# Evaluating oxygen dynamics, water quality parameters and growth performance of Nile Tilapia by applying different dietary nitrogen levels

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**Abstract:** Nile tilapia juveniles with initial weights range of 95.1 to 106.8 grams /fish were distributed into 18 concrete tanks with a constant water depth of 75 cm to evaluate the effect of different feed loads and crude protein levels on oxygen dynamics, water quality parameters and growth performance. Two feeding loads (inputs) were added at 7 and 10 grams diet/m$^2$/day, six days a week. The commercial feed contained three levels of dietary protein (25, 30 and 35%). The rearing experiment lasted 60 days. There was no effect on oxygen concentrations at sunset among the 7 grams and 10 grams treatments. Slightly higher early morning oxygen deficits were observed in the 10 grams treatments. When feed loads increased from 7 grams to 10 grams algal blooms took place in the higher feed load. There were no significant differences in TAN, $PO_4P$ and $NO_2$-N concentrations among treatments. Feeding Nile tilapia at 7 grams/m$^2$/day had comparable growth performance and better feed conversion ratios to those fed at 10 grams/m$^2$/day. Consequently, higher feed inputs neither improved economic efficiency, nor enhanced oxygen budget. Increasing crude protein within the 7 gram treatments above 30% did not improve protein efficiency ratio (PER).

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**Key words:** Nile tilapia, protein levels, oxygen dynamics, water quality, growth performance.

## 1. Introduction:

Aquaculture is an important source of animal protein worldwide due to the stabilization of marine and freshwater fisheries during the past two decades. Recently, growth rate of Aquaculture business has been increasing rapidly, while animal food production has not been increasing at the same level on a worldwide basis.

The primary driving force for a pond aquaculture system is the level of feed input (David, 1997). Optimal feed inputs that maximize harvest weight are considered economical aquaculture practices where there is a balance between optimizing feed utilization and maximizing growth (Van der Meer *et al*., 1997). This goal could be accomplished when the application of feed inputs were restricted (Cho and Lovell, 2002). Higher nutrient loading will lead to more eutrophic conditions with associated water quality deterioration; for example, excessive algal growth can lead to elevated photosynthesis and consequently high pH levels, fluctuations of dissolved oxygen concentrations, production of cyanobacterial toxins, etc., in nutrient-rich waters causing stress to the fish (Jacob and Culver, 2010).

The dietary nutrient requirements of cultured species within semi-intensive fish farming systems is largely fulfilled through the consumption of natural food organisms produced within the pond and/or through the direct consumption of supplied "supplementary" feed inputs (Tacon and De silva, 1997).

Dietary protein is the major but most expensive source in animal feed which is necessary to obtain suitable growth rate of farmed fish. Protein provides the essential and nonessential amino acids which are important to synthesize body protein and partially provides energy for maintenance (Gan *et al*., 2012). By increasing the level of protein in artificial diets, costs of production are considerably elevated: for this reason, it is important to use diets rationally to attain optimal yield (Gan *et al*., 2012).

Knowledge of optimum levels of protein and other nutrients, such as lipid and carbohydrates in artificial diets, can reduce feeding costs (Taboada *et al*., 1998). Percent weight gain of fish increased with increasing dietary protein level up to a point, and slightly decreased thereafter with further increases in dietary protein level (Yang *et al*., 2002). This is probably because exceeded dietary protein is used as a spare source of energy (Kim *et al*., 1991). The reason for quantifying protein requirements is to develop the lowest- cost feed that provides adequate or maximum growth (Brunty *et al*., 1997).

Furthermore, Protein content and availability in feeds affect water quality via nitrogen excretion; an optimum dietary protein requirement is therefore desired for individual fish species in order to provide optimum protein assimilation efficiency and minimize nitrogen excretion (Jayaram and Beamish, 1992; Medale *et al*., 1995; Stibranyiova and Parova 1996). The same meaning was accentuated by Filbrum *et al*. (2013) who demonstrated that excessive feeding rates of high protein diets into ponds are not desirable and by De Silva *et al*.(1989) and Gomez *et al*.(2005) who indicated that feeds which contain the least amount of protein necessary for optimum growth should be formulated.

