Spirulina platensis as an alternative protein source for the African catfish *Clarias gariepinus*

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Abstract. The efficiency of diets containing different levels of Spirulina platensis on the growth, survival and feed efficiency of African catfish *Clarias gariepinus* larvae was investigated on a 90-day feeding experiment. The study was carried out both in aquarium and tank conditions. The experimental treatments evaluated were: 100% commercial feeds (CF), 100% formulated feeds (FF), 90% formulated feeds (FF) + 10% *S. platensis* meal (SPM), 80% formulated feeds (FF) + 20% *S. platensis* meal (SPM), 70% formulated feeds (FF) + 3 0% *S. platensis* meal (SPM) and 60% formulated feeds (FF) + 40% *S. platensis* meal (SPM). In aquaria, 60% FF + 40% SPM gave the highest weight gain with a mean of 22.16±2.67 g whereas 100% FF gave the lowest weight gain with a mean of 16.20±0.36 g. In terms of gain in length, 100% CF gave the highest gain in length with mean of 96.21±8.24 mm among treatments. Daily weight gain (DWG) and specific growth rate (SGR) of catfish larvae with 60% FF + 40% SPM obtained the highest DWG and SGR among treatments while 100% FF obtained the lowest means respectively. Diets with 80% FF + 20% SPM and 70% FF + 30% SPM gave a better FCR of 1.45±0.20 and 1.45±0.64, respectively. Data on percent survival showed no significant difference among treatment groups. Highest survival rate was obtained in 90% FF + 10% SPM treatment with a mean of 28.89±1.11%. In tank condition, *C. gariepinus* larvae fed with diets having inclusion levels of *S. platensis* gave a significant higher weight gains, better DWG, SGR, and FCR values which significantly differed when compared to control diets. Survival rate showed no significant difference among treatment groups. These results clearly indicated that Spirulina-incorporation in catfish diets has potential advantages of improving the growth performance of *C. gariepinus* larvae both in aquaria and tank conditions.

Key Words: *S. platensis,* aquaria, tanks, meal, larvae.

Introduction. Despite of the popularity of the catfish species and its great market potentials, the production is still basically a small-scale level due to feeding problems and inadequate availability of seed for stocking. Suboptimal feeding can impact not only on growth but also on survival. The larvae of most fish species have a narrow resource spectrum and they generally require live food which is expensive, manpower demanding or complicated to produce. Live foods possess one major advantage in that they remain alive and accessible for a longer time in contrast to commercial feeds. Intensification of aquaculture has also led to growing concern of proper feeding strategies as to types of culture systems, species and fish size. Moreover, demand for catfish has even increased locally and internationally as regards for food items and hatcheries therefore, developing such production techniques is indispensable.

Success in aquaculture production is always based on certain criteria, one of which is the selection of a suitable feed and its potential use as a viable aquaculture feed (Velu & Munuswamy 2007). Davy & Chouinard (1980) noted that the most critical area of fish fry production and the major critical period is immediately before and during the initiation of first feeding. If food is not immediately available to fish hatchlings, the fry may become weak and become predisposed to predation in natural rearing system (Rana 1990). If the initial feeding of catfish fry is delayed beyond 5.4 days, more than 50% of the fish may die (Owodeinde et al 2004). Availability of food during initial feeding is thus very essential for the survival and growth of fish. Huisman et al (1976) considered the lack of suitable food as the main cause of mortality in most fishes at this stage, emphasizing the importance of the quantity, quality, and feed size.

Microalgae, like many other organisms are considered as natural sources of food in the food chain of fish (Giwojna 1987). One of which is the *Spirulina sp.* wherein it has been used as food for humans and animals due to its higher nutritional value (Hayashi et al 1998; Belay et al 1996; De Lara Andrade et al 2005; El-Hindawy et al 2006). It was also been reported that it contains a higher protein (55-65%), energy and phosphorus availability (Clement et al 1967; Bourges et al 1971; Anusuya Devi et al 1981), 2.5-3.29 kcal/g (Clement et al 1967; Bourges et al 1971; Anusuya Devi et al 1981) and 41% (Yoshida & Hoshii 1980; Blum et al 1976) respectively.

