CHAPTER 2
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EFFECTS OF DIETARY PYRIDOXINE LEVELS ON GROWTH, CONVERSION EFFICIENCIES AND BODY COMPOSITION OF FINGERLING *CIRRHINUS MRIGALA* (HAMILTON)

Introduction

In addition to the growth and health of cultured fish, the quality of the feed can also affect the organoleptic quality of meat. Particularly important in this regard is the contribution of vitamins and trace elements, which if provided in sufficient quantities, can enhance the nutritional value of the animal meat (Lanari et al., 1995). Vitamins are a heterogeneous group of organic compounds essential for the growth and maintenance of animal life. The majority of vitamins are not synthesized by the animal body or at a rate sufficient to meet the animal’s needs. They are distinct from the major food nutrients like proteins, lipids and carbohydrates. These are present in very small quantities within animal and plant feedstuffs and are required by the animals in trace amounts (Halver, 1989; Macrae et al., 1993; Chew, 1996). Vitamin premixes can account for as much as 15% of total feed ingredient cost, so the inclusion of excessive vitamins can be costly (Akiyama et al., 1992). In addition, over-fortification of certain vitamins like riboflavin, niacin and pyridoxine can result in reduced fish growth (Deshimaru and Kuroki, 1979; Catacutan and Cruz, 1989; Conklin, 1997) and negatively affect production and profitability for the farmer (Moss et al., 2006).
Pyridoxine is an important water-soluble vitamin, functions as a precursor of the coenzyme for several enzymatic reactions, including decarboxylation, deamination, transamination, desulfuration, transfer of amino acids into cells and neurotransmitter function (Dakshinamurti, 1990; Marcus and Coustan, 1996; Huang et al., 2005). Among them, the most important is to act as the coenzyme of aminotransferase and decarboxylase in the reactions of amino acid and nitrogenous compound (Leklem, 1996; Giri et al., 1997; Mai et al., 2007). Furthermore, studies revealed that pyridoxine is involved in the antioxidant reaction and the synthesis of DNA and RNA (Trakatellis and Dimitriadou, 1992; 1997) and also regulate the gene expression of glucocorticoids hormone and albumin (Allgood and Cidlowski, 1991; Natori and Oka, 1997). Due to multiple roles of pyridoxine at various metabolic levels, metabolic disturbances relating to pyridoxine have profound effects on physiological functions of animals (Chen et al., 2005). In fish, pyridoxine deficiency has been associated with poor growth, anorexia, edema, tetany, convulsions and rapid postmortem rigor mortis, rapid and gasping breathing, flexing of opercles, epileptiform fits and other nervous disorders (Halver, 1989; Huang et al., 2005; Mai et al., 2007).

Freshwater aquaculture in India is mainly based on Indian major carps (Labeo rohita, Catla catla and Cirrhinus mrigala) with an annual production of 1.66 million tonnes and exotic carps, which together contribute to over 87% of total aquaculture production of 1.93 million tonnes (FAO, 2001°). These are the most commercially important freshwater fishes in India due to their relatively fast growth rate and consumer preference (Zhang and Reddy, 1991). C. mrigala, the fish under study, is a promising species for aquaculture exploitation with its omnivorous feeding habits, rapid growth and good market potential and forms an important component of polyculture with the other species of major carps.
Although quantitative requirement of pyridoxine has been determined in chinook salmon, *O. tshawytscha* (Halver, 1957); coho salmon, *O. kisutch* (Coates and Halver, 1958); brook trout, *Salvelinus fontinalis* (Phillips and Livingston, 1965); common carp, *Cyprinus carpio* (Ogino, 1965); Japanese amberjack, *Seriola quinquiradiata* (Sakaguchi et al., 1969); red seabream, *Pagrus major* (Takeda and Yone, 1971); turbot, *Scophthalmus maximus* (Adron et al., 1978); channel catfish, *Ictalurus punctatus* (Dupree, 1966; Andrews and Murai, 1979); juvenile shrimp, *P. japonicus* (Deshimaru and Kuroki, 1979); gilthead seabream, *Sparus auratus* (Kissil et al., 1981); red hybrid tilapia, *Oreochromis mossambicus* x *O. niloticus* (Lim et al., 1995); hybrid tilapia, *O. niloticus* x *O. aureus* (Shiau and Hsieh, 1997); stinging catfish, *Heteropneustes fossilis* (Mohamed, 2001); barred knife jaw, *Oplegnathus fasciatus* (Yasunorl et al., 2002); grass shrimp, *Penaeus monodon* (Shiau and Wu, 2003); orange-spotted grouper, *Epinephelus coioides* (Huang et al., 2005) and abalone, *Haliotis discus hannai* (Mai et al., 2007), no information is available on dietary pyridoxine requirement of this fish. Therefore, present study was undertaken to determine the pyridoxine requirement of fingerling *C. mrigala*.