However, Akiyama (1993) demonstrated that the use of sub-optimal quality feeds (feeds which were formulated and not adequate on their own to provide complete nutritional supplies of the species) resulted in good, acceptable yields, comparable to those that are obtained with use of high-quality feeds.

Our experiment was conducted to evaluate growth and feed performance as well as oxygen dynamics and water quality parameters in rearing tanks of Nile tilapia under different feed loads and crude protein levels.

## 2. Material and methods:

### Experimental design

Our experiment was conducted in outdoor concrete tanks. The experimental tanks were filled from a nearby well water pump with water to a depth of 75-cm. Each tank had a surface water area of 2.5 $m^2$. Nile tilapia juveniles with initial weights range of 95.1 to 106.8 grams/fish were distributed into 18 concrete tanks. A total of 216 fish were randomly distributed into tanks at the rate of 12 juveniles per tank.

The effect of dietary input (grams diet/$m^2$/day) and crude protein content (25, 30 and 35% C.P.) of tested diets on growth performance of Nile tilapia (*Oreochromis niloticus*) beside the water quality parameters and oxygen dynamics in concrete tanks were studied. The rearing experiment lasted 60 days.

Two commercial floating feed inputs were employed in the experiment at 7 and 10 grams diet/$m^2$/day, six days a week with constant feed input per tank per day during the whole experiment. The commercial diet contained three levels of dietary protein (25, 30 and 35%). Therefore, the experiment consisted of 6 treatments, with three replicate tanks per treatment.

**(1) The 7 grams diet / $m^2$/ day with 25% crude protein treatment**

**(2) The 7 grams diet / $m^2$/ day with 30% crude protein treatment**

**(3) The 7 grams diet / $m^2$/ day with 35% crude protein treatment**

**(4) The 10 gram diet/ $m^2$/ day with25% crude protein treatment**

**(5) The 10 grams diet / $m^2$/ day with 30% crude protein treatment**

**(6) The 10 grams diet / $m^2$/ day with 35% crude protein treatment**

Fish in each tank were individually weighed and counted at the start of the experiment. At the end of the experiment, concrete tanks were completely drained and the fingerlings were harvested, counted and individually weighed to the nearest 0.1 g. All test diets were subjected to proximate analysis using standard methods (AOAC, 2005). The proximate composition of the commercial diets is illustrated in Table (1).

**Table (1): Chemical composition of the experimental diets (%).**

| Proximate Composition% | 25% C.P. | 30% C.P. | 35% C.P. |
|---|---|---|---|
| **Moisture** | 9.61 | 9.64 | 9.65 |
| **Crude protein** | 25.8 | 29.2 | 32.5 |
| **Crude lipid** | 2.46 | 2.7 | 2.00 |
| **Ash** | 9.37 | 8.30 | 8.58 |
| **Crude fiber** | 2.89 | 2.60 | 2.25 |
| **NFE** | 49.87 | 47.56 | 45.02 |
| **Total** | 100 | 100 | 100 |

Dissolved oxygen (DO) were measured four times daily once per week (early morning at 07:00 a.m., dusk at 06:00 p. m., midnight at 00:00 h and next early morning at 07:00 a.m.) the duration of nighttime hours (from dusk to dawn) was approximately (11:00 – 12:00 hours). Water temperature was measured at 6.00 p.m. and at 7.00 a.m. once per week. Both parameters were measured using dissolved oxygen meter (Hanna model 55). Also pH was measured once weekly by pH digital meter.

### Oxygen dynamics:

Oxygen dynamics parameters were calculated as follows:

1- Nighttime community respiration per hour ($nCRh^{-1}$) = (dusk oxygen concentration – next early morning oxygen concentration) /dark period (hours).

2- Nighttime community respiration (nCR) = hourly nighttime community respiration * dark period (hours).

3- Daytime net primary production (dNPP) = dusk oxygen concentration – early morning oxygen concentration.

4- Early morning oxygen surplus or deficit (budget) = dNPP– nCR.

5- Nighttime community respiration: daytime net primary production (nCR: dNPP ratio) = nCR/dNPP.

6- Average algal gross photosynthesis (g C $/m^2$/day) = (Net daytime production of dissolved oxygen + nighttime community respiration)*0.375.

**Water quality parameters**

Water temperature was measured using dissolved oxygen meter (Hanna model 55), while Secchi disk visibility was measured using a wooden apparatus.

