	21.1±1.0^{a}	23.2±1.0^{x}	25.4±0.7^{x}	22.8±1.4^{x}	24.7±0.9^{x}	*	Ns	Ns
Hepatosomatic index (%)[7]	1.24±0.14^{a}	0.98±0.02^{a}	1.61±0.03$^{b▲}$	1.22±0.01^{a}	1.46±0.06^{y}	1.27±0.22^{xy}	1.05±0.06$^{xy▲}$	0.88±0.08^{x}	Ns	*	**
Intraperitoneal fat ratio (%)[8]	2.30±0.14^{a}	2.66±0.24^{a}	2.44±0.12^{a}	2.69±0.22^{a}	2.62±0.10^{x}	2.52±0.06^{x}	2.54±0.08^{x}	2.87±0.12^{x}	Ns	*	Ns
Whole body composition (% wet wt)											
	Initial	*4/25*	*4/30*	*4/35*	*4/40*	*7/25*	*7/30*	*7/35*	*7/40*		
Moisture	73.5±0.6	71.9±0.3^{bc}	68.5±0.3$^{a▲}$	72.6±0.4^{c}	71.2±0.1$^{b▲}$	69.7±1.2^{xy}	73.4±0.2$^{z▲}$	72.2±0.5^{yz}	66.6±0.4$^{x▲}$	Ns	**	***
Protein	14.8±1.2	16.3±0.2^{a}	16.0±0.3^{a}	16.1±0.3^{a}	16.9±1.0^{a}	16.4±0.6^{x}	15.7±0.7^{x}	15.7±0.3^{x}	21.6±0.4^{x}	Ns	Ns	Ns
Lipid	8.52±0.75	7.79±0.25$^{a▲}$	9.80±0.62$^{b▲}$	6.84±0.01^{a}	8.47±0.03$^{ab▲}$	10.01±0.09$^{yz▲}$	6.73±0.41$^{x▲}$	8.30±0.69^{xy}	11.33±0.64$^{z▲}$	*	*	**
Ash	2.51±0.32	3.45±0.03^{a}	3.40±0.04^{a}	3.62±0.05^{a}	3.57±0.05^{a}	3.68±0.09^{x}	3.56±0.08^{x}	3.59±0.12^{x}	3.44±0.12^{x}	Ns	Ns	Ns
Energy (MJ/kg)	6.19±0.54	6.46±0.21^{a}	6.82±0.25^{a}	5.87±0.06^{a}	6.26±0.07^{a}	6.61±0.27^{x}	6.00±0.47^{x}	6.24±0.22^{x}	6.85±0.31^{x}	Ns	Ns	Ns
Carcass composition (% wet wt)											
Moisture		72.1±0.3^{a}	72.5±0.3^{a}	73.4±0.4^{a}	73.4±0.6^{a}	72.9±0.6^{x}	72.9±0.9^{x}	73.5±0.7^{x}	72.3±0.6^{x}	Ns	Ns	Ns
Protein		17.7±0.4^{a}	18.2±0.3^{a}	17.5±0.2^{a}	17.5±0.4^{a}	17.7±0.5^{x}	17.9±0.1^{x}	17.6±0.2^{x}	17.9±0.2^{x}	Ns	Ns	Ns
Lipid		6.52±0.79$^{a▲}$	6.06±0.17^{a}	5.53±0.15^{a}	4.99±0.03$^{a▲}$	4.63±0.24$^{x▲}$	5.44±0.61^{x}	5.04±0.35^{x}	7.15±0.11$^{y▲}$	Ns	Ns	*
Muscle glycogen (g/kg)		0.40±0.03^{a}	0.32±0.05^{a}	0.38±0.06^{a}	0.40±0.04^{a}	0.50±0.08^{x}	0.39±0.07^{x}	0.44±0.06^{x}	0.30±0.04^{x}	Ns	Ns	Ns
Liver composition (% wet wt)											
Lipid		8.19±0.49^{a}	9.26±0.65^{a}	6.31±0.86^{a}	5.88±0.70^{a}	7.02±0.55^{x}	6.94±0.67^{x}	7.22±0.70^{x}	6.71±0.41^{x}	Ns	**	Ns
Glycogen		3.47±0.64^{a}	3.45±0.15^{a}	3.71±0.14^{a}	3.07±0.20^{a}	3.41±0.42^{x}	3.87±1.29^{x}	4.10±0.65^{x}	4.87±0.78^{x}	Ns	Ns	Ns