**Materials and methods**

**Experimental diets**

Vitamin-free casein-gelatin based isonitrogenous (40% crude protein) and isoenergetic (18.35kJg⁻¹ gross energy) diets with seven levels of pyridoxine (0, 1, 2, 4, 6, 8 and 10 mg/kg) were formulated (Table 1). Levels of pyridoxine were taken on the basis of the information available on other fishes. The dietary protein level was fixed at 40% of the diet, reported optimum for the growth of fingerling *C. mrigala* (Khan, 1991). A combination of
cod liver oil and corn oil (2:5) was used as a source of lipid. Vitamin and mineral premixes were prepared as per Halver (2002).

Method of preparation of experimental diets has been discussed under general methodology section (Page 12).

**Experimental design and feeding trial**

Source of the fish, their acclimation and details of the general experimental design has already been discussed under the general methodology section (Page 11-12).

_C. mrigala_ fingerling (4.35±0.05 cm; 0.58±0.03 g) were taken from the above acclimated fish lot and stocked in triplicate groups in 70- L circular polyvinyl troughs (water volume 55 L) fitted with a continuous water flow-through (1-1.5 L min⁻¹) system at the rate of 20 fish per trough for each dietary treatment level. Fish were fed test diets in the form of moist cake at 5% body weight twice daily at 0900 and 1700h. Initial and weekly weights were recorded on a top-loading balance (Precisa 120A; 0.1 mg sensitivity, Oerlikon AG, Zurich, Switzerland). Fish were deprived of feed on the day they were weighed. The feeding trial lasted for 16-weeks. Faecal matter, if any, was siphoned off before every feeding. Water quality indices were monitored daily during the feeding trial and were recorded following standard methods (APHA, 1992). The average water temperature, dissolved oxygen, free carbon dioxide, pH, and total alkalinity based on daily measurements, were 26.2-28.1 °C, 6.8-7.2 mg L⁻¹, 5.8-9.5 mg L⁻¹, 7.1-7.4 and 64.8- 80.4 mg L⁻¹, respectively.
Chemical analysis

Proximate composition of casein, gelatin, experimental diets, and initial and final body was estimated using standard methods as detailed earlier (12-14). Six sub samples of a pooled sample of 40 fishes were analyzed for initial body composition. At the end of the experiment 8 fishes from each replicate of dietary treatments were pooled separately and six subsamples from each pooled replicate were analyzed for final body composition.

Statistical analysis

Statistical analyses of growth data were done using procedures detailed earlier (Please see page 16).

Results

Over the 16-weeks growth trial, significant differences were observed in live weight gain (%) of the fingerling *C. mrigala* fed diets containing different levels of dietary pyridoxine (Table 2). Fish receiving 6 mg pyridoxine/kg diet (D5) reflected a maximum live weight gain (900.67%), best FCR (1.46), SGR (2.06 %) and PER (1.71) while those fed diets with lower pyridoxine levels showed reduced weight gain and efficiency of feed utilization. However, fish fed higher levels of pyridoxine did not provide additional growth. Poorest live weight gain per cent (558.6), FCR (3.31), lowest SGR (1.68%) and PER (0.76) were observed for fish fed diet containing pyridoxine free diet (D1). A survival was found to be in the range of 86-100%. Poor survival of the fish fed pyridoxine free diet (D1) was evident (Fig 5). Live weight gain and feed conversion ratio of fish improved (P<0.05) as dietary pyridoxine level increased from 0 to 6 mg/kg of the diet whereas at higher levels growth
responses were almost constant (P>0.05), indicating that 6 mg pyridoxine/kg diet satisfied the requirement and is considered optimum for achieving maximum growth in fingerling *C. mrigala*.

