Dietary myo-inositol requirement for juvenile gibel carp (Carassius auratus gibellio)

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Abstract
An 11-week growth trial was conducted to determine dietary myo-inositol (MI) requirement for juvenile gibel carp (Carassius auratus gibellio). Myo-inositol was supplemented to the basal diet to formulate six purified diets containing 1, 56, 107, 146, 194 and 247 mg MI kg⁻¹ diet, respectively. Each diet was fed to triplicate groups of juvenile gibel carp (initial body weight 3.38 ± 0.27 g, mean ± SD) in a flow-through system. The diets were randomly assigned to different fish tanks. Fish fed ≥ 107 mg MI kg⁻¹ diet had significantly higher weight gain (WG), feed efficiency (FE) and protein efficiency ratio than those fed 1 mg MI kg⁻¹ diet. Fish fed ≥ 56 mg MI kg⁻¹ diet had higher feeding rate and survival compared with fish fed 1 mg MI kg⁻¹ diet. Dietary supplemental inositol did not affect fish liver inositol concentration. Fish fed ≥ 56 mg MI kg⁻¹ diet had higher body dry matter, crude protein and gross energy and lower hepatosomatic index than fish fed 1 mg MI kg⁻¹ diet. Dietary inositol supplementation decreased fish body ash. Quadratic regression of weight gain indicated that the myo-inositol requirement to maximum growth for juvenile gibel carp was 165.3 mg MI kg⁻¹ diet.

KEY WORDS: Carassius auratus gibellio, gibel carp, myo-inositol, requirement

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Introduction
Myo-inositol (MI) is the most prevalent naturally occurring biologically active isomer of inositol. It is widely distributed in plants and animals mainly as a structural component of biological membranes in the phospholipid form. As part of the phospholipid form, phosphatidylinositol is an important participant in transmembrane signal transfer (Aukema & Holub 1994). Inositol can be synthesized de novo from glucose by various animal organs including liver, kidney, brain and other tissues (Burtle & Lovell 1989; Deng et al. 2002). The intestinal microflora has also been suggested to contribute to myo-inositol nutrition for some species (Aukema & Holub 1994; Mai et al. 2001). For some fish and shellfish, de novo synthesis of myo-inositol is inadequate to meet their metabolic needs and require an exogenous dietary source of this vitamin (Aoe & Masuda 1967; Shiau & Su 2004; Jiang et al. 2009). Myo-inositol is classified as an essential vitamin nutrient and is often supplemented to aquatic feeds (Jiang et al. 2010).

Quantitative dietary requirement of myo-inositol has been determined in many aquatic animals. It has been reported that the requirement of myo-inositol was 440 mg MI kg⁻¹ diet in common carp, Cyprinus carpio L. (Aoe & Masuda 1967), 250–500 mg MI kg⁻¹ diet in rainbow trout, Oncorhynchus mykiss (Kitamura et al. 1967), 550–900 mg MI kg⁻¹ diet in red sea bream, chrysophrys major (Yone et al. 1971), 300 mg MI kg⁻¹ diet in Atlantic salmon, Salmo salar L. (Waagbo et al. 1998), 400 mg MI kg⁻¹ diet in hybrid tilapia, Oreochromis niloticus × O. aureus (Shiau & Su 2005), 166 mg MI kg⁻¹ diet in grass carp, Ctenopharyngodon idella (Wen et al. 2007), 518 mg MI kg⁻¹ diet in Jian carp, Cyprinus carpio var. Jian (Jiang et al. 2009), 617 mg MI kg⁻¹ diet in olive flounder, Paralichthys olivaceus (Lee et al. 2009), 3400 mg MI kg⁻¹ diet in grass shrimp, Penaeus monodon (Shiau & Su 2004). Myo-inositol deficiency has been associated with reduced growth, depressed feed intake, increased liver lipids, low activities of cholinesterase and transaminase, slow gastric emptying, fin erosion, dark skin coloration and anaemia (NRC 2011). Deficient dietary myo-inositol could also lead to white-grey