Water quality parameters were carried out according to Boyd and Trucker (1992). Total Ammonia concentration was measured by phenate method. Nitrite- nitrogen concentration was measured by the diazotizing method using photometer (Lovibond Multi Direct photometer, Germany). Filterable orthophosphate was measured by ascorbic acid method using photometer (Lovibond Multi Direct photometer, Germany).

**Growth and Feed Performance**

Growth performance of cultured fish was measured in terms of final individual fish weight (g), weight gain (g/fish), daily weight gain (g/fish/day), and specific growth rate (SGR-%/day). Feed performance was measured in terms of feed conversion ratio (FCR) and protein efficiency ratio (PER). The growth and feed performance parameters were calculated as follows:

**a. Body weight**

Individual weights of fish were measured at the start and end of the experimental period using digital balance to the nearest 0.1 g.

**b. Weight gain (WG)**

Weight gain was calculated as:

**WG =WF-Wi**

Where;

WG = weight gain (gram/fish)

WF = final weight per fish at the end of the experiment

Wi = initial weight per fish at the start of the experiment

**c. Daily weight gain (DWG)**

**DWG = (final body weight -initial body weight)/experiment period (days).**

**d. Specific growth rate (SGR)**

Specific growth rate based on weight (SGRW) was determined:

**SGR (W) = (ln Wt – ln W0)*100 / t.**

Where;

Wt: is weight at time t, W0 weight at time 0, and t is the duration of time in days.

**e. Feed conversion ratio (FCR)**

Feed conversion was determined as the grams of wet weight gain of fish per gram of dry diet consumed.

**FCR = dry weight of feed fed (g) / fish weight gain (g).**

**f. Protein efficiency ratio (PER)**

Protein efficiency ratio was calculated as the grams of wet weight gain of fish per gram of protein consumed.

**PER = Fish weight gain (g) / protein fed (g).**

**5. Statistical analysis**

Statistical analysis was performed using two ways analysis of variance (ANOVA) for treatment effect. Duncan's multiple range test was used to separate treatment means at significance level of 0.05. Statistical tests on parameter values were conducted using SPSS computer software (SPSS Inc., 1997).

## 3. Result and Discussion:

**Oxygen Dynamics:**

Oxygen dynamics and water quality parameters are shown in Table (2). Increasing dietary protein contents within the 7 gram and 10 gram treatments did not affect oxygen concentration at sunset (13.81 to 14.67 g $O_2/m^2$ and 11.9 to 14.15 g $O_2/m^2$respectively)with no significant differences among treatments ($p>0.05$). Similarly, increasing the diet inputs from 7 grams to 10 grams did not affect oxygen concentration at sunset ($p>0.05$).

Within the 7 gram treatments, increasing dietary protein from 25% to 35% did not affect oxygen concentrations in water at early morning which ranged 5.88 to 6.33 g $O_2/m^2$, with no significant differences among treatments. Similarly, increasing dietary protein content from 25% to 35% within the 10 gram treatments did not significantly affect oxygen concentrations at sunrise ($p>0.05$) and ranged 3.60 to 5.89 g $O_2/m^2$. Oxygen concentrations at early morning were slightly higher in the 7 gram treatments than those of the 10 gram treatments due to the increased accumulation of waste feed and algal detritus in the latter treatments, which consumed more oxygen through bacterial degradation of organic matter.

However, oxygen concentrations at early morning in the 7 and 10 gram treatments indicated healthy balance ponds. Ghosh and Tiwari (2008) reported that a healthy balance pond should leave an adequate oxygen concentration in water that can support fish respiration during nighttime hours. They further indicated that the lowest oxygen level occurs just before daybreak.

Increasing dietary protein level within the 7 gram treatments did not affect daytime oxygen gain (dNPP) which ranged 7.76 to 8.39 g $O_2/m^2$/daytime, with no significant differences among treatments ($p>0.05$). Similarly, daytime oxygen gain ranged 8.25 to 8.77

and did not differ significantly among treatments with increasing dietary protein level from 25% to 35% within the 10 gram treatments.