[1] Feed intake × 100/[(W_0 + W_t + dead fish wt) × T/2], where W_0 and W_t are initial and final body weights and T is no. of days reared
[2] $100(W_t - W_0)/W_0$
[3] $100(W_t^{1/3}-W_0^{1/3})/T$
[4] Dry feed intake/fish wt gain
[5] Fish wt gain/protein intake
[6] $100[(W_t \times C_t) - (W_0 \times C_0)]/(C_{diet} \times$ dry feed intake), where C_0 and C_t are initial and final contents in whole fish body and C_{diet} is dietary content
[7] 100(liver wt)/body wt
[8] 100(intraperitoneal fat wt/body wt)
[9] Means in the same column and within each dietary lipid level followed by different superscripts significantly differ (p<0.05). Means at the same dietary carbohydrate level were compared between 4% and 7% dietary lipid; triangle (▲) indicates significant difference (p<0.05).
* p<0.05, ** p<0.01, *** p<0.001, Ns = not significant

Discussion

The best weight gain, daily growth index, FCR, PER, and nitrogen and energy retentions were obtained in fish fed the 7% lipid/40% carbohydrate diet. There were no significant differences between groups fed the 4% lipid diets, indicating that juvenile blunt snout bream perform equally well when carbohydrate contents are increased from 25% to 40% at the 4% lipid level. Our results are similar to those in grass carp (*Ctenopharyngodon idella*), which share similar feeding habits and where the optimum carbohydrate

requirement ranged 37-56% (Lin, 1991). Similarly, there were no significant differences in growth and feed utilization of hybrid striped bass (*Morone chrysops* × *M. saxatilis*; Nematipour et al., 1992), tilapia (*Oreochromis niloticus* × *O*. *aureus*; Wang et al., 2005), or jundiá (*Rhamdia quelen*; Moro et al., 2010) within the tested carbohydrate range.

The highest level of cellulose microcrystalline used in this study was 18.9%, thus, it is unlikely to have affected growth performance. In other studies of juveniles of this species, 21% cellulose did not result in growth retardation (Li et al., 2013; Zhou et al., 2013). Similarly, 37% cellulose did not negatively affect growth of juvenile grass carp (Tian et al., 2012) and cellulose has been used at levels as high as 40% for tilapia (Wang et al., 2005) and catfish jundiá (Moro et al., 2010) without affecting growth rates.

Fish species have different capabilities to utilize dietary lipid and carbohydrate for energy purposes. Rainbow trout (Brauge et al., 1994) and European sea bass (Lanari et al., 1999) utilize lipid better than carbohydrate whereas the opposite is true for Nile tilapia (Shimeno et al., 1993), Indian major carps (Erfanullah and Jafri, 1998a), and African catfish (Ali and Jauncey, 2004). Walking catfish (Erfanullah and Jafri, 1998b) and grass carp (Gao et al., 2010) utilize the two nutrients equally well. The present study suggests that juvenile blunt snout bream utilize dietary lipid more efficiently than carbohydrate as weight gain, daily growth index, FCR, PER, and nitrogen and energy retention efficiencies significantly improved with the increase in dietary lipid level but did not significantly differ within the tested carbohydrate range. The positive correlation between growth performance and dietary lipid increase might be due to the digestive and metabolic adjustments made by this species in response to dietary changes. An appropriate increase of dietary lipid enhances digestive enzyme activity (non-specific protease, lipase, amylase) and depresses amino acid catabolism in this species (Li et al., 2012), leading to improved feed utilization and growth. These trends indicate that supplementation of dietary lipids rather than carbohydrates as a non-protein energy source is a more effective method of improving protein and energy utilization in this species.