Gibel carp (*Carassius auratus gibelio*) is an improved strain of crucian carp and becomes a popular aquaculture species in China. The annual production of this species is more than 2 million tons (China Fisheries Yearbook 2007). With decades of studies, the requirements of gibel carp for dietary protein, lipid, carbohydrate and essential fatty acids have been estimated (Qian 2001; Pei et al. 2004; Tan et al. 2006; Chen et al. 2011). Recently, some studies have focused on the requirements of minerals in gibel carp (Pan et al. 2008, 2009; Han et al. 2011). However, very few studies have addressed vitamin nutrition in gibel carp. In our laboratory, the requirements of dietary vitamin B<sub>6</sub> and choline for juvenile gibel carp been investigated (Wang et al. 2011; Duan et al. 2012). The essentiality of myo-inositol in the diet of this species was still not clear. Therefore, the purpose of the present study was to determine the dietary myo-inositol requirement for juvenile gibel carp.

**Materials and methods**

**Experimental diets**

The basal diet formulation is presented in Table 1. Vitamin-free casein and gelatine were used as dietary protein sources. Fish oil and corn oil were used as dietary lipid sources. Dextrin and corn starch were used as dietary carbohydrate sources. Myo-inositol (AR grade; concentration 98%; Roche, Basel, Switzerland) was added to the basal diet at the expense of cellulose to formulate six purified diets. The determined dietary myo-inositol contents were 1 (the control), 56, 107, 146, 194 and 247 mg kg<sup>-1</sup>, respectively. Diet ingredients were ground and passed through 0.246 mm screen mash. The ingredients were thoroughly mixed and made into pellets (2 mm in diameter) using laboratory pellet machine. The pellets were air-dried at room temperature and stored at 4 °C until used.

**Experimental fish and feeding**

Juvenile gibel carp were obtained from a local hatchery farm of Hubei, China. Prior to the feeding trial, fish were acclimated to laboratory conditions for 4 weeks. During the first 2 weeks of acclimatization, fish were fed with a practical diet formulated by our laboratory (containing 38% crude protein). Then, the fish were fed the basal diet without myo-inositol supplementation for 2 weeks. At the start of experiment, fish were fasted for 24 h and pooled. The 20 fish (initial weight 3.38 ± 0.27 g ind<sup>−1</sup>, mean ± SD) were randomly selected, batch-weighted and randomly allocated to each tank. Each diet was randomly assigned to triplicate tanks.

The experiment was conducted in an indoor flow-through system consisting 18 rectangle plastic tanks (65 × 48 × 40 cm), and the flow rate was about 1.5 L min<sup>−1</sup> per tank. Each tank was provided continuous aeration. During the experiment, pH and water temperature were measured daily, and dissolved oxygen and ammonia-N measured weekly. Water temperature ranged 23–31 °C; pH 6.7–7.2; residual chlorine was less than 0.01 mg L<sup>−1</sup>; dissolved oxygen was above 5 mg L<sup>−1</sup> and ammonia

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casein (vitamin-free)</td>
<td>460.0</td>
</tr>
<tr>
<td>Gelatine</td>
<td>20.0</td>
</tr>
<tr>
<td>Corn starch</td>
<td>150.0</td>
</tr>
<tr>
<td>Dextrin</td>
<td>60.0</td>
</tr>
<tr>
<td>Fish oil</td>
<td>50.0</td>
</tr>
<tr>
<td>Corn oil</td>
<td>50.0</td>
</tr>
<tr>
<td>Mineral premix</td>
<td>50.0</td>
</tr>
<tr>
<td>Vitamin premix (inositol-free)</td>
<td>4.0</td>
</tr>
<tr>
<td>Choline chloride</td>
<td>1.1</td>
</tr>
<tr>
<td>Filler</td>
<td>43.3</td>
</tr>
<tr>
<td>Cellulose</td>
<td>101.6</td>
</tr>
<tr>
<td>Chromium oxide</td>
<td>10.0</td>
</tr>
<tr>
<td>Chemical composition (g kg&lt;sup&gt;-1&lt;/sup&gt;)</td>
<td></td>
</tr>
<tr>
<td>Crude protein</td>
<td>432.2</td>
</tr>
<tr>
<td>Crude lipid</td>
<td>80.9</td>
</tr>
<tr>
<td>Gross energy (kJ g&lt;sup&gt;−1&lt;/sup&gt;)</td>
<td>19.0</td>
</tr>
</tbody>
</table>