Several published studies have also shown significant therapeutic and health benefits of *Spirulina* or its extracts on animals and humans (Belay et al 1996) as well as its wide application in aquaculture. Some benefits of using *Spirulina* as fish food includes, increased and more uniform growth rates; improves the intestinal flora in fish by the breakdown of indigestible feed components, thereby extracting more nutrients from the feed; increased survival rate; improves and intensifies fish coloration.

In an attempt to respond to a more organically produced-larvae, steps have to be initiated for the improvement of its production. Hence, this study focused on the growth response of *C. gariepinus* larvae with the incorporation of different levels of *Spirulina platensis* meal on its diets under aquaria and circular tanks to test its use in aquaculture feeding.

Material and Method

Experimental set-up and design. Eighteen aquaria with a dimension of 30x60x30 cm and eighteen circular tanks (100 cm) were set at the Wet Laboratory of Freshwater Aquaculture Center (FAC) following the Completely Randomized Design (CRD) for six treatments replicated three times.

Experimental fish. A total of 1,440 *C. gariepinus* larvae were used in this study. The larvae were produced by induced spawning of one pair of *C. gariepinus* breeders at the Freshwater Aquaculture Center (FAC), Central Luzon State University (CLSU). Yolk sac fry were fed with tubifex (*Tubifex tubifex*) for about ten days and were acclimatized in a flow-through fiber glass tanks for five days. After acclimatization, larvae were subjected to a fish grader to avoid size variability and stocked in aquaria at a rate of 30 individuals/aquarium and 50 individuals/tank. Stocking of the larvae were done early in the morning. Initial mean weight and length of the larvae were recorded at the beginning of the experiment.

Experimental diets. There were six treatments tested in the present study: Treatment 1 was 100% commercial feed (control I); Treatment 2 was 100% formulation of rice bran and fish meal (Control II); Treatments 3, 4, 5, and 6 used formulated feed with incorporation of 10%, 20%, 30%, and 40% of *S. platensis,* respectively. The alga, *S. platensis* used in this study was obtained from Maejo Spirulina Farm 212 Moo 14, Papri, Sansai District, Chiang Mai, Thailand. Fish meal (Peruvian) and rice bran (D1) were purchased from the local market. Each ration was prepared in a one kilogram with varying inclusion levels of Spirulina powder. All the ingredients were sieved through a fine-meshed sieve and manually mixed. Formulated diets were air-dried, stored in plastic container and placed at room temperature.

Proximate analysis of feeds. *S. platensis* powder was analyzed at the Central Laboratory (Thailand) Co., Ltd., Bangkok, Thailand. Fish meal (Peruvian) and rice bran (D1) were analyzed at QualiBet Testing Services Corporation, Quezon City, Philippines.

Feeding and management. The experimental diets were fed to the larvae at a rate of 20% of their body weight on the first month, 15% on the second month and 10% on the third month. Feeding was done thrice a day for all treatments in both conditions. More so, 30% of the water was changed daily in the morning in aquaria and weekly in the tank system. Physico-chemical parameters such as temperature, dissolved oxygen and pH were also monitored regularly.

Sampling. Sampling was done bi-weekly to adjust feeding rate. Thirty percent of the population from each replicate of the treatments were sampled for feed adjustment.

Parameters gathered. Initial and final weights of *C. gariepinus* larvae were measured before and after the experimental period using a weighing scale (Sartorius) while the initial and final lengths were determined using a ruler. Thirty percent of the experimental animals individuals/replicate for both aquaria and tanks were used in determining the various growth parameters.

Statistical analysis. The experiment was arranged following Completely Randomized Design (CRD). The analyses of data were done with the Statistical Package for Social Sciences (SPSS) Version 17.0. Data gathered were subjected to Analysis of variance (ANOVA) to determine significant differences among treatments. Comparison of means was done at 5% probability level effects by Duncan's Multiple Range Test (DMRT).