In order to generate more precise data on pyridoxine requirement for fingerling *C. mrigala*, all the growth data were subjected to broken-line regression analysis. On subjecting the live weight gain data to broken-line regression analysis, a break point indicating pyridoxine requirement to be at 5.85 mg/kg diet (Fig.1). The relationship being;

\[ Y = 58.04X + 543 (R^2 = 0.994), \quad Y = 3.91X + 859.5 (R^2 = 1) \]

The FCR (Y) to dietary concentrations of pyridoxine (X) relationship was estimated by the following broken-line regression equation (Fig. 2). A break point was evident at 5.21 mg pyridoxine/kg diet. The relationship being;

\[ Y = -0.3082X + 3.201 (R^2 = 0.969), \quad Y = -0.025X + 1.73 (R^2 = 1) \]

The PER (Y) to dietary concentrations of pyridoxine (X) relationship was estimated by the following broken-line regression equation (Fig. 3). a break point indicating pyridoxine requirement to be at 5.14 mg/kg diet. The relationship being;

\[ Y = 0.1593X + .723 (R^2 = 0.992), \quad Y = 0.03X + 1.39 (R^2 = 1) \]

The SGR (Y) to dietary concentrations of pyridoxine (X) relationship was estimated by the following broken-line regression equation (Fig. 4). A break point was obtained at 5.71 mg pyridoxine/kg diet. The relationship being;
On the basis of the above broken-line analysis, maximum live weight gain, best FCR, PER and SGR occurred at 5.85, 5.21, 5.14 and 5.71 mg pyridoxine/kg diet respectively.

Data related to whole body composition are summarized in Table 3. Dietary pyridoxine levels significantly (P<0.05) affected the body composition of fingerling *C. mrigala* (Table 3). Maximum moisture content was recorded in fish fed basal diet (D1) without supplementation of pyridoxine. However, it significantly decreased for the groups receiving diets D2, D3, D4 and D5 with 1, 2, 4 and 6 mg pyridoxine/kg diet and no significant difference in moisture content of fish was noted in fish fed diets containing 8 and 10 mg pyridoxine/kg diet (D6 and D7). Whole body lipid of fingerling *C. mrigala* was found to increase with the increase in dietary pyridoxine incorporation up to 6 mg/kg dry diet. *C. mrigala* fed pyridoxine supplemented diets had a significantly higher (P<0.05) whole body protein than the fish fed diet without supplemental pyridoxine (D1). Body protein tended to increase significantly (P<0.05) with increasing dietary pyridoxine up to 6 mg/kg (D5) of the diet and further supplementation of pyridoxine did not show any significant improvement (D6 and D7). Ash content remained unaffected among the fish fed various dietary pyridoxine levels.

**Discussion**

Pyridoxine is an essential nutrient of animals, including aquatic animals such as fishes and crustaceans. Its major active forms in animals are pyridoxal 5'-phosphate (PLP) and
pyridoxamine 5'-phosphate (PMP). The availability of this vitamin could optimize both
metabolisms, with positive effects on the levels of growth, state of health and composition
of the muscle tissue of the fish, thereby enhancing their nutritional value (Maranesi et al.,
2005). Phosphorylated pyridoxine forms serve as coenzymes for transaminases that are key
enzymes in many pathways involving oxidative catabolism and de novo synthesis of amino
acids (Friedrich, 1988). Pyridoxine supplementation increases the docosahexaenoic acid
concentration of muscle lipids of rainbow trout (O. mykiss). Some authors reported that, in
the rat, the availability of pyridoxine influences the activity of some enzymes involved in
polyunsaturated fatty acid metabolism, as D6 desaturase and acyl-CoA oxidase (She et al.,
1994; Bordoni et al., 1998; Tsuge et al., 2000). Pyridoxine containing enzymes are involved
in decarboxylation, oxidation, transamination, desulfhydration, cleavage and the other
reactions with amino acids (Halver, 1972; Mai et al., 2007).

