Chapter 6

Dietary curcumin accelerates growth through improving the physiological status of *Anabas testudineus* (Bloch)

Introduction

Fish farming has developed into a highly productive and efficient industry for the production of animal protein for human consumption. In addition to good growing conditions, a prerequisite for productivity and economic sustainability in fish farming is a reliable supply of effective feeds. Although there are reports on the influence of curcumin on growth of higher animals such as pigs, broiler chickens and mice, no study hitherto has been reported on the effect of curcumin on fish growth. The present study evaluates the relation between curcumin intake and its physiological effects on growth, serum lipid profile, lipid peroxidation and other biochemical parameters of *Anabas testudineus* (Bloch).

Experimental design

At the end of acclimatization, the fish weighing 31.9 ± 0.69g and measuring 12.2 ± 0.13cm long were transferred to aquarium tanks (61x30.5x30.5 cm) which maintained the conditions identical to the stock tanks. The experimental tanks and fish were set as described in the previous chapter. A long term study was conducted for a period of six months. In order to assess the feed conversion
efficiency and assimilation efficiency, accurately weighed (10% BW) amounts of respective diets were given. Unconsumed pellets were siphoned out from the tank bottoms, three hours after feeding. The fecal matter was collected the next day prior to feeding. The amount of feed and fecal matter ingredients dissolved in surrounding water was not taken into account assuming the dissolved amount was equal for control and the treated groups. The unconsumed feed and fecal matter were dried at 60°C and weighed in order to calculate the total feed consumption and assimilation. Fish were sampled every three months and individual measurements of weight (g) and total length (cm) were taken. Since the water was changed every day, water quality measurements were not taken. The feed was stopped a day before weight was recorded. The mean weight of fish in each aquarium was calculated to work out the feeding rate for next week. Serum was also collected from eight randomly selected fish from each triplicate group and stored in -80°C. The biological parameters used for evaluating rearing results were defined and computed as follows:

\[
\text{Length gain (cm)} = \text{final length (cm)} - \text{initial length (cm)}
\]

\[
\text{Length gain\%} = \left[\frac{\text{length gain}}{\text{initial length}}\right] \times 100
\]

\[
\text{Weight gain (cm)} = \text{final weight (cm)} - \text{initial weight (cm)}
\]

\[
\text{Weight gain\%} = \left[\frac{\text{weight gain} \times \text{initial weight}}{\text{initial weight}}\right] \times 100
\]

\[
\text{Feed consumed (g)} = \text{amount of feed given (g)} - \text{feed remains (g)}
\]

\[
\text{Feed assimilated (g)} = \text{feed consumed (g)} - \text{weight of faecal matter (g)}
\]
Sample preparation and parameters analyzed

At the end of three and six months, eight fish were selected at random from each triplicate group, fasted overnight and blood was collected from the caudal artery. They were killed by decapitation. Dorsal muscle was collected from all fish. All sample preparation steps were carried out at 4°C. The tissue (100 mg) was homogenized in sucrose buffer and centrifuged at 5000 rpm for 10 min and the supernatant was used for assessing the enzyme activities. For determining the TBARS content, the tissue (100 mg) was homogenized in Tris-HCl buffer, centrifuged and the same fraction was taken. At the end of six months, the plasma was collected and stored at -80°C for measuring the lipid profile.

Muscle protein content (mg g⁻¹ tissue), TBARS content [μmol MDA (g⁻¹ tissue)], GSH [μmol (100 g⁻¹ tissue)], Na⁺/K⁺ and Ca²⁺ ATPase activities [nmol iP liberated (mg protein)⁻¹ (min)⁻¹], Na⁺, K⁺ and Ca²⁺ ions (μg gwt⁻¹), RNA content [density (mm)⁻²; mg (g tissue)⁻¹], plasma glucose concentration (mg mL⁻¹), and activities of AST (UL⁻¹), ALT (UL⁻¹) were determined as per the methods described in materials and methods section. Serum lipid profile (mg dL⁻¹), urea
(mg dL$^{-1}$) and creatinine (mg dL$^{-1}$) were measured in Advanced Clinical and Research Laboratory, Medical College, Thiruvananthapuram.

Statistical analyses

The data were statistically analyzed by one-way and two-way analysis of variance (ANOVA), using the SPSS set up. The results were expressed as mean ± S.E. The significant difference among means was determined by Duncan's multiple range test (Duncan, 1955) at the level, $p<0.05$.