Results

Indoor. The growth performances of *C. gariepinus* larvae fed with diets containing different levels of *S. platensis* on a 90-day feeding experiment in aquaria are shown in Tables 1 and 2.

Outdoor. The growth performances of *C. gariepinus* larvae fed with diets containing different levels of *S. platensis* on a 90-day feeding experiment in circular tanks are shown in Tables 3 and 4.

Table 1

Growth performance of *Clarias gariepinus* larvae fed with diets containing different levels of *Spirulina platensis* on a 90-day feeding experiment in aquaria

Diet	*WG (g)*	*LG (g)*	*DWG (g)*	*SGR (%)*	*SR (%)*
100% CF	18.39±0.85[ab]	96.21±8.24[b]	0.20±1.16[ab]	4.72±1.10[ab]	28.33±1.67
100% FF	16.2±0.36[a]	84.31±4.33[a]	0.18±1.26[a]	4.53±1.08[a]	26.56±1.11
90% FF + 10% SPM	17.38±0.71[a]	89.83±7.61[ab]	0.20±1.15[ab]	4.63±1.09[a]	28.89±1.11
80% FF + 20% SPM	18.65±0.43[ab]	64.57±4.18[a]	0.21±1.13[ab]	4.75±1.24[ab]	24.44±2.94
70% FF + 30% SPM	21.01±0.91[bc]	72.67±791[a]	0.23±1.03[bc]	4.86±1.09[b]	26.44±1.22
60% FF + 40% SPM	22.16±1.54[c]	71.17±3.64[a]	0.25±1.17[c]	4.90±1.17[b]	23.11±1.24

CF - commercial feed, FF - formulated feed, SPM - *S. platensis* meal, WG - weight gain, LG - length gain, DWG -daily weight gain, SGR - specific growth rate, SR - survival rate.

Table 2

Food conversion ratio (FCR) and protein efficiency ratio (PER) of *Clarias gariepinus* larvae fed with diets containing different levels of *Spirulina platensis* on a 90-day feeding experiment in aquaria

Diet	*Protein efficiency ratio*	*Food conversion ratio*
100% CF	1.39±0.07[b]	1.49±0.07
100% FF	1.33±0.15[a]	1.50±0.06
90% FF + 10% SPM	1.38±0.45[b]	1.51±0.80
80% FF + 20% SPM	1.36±0.32[ab]	1.50±0.19
70% FF + 30% SPM	1.42±0.26[bc]	1.45±0.20
60% FF + 40% SPM	1.48±0.73[c]	1.45±0.64

CF - commercial feed, FF - formulated feed, SPM (*S. platensis* meal).

Table 3

Growth performance of *Clarias gariepinus* larvae fed with diets containing different levels of *Spirulina platensis* on a 90-day feeding experiment in circular tanks

Diet	*WG (g)*	*LG (g)*	*DWG (g)*	*SGR (%)*	*SR (%)*
100% CF	69.40±3.19^{ab}	185.29±0.59^{c}	0.66±1.03^{ab}	5.51±2.07^{ab}	77.33±1.86
100% FF	66.90±1.92^{a}	182.60±3.18^{ab}	0.63±3.02^{ab}	5.50±1.04^{ab}	78.67±4.06
90% FF + 10% SPM	74.87±1.29^{bc}	184.61±1.85^{bc}	0.72±3.02^{bc}	5.62±2.05^{bc}	76.00±3.03
80% FF + 20% SPM	76.29±0.97^{c}	182.89±1.70^{abc}	0.74±2.04^{c}	5.68±3.04^{c}	77.29±1.16
70% FF + 30% SPM	74.29±1.63^{bc}	180.48±1.64^{ab}	0.72±3.02^{bc}	5.63±2.04^{bc}	77.57±2.91
60% FF + 40% SPM	70.45±0.31^{abc}	186.26±1.93^{c}	0.67±2.03^{abc}	5.56±1.04^{ab}	81.33±3.53

CF - commercial feed, FF - formulated feed, SPM - *S. platensis* meal, WG - weight gain, LG - length gain, DWG -daily weight gain, SGR - specific growth rate, SR - survival rate.