Hargreaves (2006) reported that respiration resulting from the decomposition of waste organic matter (including waste feed and algal detritus) and fish respiration often exceed gross photosynthesis in aquatic systems with high rates of feed inputs. Photosynthetic activities of algae is the major contributor of DO during the day while nighttime diffusion of Oxygen from air into surface water take place only when DO is below saturation at night (Datta, 2012). Semi-intensive aquaculture systems are characterized by a wide range fluctuation in dissolved oxygen concentrations between sunset and early morning which amounted from 7.76 to 8.77 in our study.

In the current experiment the gap in DO concentrations between dusk and dawn indicates hyper eutrophic systems with intensive growth of algae as indicated by Secchi disk readings. Chang and Ouyang (1988) indicated that the maximum gap in DO between day and night was as great as 10 g $O_2$/ $m^2$ within the same day. Tucker (2003) indicated that DO concentrations at sunset could be enhanced through moderate phytoplankton blooms. Better oxygen concentrations at dusk in the 7 and 10 gram treatments were linked to the moderate feed load below the assimilative capacity of water and sediment.

Daytime net oxygen production (dNPP) among treatments was within the normal ranges observed in semi-intensive aquaculture. Assuming that daytime respiration equal nighttime respiration, while gross oxygen production per day is twice as much as nighttime oxygen respiration (nighttime oxygen loss) which ranged 7.80 to 9.58 g $O_2/m^2$/nighttime, the total daily oxygen production by algae in the current experiment should range between 15.6 to 19.16 g $O_2/m^2$/day, which is of normal value under Egyptian conditions. Daily gross algal production ranged 5.84 to 7.2 grams carbon per square meter per day in the current experiment. Nighttime community respiration per hour (nCRh-1) in the 7 gram and 10 gram treatments ranged between 0.67 to 0.82g $O_2/m^2$/hour, with no significant differences among treatments due to feed loads or dietary protein contents.

During daytime hours, oxygen concentration in pond water increases gradually from dawn to dusk through algal photosynthesis, while respiration of aquatic communities (including bacterial and algal respiration) during dark period gradually decreases oxygen concentration which reaches a minimum concentration just before sunrise (Ghosh and Tiwari, 2008; Mukherjee *et al*., 2008). Plankton respiration can account for 60% of the overnight DO decline (Losordo, 1980).

In order to have net autotrophy nCR must equal or be less than dNPP according to Hargreaves and Steeby (1999). Most of the variation in daytime and nighttime oxygen budget among treatments could be explained by the effect of higher feed input on oxygen deficits. Santa and Vinatea (2007) pointed out that dissolved oxygen demanded by fish (22.5%) and sediment (19.4%) respiration during 24-hours was lower than those consumed by phytoplankton respiration (57.5%). The increase in feed inputs (7 grams versus 10 grams) had slightly negative effect on oxygen budget during the current experiment.

Dawn oxygen deficits ranged -0.04 to -0.22 g $O_2/m^2$ in the 7 grams treatments, while higher early morning oxygen deficits (-0.57 to -0.91 g $O_2/m^2$) were observed in the 10 grams treatments. The higher oxygen deficits observed among the 7 gram and 10 gram treatments were caused by their lower daytime net primary production (dNPP) compared to slightly higher nighttime community respiration (nCR) as illustrated in table (2).

Aquaculture ponds are generally characterized by high phytoplankton blooms, being hypertrophic (Chang and Ouyang, 1988). Gross photosynthesis (oxygen production) slightly equaled community respiration in the 7 gram treatments, while community respiration slightly exceeded gross oxygen production in the 10 gram treatments.

The nCR: dNPP ratio in the 7 gram treatments (1.0 to 1.02) were slightly better than those of the 10 gram treatments (1.06 to 1.11) which indicated that lower feed input treatments (7 gram/$m^2$/day) performed better compared to the higher feed input treatments (10 grams/$m^2$/day). Consequently, increasing feed inputs affected the oxygen budget, resulting in slightly higher nCR: dNPP ratios. Higher feed oxygen demand is due to the active metabolism by fish and increased bacterial activities during the decomposition of algal detritus and feces. Excess feed load can result in excessive feed oxygen demand since each gram of diet requires 1.3 grams of oxygen during the process of metabolic activities in fish (Boyd, 2008).