Significant differences in growth and conversion efficiency of C. mrigala fed diets
with variable levels of pyridoxine clearly demonstrates that pyridoxine is required in the diet
of C. mrigala for normal growth. Based on growth parameters, the optimum dietary level of
pyridoxine by C. mrigala for maximum growth was found to be at 6 mg/kg of diet (Table 2).
The above optimum dietary pyridoxine requirement of C. mrigala is higher than that
reported for turbot, 1–2.5 mg/kg (Adron et al., 1978); channel catfish, 3 mg/kg (Andrews
and Murai, 1979); gilthead seabream, 1.97 mg/kg (Kissil et al., 1981) and red hybrid tilapia,
3 mg/kg (Lim et al., 1995); but lower than the requirement reported for salmonids, 10-15
mg/kg (Halver, 1972); hybrid tilapia, 15–16.5 mg/kg (Shiau and Hsieh, 1997); abalone, 40
mg/kg (Mai et al., 2007) and comparable to that of common carp, 5.4 mg/kg (Ogino, 1965);
red seabream, 5–6 mg/kg (Takeda and Yone, 1971).
Body composition of fingerling *C. mrigala* was significantly (P<0.05) affected by the dietary pyridoxine levels (Table 3). *C. mrigala* fed pyridoxine supplemented diets had a significantly higher (P<0.05) whole body protein content than the diet without supplemental pyridoxine. Similar trend was also observed in whole body protein content of prawn, *P. japonicus* (Giri et al., 1997). Since metabolism of pyridoxine is related to the dietary protein or amino acid metabolism in the animal, Hilton (1989) hypothesized that an interaction between dietary pyridoxine and protein levels possibly occurred in fish. An increase in efficiency of protein utilization with increasing levels of dietary pyridoxine has been reported in gilthead seabream fry (Friedrich, 1988; Halver, 1989; Baker and Davies, 1995).

Body lipid content was also found to be significantly affected by varying dietary pyridoxine levels. A continuous and significant increase in lipid was noted with increase in dietary pyridoxine from 0-6 mg/kg diet (D1-D5) and further supplementation of dietary pyridoxine did not show significant improvement (D6 and D7). Maranesi et al. (2005) reported that docosahexaenoic acid concentration of muscle lipids of rainbow trout, *O. mykiss* increases with the supplementation of dietary pyridoxine.

Pyridoxine deficiency can result in anorexia, anemia and dark coloration, loss of balance, poor growth, and high mortality in fish (Smith et al., 1974, Kissil et al., 1981, Herman, 1985, Albrektsen et al., 1993). In the present study, pyridoxine deficiency signs appeared among fish fed basal diets after 10-weeks. Fish fed the pyridoxine deficient diet showed anorexia, erratic swimming, convulsions and poor growth. These deficiency signs were similar to those reported for other species (Kissil et al., 1981; Lim et al., 1995; Mohamed, 2001b; Huang et al., 2005; Mai et al., 2007). Andrews and Murai (1979) reported
tetany, nervous disorder and blue-green colour occur in pyridoxine-deficient channel catfish. Japanese eel showed anorexia and convulsions in 3-4 weeks on a pyridoxine-deficient diet (Arai et al., 1972). Anorexia, convulsions, erratic swimming, high mortality, hyperirritability, lethargy, muscle spasms, poor feed conversion and growth have been reported in red hybrid tilapia fed the diet without pyridoxine supplementation (Lim et al., 1995). Chen et al. (2005) demonstrated that dietary deficiency of pyridoxine suppresses the immune functions in *H. discus hannai*. Generally, pyridoxine supplementations (40-800 mg/kg of diet) in abalone diet increased the values of most immune parameters. Some pyridoxine deficiency signs have been reported in aquatic animals.

Broken-line regression analyses of live weight gain, feed conversion ratio, protein efficiency ratio and specific growth rate of fingerling *C. mrigala* fed diets with varying pyridoxine concentration indicated that pyridoxine requirement ranges between 5.14-5.85 mg/kg.