Table 4

Food conversion ratio (FCR) and protein efficiency ratio (PER) of *Clarias gariepinus* larvae fed with diets containing different levels of *Spirulina platensis* on a 90-day feeding experiment in circular tanks

Diet	*Protein efficiency ratio*	*Food conversion ratio*
100% CF	1.80±3.10^{b}	1.20±2.11^{ab}
100% FF	1.71±3.01^{ab}	1.32±4.17^{b}
90% FF + 10% SPM	2.03±2.71^{c}	1.15±2.03^{a}
80% FF + 20% SPM	1.96±3.11^{bc}	1.13±2.18^{a}
70% FF + 30% SPM	1.79±02.96^{b}	1.16±3.05^{a}
60% FF + 40% SPM	1. 90±2.56^{bc}	1.22±2.07^{ab}

CF - commercial feed, FF - formulated feed, SPM (*S. platensis* meal).

Discussion

(Indoor)

Weight and length gain. During the first 2 weeks of the experiment, *C. gariepinus* fed with commercial diet (Treatment I) weighed more and recorded bigger bogy size than those fed with increasing levels of *Spirulina* inclusion. Increase in growth rate was observed during the second to third week and continued until the last month of culture period (Table 1). Similar observation has been reported by Ross & Dominy (1990) who evaluated the growth performance of growing chickens fed diets that contained 0, 5, 10, 15 and 20% *Spirulina* to replace dehulled soybean. Significant growth depression occurred as early as the first week. By the third week, the chicks receiving 10 and 20% *Spirulina* had attained comparable growth among treatments and the control diet.

Improvement in fish growth, increased uniform growth, feed efficiency, carcass quality, and physiological response to stress and disease in several species of fish by dietary inclusion of *Spirulina* has been reported earlier in several studies (Nakazoe et al 1986; Mustafa et al 1994; Mustafa & Nakagawa 1995). Intensive work was also carried out to test the utilization of *Spirulina* as mixed feed for abalone, scallops and penaeid shrimp (Zhou et al 1991). It was then concluded that *Spirulina* mixed feed made a good substitute for live microalgae in the culture of parent scallops as it proved to be useful for the normal development that makes them achieve higher fecundity and hatching rate. Experimental formulations for white shrimp have also been successful (Jaime et al 1996; Marquez 1997; Artiles et al 1999).

Results of the present study regarding weight gain conform to those found by Abdel-Tawwab et al (2008) who reported that final fish weight, weight gain, and specific growth rate of *O. niloticus* fry increased significantly (P<0.05) with the increase in *Spirulina* levels in fish diets reared in aquaria. The optimum growth was obtained at 5.0-10.0 g *Spirulina*/kg diet, whereas the control diet produced the lower fish growth. Santiago et al (1987) also presented an interesting result on *Azolla* as feeds for *O. niloticus.* They observed that dry *Azolla* meal used as a dietary component for young *O. niloticus* gave a significant increase on their growth and feed conversion efficiency. Results showed that growth response and food conversion were directly influenced by the increasing levels of *Azolla* meal.

In terms of length gain, *C. gariepinus* fed with commercial diet (Treatment I) obtained the highest length gain with a mean of 96.21 g followed by Treatment III, II, V, VI and IV. This result may have been accounted to the fact that commercial diets has been formulated to contain the necessary nutrients and are generally supplemented with a vitamin premix to meet the complete dietary requirements by the fish. Considerable efforts has also been conducted concerning the level of dietary protein and amino acids of commercial diets needed for cost effective growth while intensive studies has been carried out which proves the efficiency of *S. platensis* as feed additive in aquaculture (Mustafa et al 1994).