Results

The results obtained in this feeding trial confirmed a growth promoting effect of curcumin in a lower vertebrate, fish. Fish with an initial mean body weight of $31.9 \pm 0.69$g and length $12.2 \pm 0.13$cm reached $37.6 \pm 1.0$g weight and $13.1 \pm 0.1$cm length in the curcumin treated group ($p<0.05$), but only $34.0 \pm 1.0$g of weight and $12.6 \pm 0.1$cm length in the control group ($p<0.05$) after 6 months. A 7% increase in total length and 17% increase in body weight were noted in curcumin fed group compared to control which increased in length by 3% and weight by 6% only (Table 6.1 & 6.2). On the other hand, there appeared to be no difference in the values of the quantity feed consumed between the control and treated groups after 3 months (Fig. 6.1). However, the feed consumption decreased by 6 months in the treated groups (Fig. 6.1). The FCE (Fig. 6.2) and FAE (Fig. 6.3) increased in the curcumin-fed groups after 3 and 6 months. The
protein content increased dose-dependently in the curcumin treated groups (Table 6.3).

The two way ANOVA results showed that there was a significant effect of time on feed consumption \( (p < 0.000; F = 25.2) \), assimilation \( (p < 0.000; F = 29.3) \) and weight gain \( (p < 0.002; F = 5.5) \) after 3 and 6 months of treatment. Similarly, the dose of curcumin also had significant effects on feed consumption \( (p < 0.000; F = 10.1) \), assimilation \( (p < 0.005; F = 5.9) \), length \( (F = 10.1; p < 0.000) \), and weight \( (p < 0.003; F = 6.36) \) of fish. The interaction between time and dose was significant only in feed consumption \( (p < 0.002; F = 7.01) \) and assimilation \( (F = 9.3; p < 0.000) \) by the fish.

Analysis of serum lipid profile indicated that curcumin modulated lipid metabolism. Curcumin treatment for three months decreased the total cholesterol content (TC), the bad LDL cholesterol, VLDL and triglycerides (TG) without altering the HDL content [Fig. 6.4(a)] whereas after six months, LDL and VLDL content were unaffected while HDL and TC increased in the 1% group with a decrease in TG content [Fig. 6.4(b)].

AST activity decreased while ALT activity remained unchanged following six months curcumin feeding. Urea decreased while creatinine content unaltered. Plasma glucose concentration remained the same in both the treated groups (Table 6.5).

In the 3 months curcumin - treated group, SOD activity decreased in the treated groups compared to control. The non-enzymatic antioxidant GSH
increased in 1% group. Lipid peroxidation products, collectively, the thiobarbituric acid reactive substances (TBARS) content was unaltered in the treated muscle following three months treatment (Table 6.3). After 6 months, both SOD activity and GSH content were unaffected while TBARS content decreased (Table 6.4). Muscle RNA content increased in the 1% curcumin fed group after 3 and 6 months (Table 6.3 & 6.4).

Activity of ATPases, the Na⁺/K⁺ ATPase was inhibited in the 1% group while Ca²⁺ ATPase increased in the 0.5% group (Fig. 6.5) after 3 months feeding. There were little differences in the ions, Na⁺ and K⁺ after curcumin feeding whereas it increased the Ca²⁺ ions compared to control (Fig. 6.6).

Agarose gel electrophoresis also showed that there was an increase in muscle RNA content in the 6 months curcumin-fed fish compared to control (Fig. 6.7).

**Discussion**

Growth in fish has been studied intensively because it is a good indicator of health. Rapid growth indicates abundance of food and other favorable conditions, whereas slow growth is likely to indicate just the opposite. Growth is commonly measured as changes in body weight, length or condition factor (i.e. weight-length relationship) over time (Kiessling et al., 2006). The quantity and quality of feed, the metabolic state of the animal, the energy demands for its maintenance and behavioral activities largely determine the fate of the food consumed and the possible growth. Feed intake is affected by the rate of gastric evacuation. There is
considerable evidence to support the hypothesis that gastric evacuation is regulated by the energy content of the food. The greater are the energy contents of the food, the slower the evacuation rate (Dos Santos & Jobling, 1988).