The interaction between dietary lipid and carbohydrate had a strong impact on weight gain, daily growth index, FCR, and PER; high dietary lipid improved carbohydrate utilization. When the dietary lipid content was 4%, high dietary carbohydrate (>30%) negatively affected growth and feed utilization but when the dietary lipid content was 7%, weight gain, daily growth index, FCR, and PER improved significantly with the increase in carbohydrate level to 40%. The mechanism for this interaction might be related to physiological adaptations made by this species in response to dietary changes. An appropriate increase of dietary lipid can significantly enhance intestine amylase activity in this species and stimulate insulin and glucagon secretion (Li et al., 2012), leading to improved carbohydrate utilization. A similar interactive effect of dietary lipid and carbohydrate was observed in pacu (Honorato et al., 2010).

The hepatosomatic index (HSI) and liver lipid content did not significantly differ with the increase of dietary lipid. This may be because the liver does not significantly contribute to lipid deposition in blunt snout bream (liver lipid contents were relatively low), or because 7% dietary lipid is not enough to induce liver lipid deposition (liver lipid content did not significantly differ in blunt snout bream fed diets containing 2-11% lipid; Liu et al., 1992), or because juvenile blunt snout bream use liver lipid for energy needs and body growth and high amounts of dietary lipid do not accumulate in the liver.

Unlike dietary lipid, the HSI of juvenile blunt snout bream was significantly affected by the dietary carbohydrate level and the interaction between dietary lipid and carbohydrate. The lowest HSI and liver lipid contents were obtained in fish fed 40% dietary carbohydrate indicating that high dietary carbohydrate does not produce a fatty liver or an undesirable liver size in this species. Fish fed the 7% lipid/40% carbohydrate diet had the lowest HSI, a low liver lipid content, and the best growth, indicating that lipid deposition from dietary lipid and carbohydrate does not occur in the liver but rather in adipose tissue. In addition, liver glycogen content increased as the dietary carbohydrate level increased, though not significantly, indicating that absorbed glucose is partly stored as liver glycogen (Nematipour et al., 1992).

Although whole body lipid increased significantly with the increase in dietary lipid, there were no significant differences in carcass or liver lipid content in regard to the dietary lipid level, which may be explained by the propensity of blunt snout bream to deposit lipid in perivisceral adipose tissue rather than in liver or muscle (Li et al., 2010; 2012). Fish fed 40% dietary carbohydrate attained the highest whole body lipid content in terms of dietary carbohydrate, indicating that increased digestible carbohydrate could produce undesirable lipid accumulation in the fish body as a result of the *de novo* synthesis of fatty acids (Mohanta et al., 2007). An interaction between dietary lipid and carbohydrate was observed in the whole body and carcass lipid content with the highest contents obtained in fish fed the 7% lipid/40% carbohydrate diet, indicating that blunt snout bream are highly capable of converting dietary non-protein energy into body lipid. Unlike body lipid, whole body protein and ash content did not significantly differ among groups, probably because the lipid content of fish is easily affected by dietary energy intake whereas the whole body protein and ash contents follow life-cycle and size-dependent variations or patterns (Lanari et al., 1999).

In conclusion, results of this study suggest that juvenile blunt snout bream have better ability to utilize dietary lipid for energy purposes than carbohydrate and that the interaction of lipid and carbohydrate significantly affects growth performance of this fish. The fish utilized up to 30% dietary carbohydrate when dietary lipid was 4% and up to 40% without growth retardation when the dietary lipid content reached 7%. In addition, excessive dietary energy derived from dietary lipid and carbohydrate may cause lipid deposition in perivisceral adipose tissue rather than in the liver and muscle.