Daily weight gain (DWG) and specific growth rate (SGR). The results may be attributed to the higher protein content of Treatments V and VI which in turn results to apparent high specific growth rate and daily weight gains of *C. gariepinus* fed with 30-40% inclusion levels of *S. platensis*. The proximate analysis evaluated on the individual ingredients of the experimental diets is shown in Table 5 and Table 6. Another special value of *Spirulina* is that it is highly digestible and assimilable due to the absence of cellulose; thereby high nutrition content is available (Sasson 1997).

The result on the specific growth rate and daily weight gain of *C. gariepinus* larvae fed with *Spirulina* inclusion conforms to the results obtained by Badwy et al (2008) who evaluated the response to partial replacement of fishmeal with dried algae in *O. niloticus*. The results indicated that the average values growth performance increased significantly (P<0.05) with increasing of both algae species (*Chlorella* sp and *Scenedesmus* sp) replacement of up to 50% algae.

These results also agree with those found by Tongsiri et al (2010) who studied the effect of replacing 5, 10 and 100% of fish meal by *Spirulina* in Mekong giant catfish, *Pangasianodon gigas*. According to the mentioned study, the highest weight yield was found at 5% *Spirulina* inclusion. They also reported that average daily gain, specific growth rate and feed conversion rate were not significantly different from each other although fish fed containing 5% *Spirulina* produced a higher average daily gain and specific growth rate than fish fed with the rest of the experimental diets. Based from their results, they had indicated that 5% dried *Spirulina* could be used to replace fish meal which resulted the highest weight and average daily gain. Previous research has also shown that *Spirulina* can be used as a protein source in feeding two important species in India, namely *Gibelion catla* and *Labeo rohita*. *Spirulina* was mixed in the ratios of 25, 50, 75 and 100 %, respectively. Growth performance of *G. catla* fed on the diets incorporated with different levels of *Spirulina* did not differ significantly ($P<0.05$). In contrast, it was found that the *L. rohita* increased its growth, protein efficiency ratio, digestibility of dry matter, and both protein and lipid content in correlation with the amount of *Spirulina* consumed. It was concluded that the growth of *G. catla* and *L. rohita* was not affected negatively at any levels of *Spirulina* inclusion clearly indicated that it was suitable to use *Spirulina* as a protein supplement source for both species (Nandeesha et al 2001). Likewise, significant differences were observed in guppy (*Poecilia reticulata*) with regard to their specific growth rate, feed conversion rate and weight gain (Dernekbasi 2010).

Table 5

Proximate composition of the individual ingredients

Ingredients	*Crude protein (%)*	*Moisture (%)*	*Crude fat (%)*	*Crude fiber (%)*	*Ash (%)*
Fish meal	57.96	18.68	10.84	0.42	12.18
Rice bran	12.4	11.55	13.66	4.53	7.02
*Spirulina platensis**	43.35	8.72	6.37	0.88	8.08

* Analyzed at Central Laboratory (Thailand) Co., Ltd., Bangkok, Thailand.

Table 6

Proximate composition of experimental diets

Diets	*Crude protein (%)*	*Moisture (%)*	*Crude fat (%)*	*Crude fiber (%)*	*Ash (%)*
100% CF*	33	12	7	5	12
100% FF	30.62	7.04	12.53	2.89	9.08
90% FF + 10% SPM	31.90	7.20	11.92	2.69	8.98
80% FF + 20% SPM	33.17	7.37	11.30	2.48	8.88
70% FF + 30% SPM	34.44	7.54	10.68	2.28	8.78
60% FF + 40% SPM	35.71	7.71	10.07	2.08	8.68

CF - commercial feed, FF - formulated feed, SPM - Spirulina platensis meal.
*Guaranteed proximate analysis of TATEH Aquafeeds, SANTEH, Feeds Corp. Analyzed using AOAC (1980) method.