The present study confirmed that curcumin has potential as a feed supplement from the viewpoint of efficient utilization of dietary components. Since muscle protein synthesis is an excellent overall measure of cell growth (Houlihan et al., 1995), the significant increase in the muscle protein indicated an appreciable effect of curcumin on fish growth. This was also confirmed by an increase in muscle RNA content. The experimental fish fed curcumin exhibited higher feed conversion efficiency (FCE) than controls in this study. Food conversion efficiency (FCE) can be considered as an index of the food utilization of the animal. Curcumin might have induced growth by influencing the feed conversion efficiency. Turmeric enhanced an overall performance of broiler chickens and an increased weight gain in 0.5% curcumin fed fish is attributed to the antioxidant activity of curcumin that stimulates protein synthesis as has been reported for the bird enzymatic system (AL- sultan, 2003). Conversely, a work by Patel and Srinivasan (1996) has revealed that curcumin had no effect on growth of rat even though it enhanced the pancreatic enzyme activity. Yet another study revealed that curcumin offered in the diet did not influence piglet performance or measures of immune function in the immediate post-weaning period (Illsley et al.,
However, studies on the growth promoting potential of curcumin in fish are not available for comparison.

The consumption of food by animals results in an increase in their rates of oxygen utilization and heat production (Warren & Davis, 1965). It is well known that an increase in oxygen consumption leads to increased production of free radicals and lipid peroxidation. MDA level in the body indicates the extent of lipid peroxidation. In the present study, MDA level decreased in the curcumin-fed group indicating improved antioxidant status. Curcumin may have scavenged the free radicals generated as a result of increased metabolism resulting in growth.

GSH is an important water-phase antioxidant and is an essential cofactor for antioxidant enzymes protecting the mitochondria against endogenous oxygen radicals. Its level reflects the free radical scavenging capacity of the body. GSH depletion leads to tissue damage due to lipid peroxidation (Loewus, 1988). The increased GSH content in the 1% curcumin-fed group, indicates a higher antioxidant status. The decreased SOD activity in both the treated groups probably indicates direct radical scavenging by curcumin, which may have depleted the superoxide level. Studies have shown that curcumin mimics SOD enzyme (Mishra et al., 2004). Dietary supplementation of curcumin enhanced antioxidant and phase II metabolizing enzymes in ddY male mice (Iqbal et al., 2003). However, there was no change in SOD activity after six months of curcumin feeding probably indicating a balanced state. Therefore, our results
indicate that curcumin has a protective effect on \textit{in vivo} muscle lipid peroxidation too and it employs a different mechanism of action depending on the dose and time.

Curcumin has been reported to produce a hypolipidemic effect in rats fed with high lipid diet, decreased TC, LDL, TG and increased HDL (Arafa, 2005). In contrast, curcumin did not produce a marked reduction in serum cholesterol levels in rats fed curcumin diets (Nagata \& Saito, 2005). It is also supported by Rao \textit{et al.} (1970) that plasma cholesterol levels of animals fed cholesterol free diets were not affected by curcumin intake. There is no change in HDL content in the three month-curcumin treated fish while it increased in the 1\% group after six months. In another study, it was reported that curcumin intake improved the proportion of HDL and LDL content and reduced the serum TG concentration in healthy rats (Nagata \& Saito, 2005). Yet another study showed that curcumin decreased lipid content and hence the increased weight may be attributed to increased protein content at the expense of lipid value. This is most probably because curcumin is known to interact with cell membranes, enhancing peptide and protein uptake but interfering with lipid uptake (Poropratto \textit{et al.}, 2005). These results imply that curcumin may contribute to the regulation of lipid metabolism. It is reported that curcumin possesses hypocholesterolemic action (Soni \& Kuttan, 1992) and this was due to a decrease in absorption of cholesterol (Rao \textit{et al.}, 1970) or an increase in HDL cholesterol (Soudamini \textit{et al.}, 1992). It is
proved that effects of liver function improvement are the typical physiological
effects associated with curcumin (Rukkumani et al., 2004). The activities of
hepatic marker enzymes, AST and ALT, decreased in 0.5% curcumin-fed fish,
after three months, indicating curcumin’s hepatoprotective effect in this lower
vertebrate as well. The renal function parameter, creatinine marginally decreased,
indicating slightly enhanced kidney functioning. Urea increased a little but within
the normal ranges. Blood glucose also decreased, suggesting a hypoglycemic effect
for curcumin in the fish (communicated). After six months curcumin feeding, the
relative stability of AST and ALT activity indicated proper liver functioning. The
histological analysis of liver did not show any pathology due to the doses studied.