1 Sigma Chemical Co., St. Louis, MO, USA.
2 Sinopharm Chemical Reagent Co. Ltd, Shanghai, China.
3 Hebei Yannan Food Co. Ltd, Xingtai, Hebei, China.
4 Damao Chemical Reagent Factory, Tianjin, China.
5 Coland Feed Co. Ltd., Wuhan, Hubei, China.
6 Fortune Food Co. Ltd., Shanghai, China.
7 Mineral premix (mg kg<sup>−1</sup> diet): NaCl, 500; NaH<sub>2</sub>PO<sub>4</sub>·2H<sub>2</sub>O, 12 500; MnSO<sub>4</sub>·7H<sub>2</sub>O, 7500; KH<sub>2</sub>P<sub>2</sub>O<sub>7</sub>·2H<sub>2</sub>O, 10 000; Ca<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub>·H<sub>2</sub>O, 1 650; ZnSO<sub>4</sub>·7H<sub>2</sub>O, 176.5; FeSO<sub>4</sub>·7H<sub>2</sub>O, 1 250; CuSO<sub>4</sub>·5H<sub>2</sub>O, 16.5; MnSO<sub>4</sub>·4H<sub>2</sub>O, 81; CoCl<sub>2</sub>·6H<sub>2</sub>O, 0.53; KI, 1.59; starch, 225.
8 Vitamin premix (mg kg<sup>−1</sup> diet): thiamin 20; riboflavin, 20; pyridoxine, 20; Vitamin B<sub>12</sub>, 2; folic acid, 5; D-calcium pantothenate, 50; niacin, 100; biotin, 1.0; Vitamin A, 1.83; Vitamin D, 0.5; Vitamin E, 10; Vitamin K, 10; ascorbic acid, 100.
9 Non-nutritive material (cellulose) provided by the premix supplier as the filler.
nitrogen was around 0.3 mg L$^{-1}$. The photoperiod was 12L: 12D with the light period from 08:00 to 20:00 h.

The feeding trial lasted for 11 weeks. During the experiment, fish were hand-fed to apparent satiation twice daily (between 09:00–10:00 and 15:00–16:00 h). The quantity of feed consumed was recorded daily. Dead fish were removed daily and recorded. At the end of the experiment, the fish of each rank were batch-weighted after 24-h food deprivation.

**Sample collection**

Triplicates of fish (15 fish each sample) were randomly taken at the beginning of the experiment from the original batch, and three fish from each tank were randomly sampled at the end of the experiment and frozen at $-20^\circ$C for the chemical analysis of initial and final body composition.

At the end of the experiment, three fish randomly selected from each tank were sampled for measuring hepatosomatic index. Liver samples were removed from six fish of each tank and were immediately frozen in liquid nitrogen and stored at $-20^\circ$C for inositol analysis.

**Chemical analysis**

The inositol content in the diets and liver samples was determined by Beijing Pony Center for Physical and Chemical Analysis (Beijing, China) using gas chromatography (GC-14C, Shimadzu, Kyoto, Japan) assay as described by Shen & Zhang (2000).

The contents of dry matter, crude protein, crude lipid, ash and gross energy were determined for the diets and the fish. Chemical analyses were conducted following standard methods of AOAC (1984). Dry matter was determined by drying at 105 $^\circ$C for 24 h, crude protein (N × 6.25) by the Kjeldahl method (2300 Kjeltec Analyzer Unit, Foss TECA-TOR, made in Sweden), crude lipid by ethyl ether extraction in the Soxtec System (Soxtec System HT6; Tecator, Hoganas, Sweden), ash by combustion at 550 $^\circ$C for 12 h, gross energy by combustion in a microbomb calorimeter (Phillipson microbomb calorimeter; Gentry Instruments Inc., Aiken, SC, USA). For each measurement, at least duplicate samples were measured.