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References

Ali M.Z. and K. Jauncey, 2004. Optimal dietary carbohydrate to lipid ratio in African catfish *Clarias gariepinus* (Burchell 1822). *Aquacult*. *Int*., 12:169-180.

Arnesen P. and A. Krogdahl, 1993. Crude and pre-extruded products of wheat as nutrient sources in extruded diets for Atlantic salmon (*Salmo salar* L.) grown in sea water. *Aquaculture*, 118:105-117.

Brauge C., Medale F. and G. Corraze, 1994. Effect of dietary carbohydrate levels on growth, body composition and glycaemia in rainbow trout, *Oncorhynchus mykiss*, reared in seawater. *Aquaculture*, 123:109-120.

Duncan D.B., 1955. Multiple-range and multiple F tests. Biometrics, 11:1-42.

Erfanullah and A.K. Jafri, 1998a. Growth rate, feed conversion, and body composition of *Catla catla*, *Labeo rohita*, and *Cirrhinus mrigala* fry fed diets of various carbohydrate-to-lipid ratios. *J. World Aquacult. Soc*., 29:84-91.

Erfanullah and A.K. Jafri, 1998b. Effect of dietary carbohydrate-to-lipid ratio on growth and body composition of walking catfish (*Clarias batrachus*). *Aquaculture*, 161:159-168.

Folch J., Lees M. and G.H. Sloane-Stanley, 1957. A simple method for the isolation and purification of the total lipid from animal tissue. *J. Biol. Chem*., 226:497-509.

Gao W., Liu Y.J., Tian L.X., Mai K.S., Liang G.Y., Yang H.J., Huai M.Y. and W.J. Luo, 2010. Effect of dietary carbohydrate-to-lipid ratios on growth performance, body composition, nutrient utilization and hepatic enzymes activities of herbivorous grass carp (*Ctenopharyngodon idella*). *Aquacult. Nutr*., 16:327-333.

Hassid W.Z. and S. Abraham, 1957. Chemical procedure for analysis of polysaccharides. pp. 34. In: S.P. Colwick, N.O. Kaplan (eds.). *Methods in Enzymology*. Academic Press, New York, USA.

Hemre G.I., Mommsen T.P. and A. Krogdahl, 2002. Carbohydrates in fish nutrition: effects on growth, glucose metabolism and hepatic enzymes. *Aquacult. Nutr*., 8:175-194.

Honorato C.A., Almeida L.C., Da Silva Nunes C., Carneiro D.J. and G. Moraes, 2010. Effects of processing on physical characteristics of diets with distinct levels of carbohydrates and lipids: the outcomes on the growth of pacu (*Piaractus mesopotamicus*) juveniles fed diets containing different protein levels. *Aquacult*. *Nutr*., 16:91-99.

Lanari D., Poli B.M., Ballestrazzi R., Lupi P., D'Agaro E. and M. Mecatti, 1999. The effects of dietary fat and NFE levels on growing European sea bass (*Dicentrarchus labrax* L.). Growth rate, body and fillet composition, carcass traits and nutrient retention efficiency. *Aquaculture*, 179:351-364.

Li X.F., Liu W.B., Jiang Y.Y., Zhu H. and X.P. Ge, 2010. Effects of dietary protein and lipid levels in practical diets on growth performance and body composition of blunt snout bream (*Megalobrama amblycephala*) fingerlings. *Aquaculture*, 303:65-70.

Li X.F., Jiang Y.Y., Liu W.B. and X.P. Ge, 2012. Protein-sparing effect of dietary lipid in practical diets for blunt snout bream (*Megalobrama amblycephala*) fingerlings: effects on digestive and metabolic responses. *Fish Physiol*. *Biochem*., 38:529-541.