**SUMMARY**

Optimum dietary pyridoxine requirement of fingerling *C. mrigala* (4.35±0.05 cm; 0.58±0.03 g) was determined by feeding seven isonitrogenous (40% CP) and isocaloric (18.35 kJg⁻¹, gross energy) experimental diets with graded levels of pyridoxine (0, 1, 2, 4, 6, 8 and 10 mg/kg) for 16-weeks in triplicate groups. Live weight gain (900.67%), SGR (2.06%) and PER (1.71) were significantly higher (P<0.05) in fish fed 6 mg/kg pyridoxine in the diet (D5). Best FCR (1.46) was also recorded at this level. On the basis of the broken-line regression analysis of live weight gain%, FCR, SGR, PER, it is concluded that dietary pyridoxine in the range of 5.14-5.85 mg/kg is optimum for maximum growth, efficient feed
utilization of 40% CP diet for fingerling *C. mrigala*. Whole body protein was found to increase significantly up to 6 mg/kg pyridoxine in the diet beyond which no significant difference with respect to increase in dietary pyridoxine was evident. Similarly whole body fat was also found to with the dietary pyridoxine levels up to 6 mg/kg (D5). In order to obtain more precise information on the effects of feeding diets with different levels of pyridoxine, broken line regression analyses of live weight gain%, FCR, SGR and PER was performed. On the basis of break-points obtained for live weight gain%, FCR, SGR and PER, it is recommended that inclusion of dietary pyridoxine in the range of 5.14-5.85 mg/kg of diet is optimum for the culture of fingerling *C. mrigala*. 
Table 1: Composition of basal diet

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Amount (g/100g dry diet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casein* (vitamin free)</td>
<td>40</td>
</tr>
<tr>
<td>Gelatin*</td>
<td>11.13</td>
</tr>
<tr>
<td>Dextrin*</td>
<td>30</td>
</tr>
<tr>
<td>Corn oil*</td>
<td>5</td>
</tr>
<tr>
<td>Cod liver oil*</td>
<td>2</td>
</tr>
<tr>
<td>Mineral mix**</td>
<td>4</td>
</tr>
<tr>
<td>Vitamin mix (Pyridoxine free)</td>
<td>3</td>
</tr>
<tr>
<td>α-Cellulose</td>
<td>1</td>
</tr>
<tr>
<td>Carboxymethyl cellulose</td>
<td>5</td>
</tr>
<tr>
<td>**Total</td>
<td>100</td>
</tr>
<tr>
<td><strong>Gross energy (kJ/g)</strong></td>
<td>18.35</td>
</tr>
</tbody>
</table>

Proximate analysis of basal diet: moisture, 32.78%; ash, 3.65%; crude protein, 40.05%; ether extract, 7.1%. Pyridoxine was added to the diets to provide concentrations of 0, 1, 2, 4, 6, 8 and 10 mg/kg diet. *Crude Protein (76%); **Crude Protein (97%); Halver (2002); Mineral mixture (g/100g) calcium biphosphate 13.57; calcium lactate 32.69; ferric citrate 0.97; magnesium sulphate 13.20; potassium phosphate (dibasic) 23.98; sodium biphosphate 08.72; sodium chloride 04.35; aluminium chloride, 6H₂O 0.0154; potassium iodide 0.015; cuprous chloride 0.010; magnesium sulphate, H₂O 0.080; cobalt chloride, 6H₂O 0.100; zinc sulphate, 7H₂O 0.40; Vitamin mixture (1g vitamin mix +2g α-cellulose) choline chloride 0.500; inositol 0.200; ascorbic acid 0.100; niacin 0.075; calcium pantothenate 0.05; riboflavin 0.02; menadione 0.004; thiamine hydrochloride 0.005; folic acid 0.0015; biotin 0.0005; alpha-tocopherol 0.04; vitamin B₁₂ 0.00001; Loba Chemie, India *Calculated on the basis of fuel values 23.08, 20.199, 16.02 and 37.64 kJ for casein, gelatin, dextrin, and fat, respectively, as estimated on Gallenkamp ballistic bomb calorimeter.
Table 2 Growth and conversion efficiencies of fingerling *C. irigala* fed diets containing varying levels of pyridoxine