**Statistical analysis**

All data were analysed by one-way analysis of variance (ANOVA). Significant differences in the means between dietary treatments were determined by Duncan’s multiple range tests. Probabilities of $P < 0.05$ were considered significant. The optimum dietary myo-inositol requirement based on weight gain (WG) was estimated using quadratic regression analysis.

**Results**

**Growth and survival**

Growth performance was significantly affected by dietary myo-inositol level ($P < 0.05$; Table 2). Weight gain (WG) was highest ($P < 0.05$) for the fish fed diets with $\geq 107$ mg MI kg$^{-1}$ diet, followed by the 56 mg MI kg$^{-1}$ diet, and the lowest for fish fed the basal diet. Based on quadratic regression between weight gain and dietary myo-inositol levels, dietary requirement for maximum growth was 165.3 mg MI kg$^{-1}$ diet (Fig. 1).

Feed efficiency (FE) or protein efficiency ratio (PER) showed a similar trend to SGR, which exhibited the highest value in fish fed the diet with $\geq 107$ mg MI kg$^{-1}$ diet and the lowest for fish fed the basal diet. Feeding rate was highest ($P < 0.05$) for fish fed with 56 mg MI kg$^{-1}$ diet.

**Table 2** Growth and survival of juvenile gibel carp fed diets containing different levels of myo-inositol (mean ± SE)$^{1,2}$

<table>
<thead>
<tr>
<th>Dietary inositol (mg kg$^{-1}$)</th>
<th>Initial body weight (g)</th>
<th>FR (% body weight day$^{-1}$)</th>
<th>Final body weight (g)</th>
<th>WG (%)</th>
<th>FE (%)</th>
<th>PER</th>
<th>Survival (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>3.38 ± 0.00</td>
<td>2.16 ± 0.11$^a$</td>
<td>6.42 ± 0.35$^a$</td>
<td>89.8 ± 10.4$^a$</td>
<td>31.82 ± 2.43$^a$</td>
<td>0.75 ± 0.06$^a$</td>
<td>63.3 ± 16.4$^a$</td>
</tr>
<tr>
<td>56.0</td>
<td>3.38 ± 0.02</td>
<td>2.62 ± 0.02$^b$</td>
<td>13.45 ± 0.46$^b$</td>
<td>298.5 ± 13.6$^b$</td>
<td>55.80 ± 1.50$^b$</td>
<td>1.26 ± 0.03$^b$</td>
<td>86.7 ± 6.0$^b$</td>
</tr>
<tr>
<td>107.2</td>
<td>3.37 ± 0.00</td>
<td>2.54 ± 0.05$^{bc}$</td>
<td>15.20 ± 0.43$^{bc}$</td>
<td>350.8 ± 12.7$^{bc}$</td>
<td>65.47 ± 1.81$^{bc}$</td>
<td>1.54 ± 0.04$^{bc}$</td>
<td>98.3 ± 1.7$^{bc}$</td>
</tr>
<tr>
<td>145.6</td>
<td>3.39 ± 0.01</td>
<td>2.56 ± 0.07$^b$</td>
<td>15.95 ± 0.67$^b$</td>
<td>370.9 ± 20.2$^b$</td>
<td>67.09 ± 1.83$^b$</td>
<td>1.57 ± 0.04$^b$</td>
<td>100.0 ± 0.0$^b$</td>
</tr>
<tr>
<td>193.7</td>
<td>3.38 ± 0.01</td>
<td>2.54 ± 0.09$^b$</td>
<td>15.45 ± 0.85$^b$</td>
<td>356.5 ± 25.6$^{b}$</td>
<td>66.38 ± 0.76$^b$</td>
<td>1.56 ± 0.02$^b$</td>
<td>100.0 ± 0.0$^b$</td>
</tr>
<tr>
<td>247.0</td>
<td>3.38 ± 0.00</td>
<td>2.32 ± 0.04$^{ab}$</td>
<td>14.55 ± 0.55$^{bc}$</td>
<td>330.2 ± 16.2$^{bc}$</td>
<td>71.03 ± 1.70$^{bc}$</td>
<td>1.59 ± 0.04$^{bc}$</td>
<td>100.0 ± 0.0$^{bc}$</td>
</tr>
</tbody>
</table>

FR, feeding rate (% body weight day$^{-1}$) = 100 × total feed intake/[days × (initial body weight + final body weight)/2].