Survival rate. In the present study, survival rates results came out to be as low as the results of similar studies conducted by (Nakazoe et al 1986; Zhou et al 1991; Scaria et al 2000). Growth and survival of *C. gariepinus* are known to be strongly influenced by stocking density (Hecht 1982; Hecth & Appelbaum 1988; Appelbaum & Van Damme 1988; Haylor 1991), photoperiod and shelter (Hecht & Appelbaum 1987). In our study, the stocking density was 30 individuals/aquarium with a dimension of 30x60x30 cm, thus, this might have contributed significantly on the fish surviving throughout the 90-day feeding experiment. In contrast with those used by Abdel-Tawwab et al (2008) in which each 100-liter aquarium has a rate of only 20 fish per aquarium which gave them a higher survival rate of 93-95.6% with same 90-day feeding period. In this regard, Hecht

& Appelbaum (1987) reported that lower stocking densities always gave the higher growth rate in an experiment with 25-day old *C. gariepinus* fingerlings.
Aquaria tanks are confined units without continuous flow of water and so water needs to be change daily to ensure optimum water exchange and good water quality throughout the treatment period. In this case, mortality was probably associated to handling during the water exchange process and to handling stress after regular sampling period. This is in agreement with Alfonso (1996), who stated that, when the quality of food is good, the survival is determined by manipulation. Although studies have shown that feeding *Spirulina* to fish could improve their survival and growth rate (Belay et al 1996; Hayashi et al 1998), little is known about the behavior of fish under culture conditions especially with the cannibalistic characteristic of catfish species.

Another factor that can be considered was the limited space for the small catfish to escape from predation. In relation to this, mild aggressive encounters were observed among larvae earlier sometime in about second to third weeks in all treatments but become more intense on fifth to sixth weeks where larvae started to lose weight decreased and continued until the last weeks of the feeding period leading to its high mortality. Aggressive behavior is known to be common in *C. gariepnus* (Haylor 1991); Hecht & Appelbaum (1988) noted that this behavior tends to increase with decreasing stocking density. It is also said that such aggression activities often results in skin lesions and in fin damage which in turn increases their susceptibility to disease and weakens, making them more liable to cannibalism or death as a consequence of their wounds (Kaiser et al 1995). Aggressive activities also cost a lot of energy which otherwise would be used for growth (Hecht & Uys 1997).

Food conversion ratio (FCR) and protein efficiency ratio (PER). Since feed is the most expensive part of catfish production, feeding at lower cost but nutritious feed which converts efficiently and promotes growth without affecting water quality is indispensable. In aquaculture systems, a very important factor which determining the economic feasibility and quality of products is feed and the efficiency of feed utilization (Ratafia & Purinton 1989). Microalgae, on the other hand, have received great attention as a possible alternative protein source for cultured fish, particular in tropical and subtropical developing countries where algae production rates are high and due to their high protein, vitamins and essential fatty acids content (El-Hindawy et al 2006). As feed additive, powdered *Spirulina* improve and increases growth rates, feed efficiency, carcass quality and physiological response to stress and disease in several fish species of fish (Jaime et al 1996; Marquez 1997; Artiles et al 1999). It was also reported by Kato (1989) that *Spirulina* improves the feed palatability and the feed conversion as well. In addition, *S. platensis* this species has been reported to have no cell wall which results in improved digestion and absorption (Becker & Venkataraman 1984; Nandeesha et al 1998).

These results are in contrast with the results reported by Dawah et al (2002) who found that FCR and PER were better when fish were maintained on artificial diets with 10% and 20% dried algae. While Abdel-Tawwab et al (2008) reported that *O. niloticus* fry fed on diets containing 0.5-7.5% *Spirulina*/kg recorded a higher feed intake than other groups giving the lowest FCR (1.22-1.32). Also, it is not comparable with Zeinhom (2004) who found that, inclusion of algae in fish diets insignificantly ($P>0.05$) improved the FCR (2.33), and PER (1.34) whereas feed intake was significantly increased. Previous study by Takeuchi et al (2002) also found that tilapia fed solely on *Spirulina* showed a lower FCR and PER than commercial diet-fed tilapia. However, these results are in agreement with those obtained by Ibrahim (2001) and Abu Zead (2001) who found out that PER ranged from 1.1 to 1.7 for *O. niloticus* and *Cyprinus carpio* fed on diets containing aquatic plant and algae. Ibrahim (2001) reported that, FCR gradually increased with increasing *Chlorella vulgaris* percentage in the diets without significant differences until 31.8% inclusion level, but the economical feed efficiency was improved as the level of the dietary *Azolla* increased from 10.6 to 31% of the diet. The efficiency of *Spirulina* as a feed additive to young prawns was also studied in the Fujian State Fishery Laboratory of China and resulted to better PER and FCR values (Jaime-Ceballos et al 2006). According to Nandeesha et al (1993), *Spirulina*-incorporated diets produced better specific growth rate and FCR than the probiotic diets. The PER indicates that *Spirulina,* followed by yeast and bacteria, significantly improves carp performance. Similar results were reported by Ghosh et al (2003) for *L. rohita*, Ziaei-Nejad et al (2006) for Indian white shrimp (*Fenneropenaeus indicus*), and Lara-Flores et al (2003) for *O niloticus*.