Ion transport across the membrane regulates a number of biochemical
reactions in the cell (Rossier et al., 1987). Turmeric and curcumin have inhibited
Na+/K+-ATPase activity (Kaul & Krishnakanth, 1994). Curcumin significantly
reduced catalytic phosphorylation of SERCA (Sumbilla et al., 2002), thus
inhibiting Ca²⁺-ATPase transport activity. Increase in ATPase in the present study
is consistent with an earlier report (Cohly et al., 2003) in mononuclear cells and
they showed an increase in ATPase activity on the 7th day of treatment, may be
due to an up regulation of the receptors associated with ATPases. In the present
study, curcumin produced differential effect on fish muscle ATPases according to
the dose. It is possible that the mechanism of action of turmeric and its products
may be the inhibition of ATPase activity while increasing the intra cellular Ca²⁺
concentration as suggested by other simulation studies (Smith –Logan et al., 2002). However, there was an increase in Ca\(^{2+}\) ions in the treated muscle in our study. At the same time, curcumin modulates other members of P\(_2\)-type ATPase super family which share significant homology (Kühlbrandt, 2004). In another study, it was shown that inhibition of Na\(^+\)/K\(^-\) ATPase is consistent with the positive effects on CFTR cells (Mahmmoud, 2005). Numerous molecules to which curcumin binds have been identified. They included Protein Kinase A, C, Ca\(^{2+}\) dependent protein kinases etc, leading to secondary responses (Reddy & Aggarwal, 1994; Hasmeda & Poyla, 1996).

In conclusion, the present study confirmed a protective and growth promoting effect of curcumin in the teleost. It is suggested that curcumin possesses the desired potential for use as a growth promoter in aquaculture and is a safe feed supplement. In view of the present study, further studies in other aquaculture species are recommended in order to include curcumin as a feed additive in aquaculture for improving the quality and quantity of the meat.
Fig. 6.1

![Graph showing feed consumption and assimilation over 3 and 6 months for control, 0.5%, and 1% treatments.]

- **Feed consumed**
- **Feed assimilated**
Fig. 6.2

![Graph showing percentage (%) over 3 months and 6 months with different treatments (ctrl, 0.5%, 1%)](image-url)
Fig. 6.3

![Bar chart showing percentage (%) over 3 months and 6 months with data points marked with 'a' and 'a' for certain conditions. The chart indicates comparisons between control (ctrl), 0.5%, and 1% treatments.](chart.png)
Fig. 6.4

(a) 400
(b) 350

mg dL⁻¹

TC HDL LDL VLDL TG

CTRL 0.5% 1%

143
Fig. 6.5

![Graph showing the activity of Ca\(^{2+}\) ATPase and Na\(^{+}/K\(^{+}\) ATPase in response to different concentrations of a compound. The x-axis represents different concentrations (ctrl, 0.5%, 1%), and the y-axis represents nmol ATP liberated min\(^{-1}\) mg protein\(^{-1}\). The graph shows a peak at 0.5% for Ca\(^{2+}\) ATPase and a decreasing trend for Na\(^{+}/K\(^{+}\) ATPase.](image-url)
Fig. 6.6

![Graph showing the concentration of Na, K, and Ca with three conditions: ctrl, 0.5%, and 1%. The graph indicates significant differences marked with 'a'.]
**Fig. 6.1** Effect of curcumin on feed consumption and feed assimilation of *Anabas testudineus* after three and six months feeding. Values are mean ± S.E. of 12 fish. a = significantly lower (p<0.05) than the control; b = significantly lower (p<0.05) than the control and 0.5%. The significant difference between groups was analyzed by One-Way ANOVA as determined by Duncan’s Multiple range test.

**Fig. 6.2** Effect of curcumin on Feed Conversion Efficiency (FCE). a = significantly higher (p<0.05) than the control. See footnotes to figure 6.1.

**Fig. 6.3** Effect of curcumin on Feed Assimilation Efficiency (FAE). a = significantly higher (p<0.05) than the control. See footnotes to figure 6.1.