Li X.F., Wang Y., Liu W.B., Jiang G.Z. and J. Zhu, 2013. Effects of dietary carbohydrate/lipid ratios on growth performance, body composition and glucose metabolism of fingerling blunt snout bream *Megalobrama amblycephala*. *Aquacult*. *Nutr*., 19(5):701-708.

Lin D., 1991. Grass carp, *Ctenopharyngodon idella.* pp. 89-96. In: R.P. Wilson (ed.). *Handbook of Nutrient Requirements of Finfish*. CRC Press, Boca Raton, FL, USA.

Liu M.Z., Shi W.L., Zhu C.W., Lu M.Y., Wang G.L. and F.Q. Wang, 1992. The effect of dietary lipid level on the growth of blunt snout bream (*Megalobrama amblycephala*) fingerling. *J. Fish. China*, 4:330-336 (in Chinese with English abstract).

MoA, 2011. *China Fishery Statistical Yearbook*. Chinese Agricultural Press, Ministry of Agriculture of the People's Republic of China, Beijing. 31 pp.

Mohanta K.N., Mohanty S.N. and J.K. Jena, 2007. Protein-sparing effect of carbohydrate in silver barb, *Puntius gonionotus* fry. *Aquacult*. *Nutr*., 13:311-317.

Moro G.V., Camilo R.Y., Moraes G. and D.M. Fracalossi, 2010. Dietary non-protein energy sources: growth, digestive enzyme activities and nutrient utilization by the catfish jundiá, *Rhamdia quelen*. *Aquacult*. *Res*., 41:394-400.

Nematipour G.R., Brown M.L. and D.M. Gatlin, 1992. Effects of dietary carbohydrate:lipid ratio on growth and body composition of hybrid striped bass. *J. World Aquacult*. *Soc*., 23:128-132.

Peragón J., Barroso J.B., García-Salguero L., de la Higuera M. and J.A. Lupiáñez, 1999. Carbohydrates affect protein-turnover rates, growth, and nucleic acid content in the white muscle of rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, 179:425-437.

Shimeno S., Ming D.C. and M. Takeda, 1993. Metabolic response to dietary carbo-hydrate to lipid ratios in *Oreochromis niloticus*. *Nippon Suisan Gakkaishi*, 59:827-833.

Tian L.X., Liu Y.J., Yang H.J., Liang G.Y. and J. Niu, 2012. Effects of different dietary wheat starch levels on growth, feed efficiency and digestibility in grass carp (*Ctenopharyngodon idella*). *Aquacult*. *Int*., 20:283-293.

Vásquez-Torres W. and J.A. Arias-Castellanos, 2012. Effect of dietary carbohydrates and lipids on growth in cachama (*Piaractus brachypomus*). *Aquacult*. *Res*., 44(11):1758-1776. doi:10.1111/j.1365-2109.2012.03183.x.

Wang Y., Liu Y.J., Tian L.X., Du Z.Y., Wang J.T., Wang S. and W.P. Xiao, 2005. Effects of dietary carbohydrate level on growth and body composition of juvenile tilapia, *Oreochromis niloticus* × *O. aureus*. *Aquacult*. *Res*., 36:1408-1413.

Watanabe T., 2002. Strategies for further development of aquatic feeds. *Fish. Sci*., 68:242-252.

Zhou Z., Ren Z., Zeng H. and B. Yao, 2008. Apparent digestibility of various feedstuffs for bluntnose black bream *Megalobrama amblycephala* Yih. *Aquacult*. *Nutr*., 14:153-165.

Zhou C.P., Liu B., Xie J., Ge X.P., Xu P., Zhou Q.L., Pang L.K. and R.L. Chen, 2013. Effect of dietary carbohydrate levels on the growth performance, blood chemistry, hepatic enzyme activities and growth hormone gene expression of the Wuchang bream (*Megalobrama amblycephala*). *Isr. J. Aquacult. - Bamidgeh*, IJA_65.2013.882, 8 pages.