(Outdoor)

Weight and length gain. As we mentioned earlier, *S. platensis* have received great attention for potential benefits as feed ingredient in aquaculture for various fish species, for crustaceans and for poultry. Grinstead et al (2000) evaluated the influence of *S. platensis* as feed additive on weanling pig performances and reported minimal improvement on its growth performance while Ross & Dominy (1990) evaluated growth performance of growing chickens fed with diets containing 0, 5, 10, 15 and 20 *S. platensis* (g/kg) inclusion and comparable results were reported. *Spirulina* has high quality protein content (55-65%) which is higher than other commonly used plant sources such as dry soybeans (35%), peanuts (25%) or grains (8-10%). However, with the increasing level of *Spirulina* in the diet, fat percentage declined owing to its low fat content as shown in Table 5.

Although it is assumed that animal meal contains higher protein content, results on the weight gain of the *C. gariepinus* emphasizes the ability of *S. platensis* to significantly enhance fish growth. Habib et al (2008) reported that *S. platensis* can be used as a partial supplementation or complete replacement for protein in aquafeeds and is its use is more cost-efficient than animal origin meals. An earlier study conducted by Nandeesha et al (1998) revealed that *S. platensis* could be used as a sole source of protein in *C. carpio* diets. These results are also in agreement with those obtained by Ibrahim (2001) who found that the addition of algae in fish diets improved growth performance of *O. niloticus*. Same results was found by Yilmaz et al (2005) who concluded that diet containing 10 to 20% duckweed meal could be used as a complete replacement of fishmeal for commercial feed in the diet formulation for *C. carpio* fry. Tamiya (1961) also reported that the weight gain of rabbits fed a 5% *Chlorella* supplemented diet was higher than those fed a 5% soybean meal supplemented diet. Moreover, Zeinhom (2004) found that, inclusion of algae in fish diets significantly increased the live body weight and Nandeesha et al (1998) reported that body weight gain of *O. niloticus* increased linearly with increasing the level of algae in administered diet.

Detailed investigations on the utilization of microalgae as feed for fish were also carried out in Israel wherein it was evaluated that fish grow better on algae-enriched diets than on any conventional fish feeds (Sandbank & Hepher 1978).

Daily weight gain (DWG) and specific growth rate (SGR). In this study, the SGRs of the C. gariepinus larvae fed with *Spirulina* supplemented diets came out to be significantly higher as compared to the results of similar studies. Abdel-Tawwab et al (2008) obtained specific growth rate ranging from 2.41 to 2.62 fed with 1.25, 2.5, 5.0, 7.5 and 10.0 *Spirulina* levels (g/kg diet) for a period of 12 weeks. Likewise, study conducted by Nandeesha et al (2001) reported that *Catla catla* and *L. rohita* after a period of 90 days feeding in concrete cisterns of 5x5x1 m^3 gained a mean specific growth rate of 1.50-1.82 with 25, 20, 75 and 100% replacement of *S. platensis* in the diet. Badwy et al (2008) also reported insignificant lower mean specific growth rate of 1.33 to 1.70 in *O. niloticus* which consumed *Chlorella* and *Scenedesmus* as fish meal replacers at zero (control), 10, 25, 50 and 75% substitution. It also similar with the results of James et al (2006) who reported that green swordtail (*Xiphophorus hellerii*) fish fed 8% *Spirulina* obtained higher specific growth rate compared to fish fed 5,3,1, or 0% respectively. Likewise, Scaria et al (2000) notified that the ornamental guppy (*Poecilia reticulate*) and platy (*Xiphophorus maculatus*) recorded higher feed intake which contained *Spirulina* than feed containing mushrooms or azolla. Also higher growth rate was reported in major carp (*Cirrhinus mrigala*) larvae and in cocinero (*Caranx vinctus*) which benefited *Spirulina* containing feed (Swain et al 1996; Okada 1991).