**Water quality parameters:**

When feed load increased from 7 grams to 10 grams, ammonia and phosphate excretion by fish increased. Consequently, algal blooms took place in higher feed load, resulting in increased algal detritus production and oxygen cycling. This was reflected in shallower Secchi disk reading (20.6-24.7cm) and lower oxygen at early morning in the 10 gram treatments compared to those of the 7 grams treatments (26.1-28.2 cm), with significant differences among means ($p<0.05$).

Overall water temperature ranged from 25.4 to 26.0$^o$C among treatments during the experiment, with no significant differences among treatments ($p > 0.05$). In Egyptian fish farms, water temperature ranged from 18 to 28°C and that was suitable for fish growth (Soltan *et al*., 2015).

There were no significant differences in Total Ammonia Nitrogen (TAN) concentrations among different crude protein levels within the 7 gram or the 10 gram treatments. Generally, TAN range values in tank water were suitable among all treatments as recommended in fish culture (Boyd, 1990).

There were no significant differences in phosphate $PO_4$-P concentrations among different crude protein levels within the 7 gram or the 10 gram treatments. Generally, $PO_4$-P range values in tank water among all treatments were very low. The decrease in $PO_4$-P concentrations was due to the high algal photosynthetic rate in tank water in all treatments which exhausted phosphorus content. The increase in algal activities consumed most of the filterable orthophosphate in water.

High plankton density often results from high nutrient loads. (Datta, 2012). Fish diet and the level of dietary protein also affect water quality via ammonia excretion (Kaushik and Cowey, 1991). Consequently, scientific research into feeding management which enhances growth and feed performance is necessary to cut down the amount of metabolic waste products released into pond water (Ballestrazzi *et al*., 1994).

The overall nitrite ($NO_2$-N) in the 7 and 10 gram treatments were found in trace concentrations ranging from 0.01 – 0.06 mg $NO_2$-N /L among treatments. There were no significant differences in nitrite values among different crude protein levels within the 7 or the 10 grams treatments.

The overall pH values in the 7 gram treatments ranged 9.2 – 9.61 units among treatments, while the overall pH values in the 10 gram treatments ranged 8.98 – 9.69 units among different dietary protein treatments (table 2). There were no significant differences in pH values among different crude protein levels within the 7 gram or the 10 gram treatments.

Generally, the pH values in tank water for the 7 gram and 10 gram treatments were higher than recommended in aquaculture pond (6.5 – 9.0) as cited in Boyd (2000). Datta (2012) demonstrated that excessive feeding decreases the concentration of dissolved oxygen, and increases the concentration of harmful metabolites like urea, ammonia, and gases like carbon dioxide, ammonia, methane, hydrogen sulfide etc. He also added that this causes algal bloom and rotting of pond bottom.

**Growth Performance:**

Growth and feed performance parameters of Nile tilapia are shown in table (3). Starting with average initial weights of 95.1 to 106.8 grams/fish, Nile tilapia juvenile grew to harvest weight of 124.6 to 146.3 grams/fish. Slightly higher weight gains (37.82 to 43.99 g/fish) and daily weight gains (0.63 to 0.73 g/fish/day) were observed in the 10 gram treatments compared to those of the 7 gram treatments (29.54 to 36.91 g/fish and 0.49 to 0.61 g/fish/day, respectively). Increasing dietary protein levels within the 7 gram treatments did not improve the weight gain.

By the end of the experiment, daily weight gains of Nile tilapia in the 10 gram treatments were slightly heavier by 19 - 28 % compared to those reared in the 7 gram treatments. However, Nile tilapia in the 10 gram treatments consumed more expensive dietary protein than those in the 7 gram treatments as indicated by protein efficiency ratio values. Consequently, it can be concluded that Nile tilapia should not be fed above 7 grams/$m^2$/day since daily weight gains did not improve significantly in parallel with the increase in feed input.

Total oxygen demand in a pond can also be tied to the feed rate. The ultimate biological oxygen demand of pellet feeds of 0.65 mg $o_2$ per mg of feed can be taken to represent the combined fish oxygen demand as well as the pond oxygen demand due to uneaten food or excreted organic waste (David, 1997).

Optimal feed inputs that maximize harvest weight are considered economical aquaculture practices where there is a balance between optimizing feed utilization and maximizing growth (Van der meer *et al*., 1997). This goal could be reached when the application of feed inputs are below satiation level or in another word are restricted (Cho and Lovell, 2002).