**Fig. 6.4** Effect of curcumin on serum lipid profile. a) 3 months -curcumin treatment b) 6 months curcumin treatment. a = significantly lower (p<0.05) than the control; b = significantly lower than (p<0.05) than the control and 0.5%; c = significantly higher (p<0.05) than the control. See footnotes to figure 6.1.

**Fig. 6.5** Effect of curcumin on ATPases activity of *Anabas testudineus* after 3 months feeding. a = significantly lower (p<0.05) than the control; b = significantly higher (p<0.05) than the control and 0.5%. See footnotes to figure 6.1.
Fig. 6.6 Effect of curcumin on ion content of *Anabas testudineus* after 3 months feeding. a = significantly higher (p<0.05) than the control. See footnotes to figure 6.1

Fig. 6.7 Effect of curcumin on muscle RNA content after 6 months curcumin feeding experiment. See footnotes to figure 6.1
Table 6.1 Effect of curcumin on growth related parameters of *Anabas testudineus* after 3 months of feeding

<table>
<thead>
<tr>
<th>Treatment</th>
<th>ctrl</th>
<th>0.5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial length (cm)</td>
<td>12.4 ± 0.1</td>
<td>13.0 ± 0.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12.9 ± 0.1&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Initial weight (g)</td>
<td>31.9 ± 0.69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final length (cm)</td>
<td>12.2 ± 0.13</td>
<td>12.2 ± 0.13</td>
<td>12.2 ± 0.13</td>
</tr>
<tr>
<td>Length gain (cm)</td>
<td>0.2 ± 0.03</td>
<td>0.8 ± 0.04&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.7 ± 0.02&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Length gain %</td>
<td>1.6 ± 0.1</td>
<td>6.1 ± 0.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.4 ± 0.01&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Final weight (g)</td>
<td>32.4 ± 0.8</td>
<td>34.7 ± 0.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>35.3 ± 0.8&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Weight gain %</td>
<td>0.5 ± 0.1</td>
<td>2.8 ± 0.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.4 ± 0.7&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Weight gain</td>
<td>1.56 ± 0.8</td>
<td>8.1 ± 0.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.6 ± 0.8&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Specific growth ratio</td>
<td>0.01</td>
<td>0.04</td>
<td>0.05</td>
</tr>
</tbody>
</table>

<sup>a</sup> significantly higher (p<0.05) than the control

Results are expressed as mean ± S.E. of triplicate groups of fish. The significant difference between groups was analyzed by One-Way ANOVA followed by Duncan's Multiple range test.
Table 6.2 Effect of curcumin on growth related parameters of *Anabas testudineus* after 6 months of feeding

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ctrl</th>
<th>0.5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial length (cm)</strong></td>
<td>12.2 ± 0.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Initial Weight (g)</strong></td>
<td>31.9 ± 0.69</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Treatment</strong></td>
<td>ctrl</td>
<td>0.5%</td>
<td>1%</td>
</tr>
<tr>
<td>Final length (cm)</td>
<td>12.6 ± 0.1</td>
<td>13.2 ± 0.1a</td>
<td>12.9 ± 0.1</td>
</tr>
<tr>
<td>Length gain (cm)</td>
<td>0.4 ± 0.05</td>
<td>1.0 ± 0.04a</td>
<td>0.7 ± 0.03</td>
</tr>
<tr>
<td>Length gain %</td>
<td>3.1 ± 0.1</td>
<td>7.5 ± 0.1a</td>
<td>5.4 ± 0.1</td>
</tr>
<tr>
<td>Final weight (g)</td>
<td>34.0 ± 1.0</td>
<td>37.6 ± 1.0a</td>
<td>36.0 ± 1.1a</td>
</tr>
<tr>
<td>Weight gain %</td>
<td>2.1 ± 0.9</td>
<td>5.7 ± 0.5a</td>
<td>4.1 ± 0.4</td>
</tr>
<tr>
<td>Weight gain</td>
<td>6.1 ± 0.7</td>
<td>15.1 ± 0.9a</td>
<td>11.3 ± 0.1a</td>
</tr>
<tr>
<td>Specific growth ratio</td>
<td>0.01</td>
<td>0.04a</td>
<td>0.03a</td>
</tr>
<tr>
<td>(Derived from the mean values)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*a* = significantly higher (p<0.05) than the control