FE, feed efficiency (%) = 100 × wet weight gain/total feed intake in dry basis.

PER, protein efficiency ratio = weight gain/protein intake in dry basis.

1 Means with different superscripts in the same column are significantly different ($P < 0.05$).

2 WG, weight gain (%) = 100 × (final body weight – initial body weight)/initial body weight.
Relationship between weight gain and dietary myo-inositol for juvenile gibel carp. Each point represents the mean of three groups of fish (n = 3). The myo-inositol requirement derived with the quadratic regression method for maximum weight gain is 165.3 mg kg\(^{-1}\) diet.

and then showed slight decrease when dietary MI was above 107 mg MI kg\(^{-1}\) diet (P > 0.05). After 11-week feeding trial, survival of the fish fed the basal diet averaged 63.3%, which was significantly lower than those (86.7–100%) fed diets with ≥ 56 mg MI kg\(^{-1}\) diet (P < 0.05).

The results indicated that myo-inositol deficiency reduced growth, depressed feed intake and reduced survival.

Liver inositol content and hepatosomatic index

Liver inositol content of gibel carp ranged from 10.08 to 25.65 mg MI kg\(^{-1}\) wet tissue, and the difference between different dietary MI was not significant (P > 0.05) (Table 3). Hepatosomatic index of the fish fed the basal diet was significant higher than those fed the diets ≥ 56 mg MI kg\(^{-1}\) diet (P < 0.05).

Body composition

Body composition of juvenile gibel carp was significantly affected by dietary inositol levels (Table 4). There was no significant difference in lipid content of fish fed different diets for 11 weeks (P > 0.05). Fish fed the basal diet had significantly lower dry matter, crude protein and gross energy compared with those fed diets supplemented with ≥ 56 mg MI kg\(^{-1}\) diet (P < 0.05), and showed an increasing trend as dietary inositol increased. Fish fed the basal diet had significantly higher ash content compared with those fed diets supplemented with ≥ 56 mg MI kg\(^{-1}\) diet (P < 0.05) and showed a decreasing trend as dietary inositol increased.

Discussion

The growth performance in the present study was comparable to that observed in previous study fed with an animal-based practical diet (Hu et al. 2008). Based on weight gain, the optimal myo-inositol requirement for juvenile gibel carp was 165.3 mg MI kg\(^{-1}\) diet, which was similar to that reported for grass carp (166 mg MI kg\(^{-1}\) diet, Wen et al. 2007), but lower than those reported for common carp (440 mg MI kg\(^{-1}\) diet, Aoe & Masuda 1967), hybrid tilapia (400 mg MI kg\(^{-1}\) diet, Shiau & Su 2005), Jian carp (518 mg MI kg\(^{-1}\) diet, Jiang et al. 2009). The difference in dietary requirement of various aquatic species for

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**Table 3** Liver inositol concentration and hepatosomatic index (HSI) of juvenile gibel carp fed diets containing different levels of myo-inositol (mean ± SE)\(^{1}\)