Natural foods provided considerable protein supplement to fish in ponds mainly bacteria and senescent phytoplankton which complement dietary protein inputs (Burford *et al*., 2003). The supplementation which is provided by natural foods could enhance the restriction of crude protein levels from 40% to 20%, without affecting fish production (Hopkins *et al*., 1995; Teichert-Coddington and Rodriguez, 1995).

Specific growth rates of Nile tilapia were non-significantly higher (0.54 to 0.59% per day) in the 10 gram treatments compared to those of the 7 gram treatments (0.44 to 0.49% per day). Moreover, survival rates approached 100 % in all treatments. Increasing dietary protein level within the 7 gram treatments did not improve SGR. Similar results were obtained in the 10 gram treatments where increasing protein level did not improve SGR performance ($p>0.05$).

Feed costs and rates of ammonia excretions in pond water can be decreased when selecting the most cost-effective feed mixture that cut down protein wastes, based on protein efficiency (Brunty *et al*., 1997). Adopting intermediate feeding inputs in culture ponds can increase fish growth and production efficacy without water quality deterioration induced by algal blooms (Filbrun *et al*., 2013).

**Feed performance:**

Feeding Nile tilapia at 7 grams/m$^2$/day had comparable growth performance and better feed conversion ratio to those fed at 10 grams/m$^2$/day as illustrated in table (3). Consequently, higher feed inputs neither improved growth, nor enhanced oxygen budget. Hargreaves and Tucker (2003) reported that waste loading rates (algal sediment and feces) due to increased feed inputs can deteriorate water quality and exceed the tolerance limits of fish resulting in reduce growth and inferior FCR.

The use of restricting feeding in fish ponds can enhance feed efficiency and reduce the amount of wasted nutrients, such as phosphorus and nitrogen, which may cause severe algal blooms (Cho and Lovell, 2002). This is consistent with other research (Li and Lovell, 1992; Munsiri and Lovell, 1993), who demonstrated that feed efficiency improved as feed allotment was reduced.

Dietary protein is the major but most expensive source in animal feed which is necessary to obtain suitable growth rate of farmed fish. Protein provides the essential and nonessential amino acids to synthesize body protein and in part provides energy for maintenance (Gan *et al*., 2012).

**Table (2): Oxygen dynamics and water quality of Nile tilapia concrete tanks under different feed loads and protein levels (g feed/m$^2$/day).**