Results are expressed as mean ± S.E. from triplicate groups of fish. The significant difference between groups was analyzed by One-Way ANOVA followed by Duncan’s Multiple range test
<table>
<thead>
<tr>
<th>Group</th>
<th>Protein (mg g⁻¹ tissue)</th>
<th>SOD (Units mg⁻¹ protein)</th>
<th>GSH (mmol 100g⁻¹ tissue)</th>
<th>TBARS (μmol MDA g⁻¹ tissue)</th>
<th>RNA (mg g⁻¹ tissue)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ctrl</td>
<td>0.76 ± 0.02</td>
<td>1.63 ± 0.11</td>
<td>2.93 ± 0.06</td>
<td>2.97 ± 0.03</td>
<td>7.00 ± 0.43</td>
</tr>
<tr>
<td>0.5%</td>
<td>1.66 ± 0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.78 ± 0.06&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.54 ± 0.08</td>
<td>2.42 ± 0.01</td>
<td>6.40 ± 0.19</td>
</tr>
<tr>
<td>1%</td>
<td>2.20 ± 0.03&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.58 ± 0.03&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.55 ± 0.11&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.87 ± 0.01&lt;sup&gt;c&lt;/sup&gt;</td>
<td>9.10 ± 0.19&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> = significantly higher (p<0.05) than the control

<sup>b</sup> = significantly higher (p<0.05) than the control and 0.5%

<sup>c</sup> = significantly lower (p<0.05) than the control

Results are expressed as mean ± S.E. of 8 fish. The significant difference between groups was analyzed by One-Way ANOVA followed by Duncan’s Multiple range test.
### Table 6.4 Effect of curcumin on lipid peroxidation and RNA content—6 months study

<table>
<thead>
<tr>
<th>Group</th>
<th>SOD (Units mg⁻¹ protein)</th>
<th>GSH (mmol 100g⁻¹ tissue)</th>
<th>TBARS (µmol MDA g⁻¹ tissue)</th>
<th>RNA (mg g⁻¹ tissue)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ctrl</td>
<td>1.28 ± 0.03</td>
<td>2.90 ± 0.14</td>
<td>3.06 ± 0.24</td>
<td>8.16 ± 0.40</td>
</tr>
<tr>
<td>0.5%</td>
<td>1.24 ± 0.02</td>
<td>3.22 ± 0.08</td>
<td>2.33 ± 0.10</td>
<td>8.77 ± 0.40</td>
</tr>
<tr>
<td>1%</td>
<td>1.32 ± 0.06</td>
<td>3.40 ± 0.17</td>
<td>2.32 ± 0.09</td>
<td>15.3 ± 0.59</td>
</tr>
</tbody>
</table>

*a = significantly lower (p<0.05) than the control

*b= significantly higher than the control

Results are expressed as mean ± S.E. of 8 fish. The significant difference between groups was analyzed by One-Way ANOVA followed by Duncan’s Multiple range test.
Table 6.5 Effect of curcumin on serum markers of hepatic and renal functions after 6 months of feeding

<table>
<thead>
<tr>
<th>Group</th>
<th>ctrl</th>
<th>0.5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma glucose (mg mL(^{-1}))</td>
<td>102.2 ± 5.2</td>
<td>90.7 ± 5.3</td>
<td>82.2 ± 5.2</td>
</tr>
<tr>
<td>Urea (mg dL(^{-1}))</td>
<td>4.00 ± 0.14</td>
<td>3.45 ± 0.06(^a)</td>
<td>3.47 ± 0.13(^a)</td>
</tr>
<tr>
<td>Creatinine (mg dL(^{-1}))</td>
<td>0.30 ± 0.10</td>
<td>0.20 ± 0.04</td>
<td>0.20 ± 0.04</td>
</tr>
<tr>
<td>ALT (UL(^{-1}))</td>
<td>22.8 ± 2.09</td>
<td>23.2 ± 3.06</td>
<td>24.2 ± 2.60</td>
</tr>
<tr>
<td>AST (UL(^{-1}))</td>
<td>35.5 ± 4.09</td>
<td>18.7 ± 1.30(^a)</td>
<td>14.2 ± 1.70(^a)</td>
</tr>
</tbody>
</table>

\(^a\) = p<0.05

Results are expressed as mean ± S.E. of 8 fish. The significant difference between groups was analyzed by One-Way ANOVA as determined by Duncan’s Multiple range test.