<table>
<thead>
<tr>
<th>Dietary inositol (mg kg(^{-1}))</th>
<th>Liver inositol (mg kg(^{-1}) wet tissue)</th>
<th>HSI(^{2}) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>11.90 ± 0.25</td>
<td>15.29 ± 2.40(^{\text{ab}})</td>
</tr>
<tr>
<td>56.0</td>
<td>10.71 ± 3.68</td>
<td>10.71 ± 0.84(^{\text{a}})</td>
</tr>
<tr>
<td>107.2</td>
<td>18.47 ± 11.19</td>
<td>10.14 ± 0.49(^{\text{a}})</td>
</tr>
<tr>
<td>145.6</td>
<td>12.37 ± 3.23</td>
<td>10.52 ± 0.95(^{\text{a}})</td>
</tr>
<tr>
<td>193.7</td>
<td>10.08 ± 1.96</td>
<td>10.30 ± 1.29(^{\text{a}})</td>
</tr>
<tr>
<td>247.0</td>
<td>25.65 ± 17.49</td>
<td>9.02 ± 1.00(^{\text{a}})</td>
</tr>
</tbody>
</table>

\(^{1}\) Means with different superscripts in the same column differ significantly (P < 0.05).

\(^{2}\) HSI: hepatosomatic index = 100 × liver weight/body weight.

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**Table 4** Body composition (wt weight basis) of gibel carp fed diets containing different levels of myo-inositol (means ± SE)\(^{1}\)

<table>
<thead>
<tr>
<th>Dietary inositol (mg kg(^{-1}))</th>
<th>Dry matter (g kg(^{-1}))</th>
<th>Protein (g kg(^{-1}))</th>
<th>Lipid (g kg(^{-1}))</th>
<th>Ash (g kg(^{-1}))</th>
<th>Gross energy (kJ g(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>257.2 ± 12.4(^{\text{a}})</td>
<td>115.5 ± 1.5(^{\text{a}})</td>
<td>64.6 ± 8.2</td>
<td>37.2 ± 1.1(^{\text{b}})</td>
<td>5.37 ± 0.39(^{\text{a}})</td>
</tr>
<tr>
<td>56.0</td>
<td>273.1 ± 6.3(^{\text{ab}})</td>
<td>133.3 ± 1.7(^{\text{a}})</td>
<td>66.7 ± 1.3</td>
<td>32.9 ± 0.1(^{\text{a}})</td>
<td>6.08 ± 0.14(^{\text{ab}})</td>
</tr>
<tr>
<td>107.2</td>
<td>271.1 ± 2.7(^{\text{ab}})</td>
<td>134.6 ± 2.4(^{\text{b}})</td>
<td>68.5 ± 1.5</td>
<td>31.1 ± 0.5(^{\text{a}})</td>
<td>6.15 ± 0.03(^{\text{b}})</td>
</tr>
<tr>
<td>145.6</td>
<td>275.9 ± 5.4(^{\text{ab}})</td>
<td>139.2 ± 1.8(^{\text{bc}})</td>
<td>66.5 ± 3.7</td>
<td>30.9 ± 0.4(^{\text{a}})</td>
<td>6.34 ± 0.14(^{\text{ab}})</td>
</tr>
<tr>
<td>193.7</td>
<td>284.3 ± 7.7(^{\text{b}})</td>
<td>143.0 ± 2.4(^{\text{c}})</td>
<td>68.7 ± 4.6</td>
<td>31.7 ± 1.2(^{\text{a}})</td>
<td>6.39 ± 0.11(^{\text{b}})</td>
</tr>
<tr>
<td>247.0</td>
<td>277.0 ± 2.9(^{\text{ab}})</td>
<td>141.5 ± 2.9(^{\text{c}})</td>
<td>63.8 ± 1.1</td>
<td>31.9 ± 0.4(^{\text{a}})</td>
<td>6.26 ± 0.12(^{\text{b}})</td>
</tr>
</tbody>
</table>

\(^{1}\) Means with different superscripts are significantly different (P < 0.05).
myo-inositol across studies may be due to species specific
(Shiau & Su 2005; Jiang et al. 2009) and/or different exper-
imental conditions.