| Treatment / Parameter | Feed load | | | | | |
|---|---|---|---|---|---|---|
| | **7g/m$^2$** | | | **10g/m$^2$** | | |
| | 25%C.P. | 30%C.P. | 35%C.P. | 25%C.P. | 30%C.P. | 35%C.P. |
| Oxygen concentrations at sunset (g $O_2$/m$^2$) | 14.10$^a$ ±2.08 | 13.81$^a$ ±1.12 | 14.67$^a$ ±1.76 | 13.59$^a$ ±3.66 | 11.90$^a$ ±2.56 | 14.15$^a$ ±2.03 |
| Oxygen concentration at midnight (g $O_2$/m$^2$) | 9.62$^{ab}$ ±1.51 | 9.29$^{ab}$ ±0.80 | 9.87$^a$±1.14 | 7.97$^{ab}$ ±3.01 | 6.73$^b$ ±1.95 | 8.90$^{ab}$ ±1.30 |
| Oxygen concentrations at early morning (g $O_2$/m$^2$) | 6.33$^a$ ±1.51 | 5.88$^a$ ±1.01 | 6.27$^a$ ±1.39 | 4.81$^{ab}$ ±3.53 | 3.60$^{ab}$ ±2.15 | 5.89$^a$±1.99 |
| Oxygen concentrations at next early morning (g $O_2$/m$^2$) | 6.30$^a$ ±1.47 | 5.81$^a$ ±1.07 | 6.05$^a$ ±1.25 | 4.00$^{abc}$ ±3.01 | 3.03$^{bc}$ ±1.75 | 4.98$^{ab}$ ±1.23 |
| Daytime oxygen gain (dNPP) (g $O_2$/m$^2$/daytime) | 7.76$^a$ ±0.84 | 7.93$^a$ ±0.66 | 8.39$^a$ ±0.59 | 8.77$^a$±0.62 | 8.29$^a$ ±0.81 | 8.25$^a$±0.74 |
| Nighttime oxygen respiration loss (nCR) (g $O_2$/m$^2$/nighttime) | 7.80$^{ab}$ ±1.04 | 7.99$^{ab}$ ±0.37 | 8.61$^a$ ±0.79 | 9.58$^a$±0.83 | 8.86$^a$ ±1.06 | 9.16$^a$ ± 0.94 |
| Nighttime oxygen loss per hour (nCR/hour) (g $O_2$/m$^/$ hour) | 0.67$^{ab}$ ±0.08 | 0.69$^{ab}$ ±0.03 | 0.74$^a$ ±0.06 | 0.82$^a$±0.07 | 0.76$^a$ ±0.09 | 0.79$^a$±0.08 |
| Dawn Oxygen deficit (g $O_2$/m$^2$) | -0.04$^a$ | -0.06$^a$ | -0.22$^a$ | -0.81$^{ab}$ | -0.57$^{ab}$ | -0.91$^{ab}$ |
| nCR: dNPP ratio | 1.00 | 1.00 | 1.02 | 1,09 | 1.06 | 1.11 |
| Temperature at 7 a.m. ($^O$C) | 25.1$^a$ ±0.28 | 25.1$^a$ ±0.64 | 24.86$^a$ ±0.05 | 24.90$^a$ ±0.01 | 24.66$^a$ ±0.25 | 24.7$^a$±0.32 |
| Temperature at 6 p.m. ($^O$C) | 25.9$^a$ ±0.32 | 25.9$^a$ ±0.77 | 25.7$^a$ ±0.00 | 25.8$^a$ ±0.01 | 25.46$^a$ ±0.23 | 26.0$^a$±0.40 |
| Secchi disc (cm) | 27.1$^a$±3.3 | 28.2$^{ab}$ ±5.8 | 26.1$^{ab}$ ±7.1 | 20.6$^b$±5.5 | 24.7$^{ab}$ ±5.4 | 20.7$^b$±3.3 |
| Ammonia $NH_3$-N (mg/l) | 0.59$^a$ ±0.65 | 0.57$^a$ ±0.63 | 0.35$^a$ ±0.16 | 0.29$^a$ ±0.13 | 0.34$^a$ ±0.17 | 0.39$^a$ ±0.17 |
| Phosphate $PO\text{-}_4P$ (mg/l) | 0.08$^b$ ±0.03 | 0.06$^b$ ±0.02 | 0.07$^b$ ±0.02 | 0.06$^b$ ±0.03 | 0.07$^b$ ±0.05 | 0.06$^b$ ±0.03 |
| Nitrite $NO_2$-N (mg/l) | 0.01$^b$ ±0.00 | 0.01$^b$ ±0.03 | 0.04$^b$ ±0.02 | 0.01$^b$ ±0.03 | 0.01$^b$ ±0.03 | 0.06$^a$ ±0.07 |
| pH values | 9.2$^{ab}$ ±0.43 | 9.6$^{ab}$ ±0.49 | 9.61$^a$ ±0.09 | 9.33$^{ab}$ ±0.14 | 8.98$^b$ ±0.37 | 9.69$^a$ ±0.14 |
| Means in the same row with different letters are significantly different ($p<0.05$) | | | | | | |

Increasing dietary protein level within our study treatments did not improve feed conversion ratios. However, slight non-significant improvements were observed when increasing dietary protein form 25 to 30 % within the 7 gram treatments, indicating better environment of the latter treatments.

Moreover, it was observed that protein efficiency ratio PER values in the 10 grams treatments deteriorated to 1.13 when Nile tilapia were fed above 30% crude protein compared to those of the 7 gram treatments where PER values ranged from 1.25 to 1.54. Although Nile tilapia consumed more protein in the 10 gram treatments, PER values were affected compared to those of the 7 gram treatments. The deterioration in PER values may be due to the adverse effect of both high feed load and high ammonia and phosphate metabolic excretion by fish during protein metabolism. The amount of excreted metabolites may have an adverse effect on algal photosynthesis and oxygen budget in the high feed load treatments. Tucker (2005) reported that negative oxygen budget had adverse impacts on feed consumption, growth rates and feed conversion ratio of pond cultured fish.