Survival rate. Hirahashi et al (2002) reported that feeding *Spirulina* to fish and poultry improved survival and growth rate. Studies in Japan on yellowtail scad (*Atule mate*) showed that larvae fed 0.5% (5 ppt) *Spirulina* resulted in significant gain in survival rate over the non-*Spirulina* fed group. Another study conducted was on *Penaeus penicillatus* and *Metapenaeus* sp which were fed with *Spirulina* enriched feed, a marked increase in the survival rate was observed at the 8^{th} day of the post-larval stages. This increase in survival rate from 57.3 to 70% actually represents an improvement of more than 22% as compared with the control (Vonshak 1997).

Values of survival rates obtained in the present study were higher than in the report of Sripanomyom (2007) who obtained survival 62-69% rate of fry fed with diets supplemented with fresh *S. platensis* and maintained in 2.4 m^2 concrete tanks. Jaime-Ceballos et al (2005) studied the effect of *S. platensis* meal inclusion in microdiets for white shrimp *Litopenaeus schmitti* larvae and obtained survival of around 80% for all treatments. However, it is significantly lower compared to the results of Nandeesha et al (2001) who reported mean survival rates of 80 to 86% in carps fed with *S. platensis* supplemented diets with a stocking density of 25/cistern for a period of 90 days.

Another factor that might contribute on these survival rate results might be the aggression behavior observed during the feeding experiment, in the same way observed in aquaria condition. In catfish, activities such as aggression, results in skin lesions and in fin damage. Hecht & Pienaar (1996) showed that in *C. gariepinus*, a gradual reduction in food availability resulted in an increase in territorial behavior and the number of aggressive acts.

Food conversion ratio (FCR) and protein efficiency ratio (PER). The FCR values of various fish feed ingredients for *C. gariepinus* under controlled conditions have been estimated by many researchers (Conceicao et al 1998; Jhingran 1991). Jhingran (1991) has also stated that value of conversion rate, besides depending upon the nutrients contents of feed, also varies with the method of presentation of food to the fish, environmental factors such as temperature, dissolved oxygen, and size of fish. He further reported that no reliable data have been obtained on the rate of conversion of feed into fish flesh. Watanabe et al (1990) mentioned that feed supplemented with *Spirulina* powder improved the feed conversion ratio and growth rates of *C. vinctus.* As reported by Palmegiano et al (2005), sturgeon fish *Acipenser baerii* fed by diets containing *Spirulina* meal had better growth than the control diet and particularly 50% inclusion seemed to result the best performance: a high increase in biomass gain and growth rate, the best FCR and a high PER.

Conclusions. Based on the results of the present study, it can therefore be concluded that the experiment clearly demonstrated that *S. platensis* could be utilized as a protein source in *C. gariepinus* fingerlings particularly levels of 10-20% without any adverse effects on fish growth performance, and feed utilization parameters. The study significantly proved that *Spirulina* inclusion in the diet of *C. gariepinus* improved its growth and survival after a 90-day feeding experiment in concrete tanks. Hereby, our findings recommend to grow *C. gariepinus* larvae in grow-out ponds in order determine their growth performance. Further studies are also suggested to consider the potential ability of *S. platensis* to replace fish meal in different fish species especially of those herbivorous.

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