Myo-inositol occurs in animal cells as a component of
phospholipids, which plays an important role in fat metab-
olism by promoting the export of fat from the liver (Halver
1989). The dietary level of lipid influenced the myo-inositol
requirement for some species (Chu & Geyer 1983). Wen
et al. (2007) suggested that the dietary myo-inositol require-
ment for grass carp (166 g MI kg\(^{-1}\) diet based on weight
gain) lower than other fish species due to low dietary lipid.
In Atlantic salmon, dietary myo-inositol requirement was
300 mg MI kg\(^{-1}\) diet and the amount of dietary lipid was
152–154 g kg\(^{-1}\) diet (Waagbo et al. 1998). In the present
study, the dietary lipid content (80.9 g kg\(^{-1}\) diet) was
reduced to be less than the requirement of gibel carp
(140.5 g kg\(^{-1}\) diet) (Pei et al. 2004) to decrease the require-
ment of myo-inositol for lipid metabolism. Thus, the myo-
inositol requirement obtained for juvenile gibel carp in the
present study might represent the minimal dietary myo-ino-
sitol requirement.

The gibel carp fed the basal diet lacking myo-inositol
exhibit low survival. Lee et al. (2009) reported that olive
flounder fed with 800 mg MI kg\(^{-1}\) and 1600 mg MI kg\(^{-1}\)
diets showed a high survival compared with the control.
Shiau & Su (2004) also reported that low survival observed
in shrimp fed diets lacking or containing an inadequate
level of myo-inositol. Similar result was obtained in
 Marinesupenaus japonicus (Kanazawa et al. 1976). But high sur-
vival was reported and not affected by dietary myo-inositol
levels in sunshine bass (Deng et al. 2002) and Nile tilapia
(Peres et al. 2004), while tissue synthesis of myo-inositol
might be sufficient to support normal growth and health in
those species.

The present results showed that up to certain levels of
dietary myo-inositol could increase PER. Similar result was
also reported in Jian carp (Jiang et al. 2009), olive flounder
(Lee et al. 2009) and grass shrimp (Shiau & Su 2004).

Tissue inositol concentrations in relation to dietary inosi-
tol have been studied in some fishes. In hybrid tilapia, liver
inositol concentration was responsive to dietary myo-
inositol levels up to a certain level (Shiau & Su 2005). Lee
et al. (2009) reported that liver inositol concentration of
olive flounder was significantly increased by supplementa-
tion of dietary inositol. However, the present study found
no significant difference in liver inositol content between
treatments with different dietary myo-inositol levels. Similar
liver inositol levels were observed in sunshine bass (Deng
et al. 2002), Atlantic salmon (Waagbo et al. 1998) and
channel catfish (Burtle & Lovell 1989), regardless of the
level of dietary inositol. It could be due to sufficient tissue
myo-inositol is synthesized to maintain normal metabolic
function. The concentration in the liver, however, was dras-
tically lower in gibel carp (11–26 mg kg\(^{-1}\)) than in olive
flounder (163–244 mg kg\(^{-1}\), Lee et al. 2009) and hybrid
tilapia (1.70–2.55 mg g\(^{-1}\), Shiau & Su 2005). Deng et al.
(2002) found that the inositol concentrations in the brain
tissue were threefold higher in sunshine bass (2500–
3000 mg kg\(^{-1}\)) than in channel catfish (800–900 mg kg\(^{-1}\)).
The probable cause of the difference in concentration is the
different fish species.

Regarding body composition, no significant differences
were observed in the lipid content, but the dry matter, pro-
tein and energy contents were significantly lower in fish fed
the inositol-deficient diets. The results were not in line with
the finding of Waagbo et al. (1998) for Atlantic salmon
and Wen et al. (2007) for grass carp. The proximate com-
position of whole body was not affected by dietary myo-
inositol levels in their studies. Some authors reported that
the changes in body composition were largely related to
changes in growth (Hogendoorn 1983; Weatherley & Gill
1983). Jiang et al. (2009) founded that Jian carp fed inosi-
tol-deficient diet reduced growth and body crude protein
and protein retentions.

In conclusion, juvenile gibel carp requires exogenous ino-
sitol for normal growth. Based on weight gain, the dietary
inositol requirement for the maximum growth of gibel carp
is estimated to be 165.3 mg MI kg\(^{-1}\) diet.

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