Culture methods that rely on excessive addition of high-protein manufactured feeds to ponds are not desirable from a food production perspective (Filbrun *et al*., 2013). Consequently, it is recommended to feed Nile tilapia at 7 grams/m$^2$/day at crude protein level not exceeding 30% in order to obtain acceptable growth with economic returns. Li and Lovell (1992) found no difference among 26%, 32% and 38% protein feeds when fish were fed to satiation in ponds.

Percent weight gain of fish increase with increasing dietary protein level up to a point, and slightly decrease thereafter with further increases in dietary protein level (Yang *et al*., 2002). A similar trend has been reported for other fish species (Mohanty and Samantaray, 1996; Gunasekera *et al*., 2000).

In addition to the protein content of feed, a balance between the digestible protein and digestible energy of the diets can result in an increase in N retention efficiency and a decrease in the ammonium waste excreted by fish (Kaushik, 1998; McGoogan and Gatlin 2000). Optimal protein energy ratio in fish diets should spare dietary protein, allowing fish to

Utilize of non-protein energy sources (fat or carbohydrate) to meet energy requirements (Amirkolaie, 2011). This phenomenon is commonly called the ‘protein sparing effect’ and has been demonstrated in many fish species (Kaushik, 1998).

Our study indicated that feeding Nile tilapia at 7 grams/m$^2$/day had comparable growth performance and better feed conversion ratio to those fed at 10 grams/m$^2$/day. Both feed loads were within the assimilative capacity of water and sediments. Consequently, higher feed inputs neither improved economic efficiency, nor enhanced oxygen budget. Similarly, Increasing crude protein within the 7 gram treatments above 30% did not improve PER values and had a negative impact on economic performance.

**Table (3): Growth and feed performance of Nile tilapia under different feed loads and protein levels (g feed/m$^2$/day).**

| Treatment / Parameter | Feed load | | | | | |
|---|---|---|---|---|---|---|
| | 7g/m$^2$ | | | 10g/m$^2$ | | |
| | 25%C.P. | 30%C.P. | 35%C.P. | 25%C.P. | 30%C.P. | 35%C.P. |
| Initial weight (grams/fish) | 95.12$^a$ ±6.43 | 104.9$^a$ ±3.38 | 106.84$^a$ ±3.77 | 100.5$^{ab}$ ±2.46 | 96.06$^b$ ±1.84 | 102.6$^{ab}$ ±3.60 |
| Final weight (grams/fish) | 124.6$^b$ ±9.73 | 141.8$^a$ ±1.53 | 141.73$^a$ ±3.08 | 144.53$^a$ ±16.66 | 133.8$^{ab}$ ±11.34 | 146.3$^a$ ±2.78 |
| Weight gain (g/fish) | 29.54$^a$ ±2.94 | 36.91$^a$ ±4.56 | 34.89$^a$ ±3.77 | 43.99$^a$ ±16.20 | 37.82$^a$ ±9.65 | 43.71$^a$ ±2.93 |
| Daily weight gain (g/fish/day) | 0.49$^a$ ±0.04 | 0.61$^a$ ±0.07 | 0.58$^a$ ±0.06 | 0.73$^a$ ±0.27 | 0.63$^a$ ±0.16 | 0.72$^a$ ±0.04 |
| SGR (%) | 0.44$^a$ ±0.01 | 0.49$^a$ ±0.06 | 0.46$^a$ ±0.05 | 0.59$^a$ ±0.19 | 0.54$^a$ ±0.11 | 0.58$^a$ ±0.04 |
| Survival (%) | 100% | 100% | 100% | 100% | 97.22% | 100% |
| Feed conversion ratio (FCR) | 2.70$^a$ ±0.27 | 2.17$^a$ ±0.26 | 2.29$^a$ ±0.23 | 2.83$^a$ ±1.32 | 3.04$^a$ ±0.71 | 2.53$^a$ ±0.17 |
| Protein conversion ratio (PCR) | 1.48$^a$ ±0.14 | 1.54$^a$ ±0.19 | 1.25$^a$ ±0.13 | 1.59$^a$ ±0.58 | 1.14$^a$ ±0.29 | 1.13$^a$ ±0.07 |
| Means in the same row with different letters are significantly different (p<0.05) | | | | | | |

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