<table>
<thead>
<tr>
<th>Dietary pyridoxine levels (mg/kg dry diet)</th>
<th>0 (D1)</th>
<th>1 (D2)</th>
<th>2 (D3)</th>
<th>4 (D4)</th>
<th>6 (D5)</th>
<th>8 (D6)</th>
<th>10 (D7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average initial weight (g)(^1)</td>
<td>0.58± 0.02</td>
<td>0.584± 0.05</td>
<td>0.58± 0.03</td>
<td>0.575± 0.03</td>
<td>0.58± 0.02</td>
<td>0.57± 0.02</td>
<td>0.58± 0.02</td>
</tr>
<tr>
<td>Average final weight (g)(^1)</td>
<td>3.82±0.17(^c)</td>
<td>4.04±0.12(^d)</td>
<td>4.33±0.14(^c)</td>
<td>4.99±0.13(^b)</td>
<td>5.8±0.09(^a)</td>
<td>5.65±0.13(^ab)</td>
<td>5.79±0.11(^a)</td>
</tr>
<tr>
<td>Live weight gain (%)(^1,2)</td>
<td>558.6±15.89(^c)</td>
<td>591.4±12.33(^d)</td>
<td>647.31±10.6(^c)</td>
<td>768.3±8.9(^b)</td>
<td>900.67±10(^a)</td>
<td>890.8±12(^a)</td>
<td>898.62±11(^a)</td>
</tr>
<tr>
<td>FCR(^1,2,3)</td>
<td>3.31±0.03(^a)</td>
<td>2.95±0.04(^b)</td>
<td>2.39±0.02(^c)</td>
<td>1.89±0.02(^d)</td>
<td>1.46±0.02(^e)</td>
<td>1.53±0.02(^d)</td>
<td>1.48±0.02(^d)</td>
</tr>
<tr>
<td>Protein efficiency ratio(^1,2,4)</td>
<td>0.76±0.01(^c)</td>
<td>0.85±0.03(^d)</td>
<td>1.05±0.03(^c)</td>
<td>1.32±0.02(^b)</td>
<td>1.71±0.06(^a)</td>
<td>1.63±0.02(^a)</td>
<td>1.69±0.04(^a)</td>
</tr>
<tr>
<td>Specific growth rate% (^1,2,5)</td>
<td>1.68±0.15(^c)</td>
<td>1.73±0.14(^d)</td>
<td>1.79±0.12(^c)</td>
<td>1.93±0.13(^b)</td>
<td>2.06±0.11(^a)</td>
<td>2.05±0.14(^a)</td>
<td>2.06±0.13(^a)</td>
</tr>
<tr>
<td>Percentage survival(^6)</td>
<td>86</td>
<td>94</td>
<td>98</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

\(^1\)Mean values of 3 replicates ± SEM;  
\(^2\)Mean values sharing the same superscripts in the same row are insignificantly different (P>0.05)  
\(^3\)FCR= Dry feed fed/Dry weight gain  
\(^4\)PER= Wet weight gain/Wet protein fed  
\(^5\)SGR= (Final body weight-In initial body weight)/No of days x 100  
\(^6\)Survival = Final no. of fish/Initial no. of fish x 100
Table 3 Body composition of fingerling *C. brigitte* fed diets containing varying levels of pyridoxine

<table>
<thead>
<tr>
<th></th>
<th>Dietary pyridoxine levels (mg/kg dry diet)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Initial</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>76.75±0.4</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>13.05±0.12</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>3.58±0.1</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>3.79±0.05</td>
</tr>
</tbody>
</table>

Mean value of 3 replicates ± SEM. Mean values with the same superscripts are insignificantly different (P>0.05).
Fig. 1. Broken-line relationship of dietary pyridoxine levels to live weight gain%
Dietary pyridoxine levels (mg/kg dry diet)

Fig. 1

Y = 5.85 mg/kg

Y = 3.91X + 859.5 (R² = 1)

5.85 mg/kg
Fig. 2. Broken-line relationship of dietary pyridoxine levels to feed conversion ratio
Dietary pyridoxine levels (mg/kg dry diet)

Fig. 2

Y = 3.092X + 3.201 (R^2 = 0.969)

Y = -0.025X + 1.73 (R^2 = 1)

Feed conversion ratio

5.21 mg/kg
Fig. 3. Broken-line relationship of dietary pyridoxine levels to Protein efficiency ratio
Fig. 3

Protein efficiency ratio

Dietary pyridoxine levels (mg/kg dry diet)

Y = 0.1593X - 0.723 (R² = 0.992)

Y = 0.03X + 1.39 (R² = 1)

5.14 mg/kg
Fig. 4. Broken-line relationship of dietary pyridoxine levels to specific growth rate
Fig. 4

Specific growth rate

Dietary pyridoxine levels (mg/kg dry diet)

Y = 0.005X + 2.01 (R² = 1)

5.71 mg/kg.