Dynamics of Dissolved Oxygen in Relation to pH and Survival of Fish Culture in Fiber Glass Tank

T. E. Adams¹,*, V. A. Okonji², R. O. Edokpia³, A. F. Yakubu¹

¹Nigerian Institute for Oceanography and Marine Research. Sapele, Delta State. Nigeria.
²Department of Production Engineering. University of Benin, Benin City. Nigeria.
³Department of Fisheries. University of Benin, Benin City. Nigeria.
*Corresponding author

Received: 15 Mar 2021; Received in revised form: 12 May 2021; Accepted: 21 Jun 2021; Available online: 27 Jun 2021
©2021 The Author(s). Published by Infogain Publication. This is an open access article under the CC BY license (https://creativecommons.org/licenses/by/4.0/).

Abstract—The study aims at determining the dynamics of dissolved oxygen in relation to pH and survival of fish culture in fibre glass tank. Three feeds were used. They are dried chicken manure only (Treatment I), mixture of dried chicken manure with commercial diet (coppens) (Treatment II) and commercial diet only (coppens only) (Treatment III). The physicochemical characteristics of water for the treatments (T₁, T₂ and T₃) in fibre glass tank were determined twice a month using standard methods. ANOVA was used to analyze the effects of the rate of changes between dissolved oxygen, pH and the fish survival.

The result from this study showed that the fish in treatment III had the highest weight gain of 272.10g followed by treatment II (172.07g) and 3 (143.47g) (P<0.05). There was no significance difference at probability level of (P<0.05) in survival rate. Variation exists in the water quality parameters examined, dissolved oxygen and pH falls within the range for fish survival. pH was correlated with dissolved oxygen. The findings also provide the useful information about the conditions of the three treatment which will ultimately help to manage the water body for sustainable production. The model showed that dissolved oxygen depends on pH.

Keywords—Dissolved Oxygen, dried chicken, commercial diet, Fiber Glass Tank.

1. INTRODUCTION

Water quality is the totality of physical, biological and chemical parameters that affect the growth and welfare of cultured organisms. Water quality affects the general condition of cultured organism as it determines the health and growth conditions of cultured organism.

Water quality parameters vary with feeding frequency and have wider impacts on primary productivity and fish production. Good water quality refers to that with adequate oxygen, proper temperature, transparency, limited levels of metabolites, and optimum levels of other environmental factors affecting fish culture.

Water quality in tanks change continuously and are affected by each other along with the physical and biological characteristics.
considered safe by the European Inland Fisheries Advisory Commission (EIFAC 1969). ANZECC and ARMCANZ (2000) and (Begum et al, 2014) recommended guide lines for pH maintained between 5.5 and 9.0 for fresh water.

It should be noted that pH can change by the hour as a function of photosynthesis which removes carbon dioxide.

Dissolved oxygen (DO) is considered as one of the most important water quality parameters in aquaculture. It is needed by fish to respire and perform metabolic activities. Thus, low levels of dissolved oxygen in fish culture cause stress to cultivated fish (Boyd, 1982) resulting in reduced feed intake, poor feed conversion and growth, and are often linked to fish kill incidents.

Dissolved oxygen refers to the level of free, non-compound oxygen present in water or other liquids. It is an important parameter in assessing water quality because of its influence on the organisms living within a body of water (Wetzel, 2001). A dissolved oxygen level that is too high or too low can harm aquatic life and affect water quality (Kemker, 2013). UNEP (2007) pointed out that dissolved oxygen level was a good indicator for water pollution.

Dissolved oxygen is also produced as by product of photosynthesis from phytoplankton, algae, seaweed and other aquatic plants (Kemker, 2013).

Dissolved oxygen and pH affects directly or indirectly other limnological parameters such as transparency, viscosity, total dissolved solids and conductivity (Whitney, 1942); all of which constitute the very important physical and chemical parameters that form the basis for an enlightened fisheries and water resources management (Araoye et al., 2007).

DO is measured by the azide modification of the Winkler method. The DO level in natural and wastewater depends on the physical, chemical and biochemical activities in the water bodies. Oxygen is considered as poorly soluble in water. Its solubility is related to pressure and temperature. In fresh water, DO reaches 14.6mg/l at 0°C and approximately 9.1, 8.3 and 7.0mg/l at 20, 25 and 35°C, the level of saturated DO is 9.0 – 7.0mg/l for living organism, about 4mg/l of minimum DO should be in water.

Initial weight of Fish in gram (g):
Final weight of fish harvested (g)

\[
Bi - \text{weekly mean weight gain (g)} = \frac{\text{Total bi - weekly weight (g)}}{\text{Total No of fish weight (g)}}
\]  

(1)

Absolute growth rate (g / day) = \[
\frac{\text{Final weight - Initial weight of fish}}{\text{Culture period (days)}}
\]

(2)

Dissolved oxygen is critical for fish and other water inhabitants. Generally, waters with dissolved oxygen concentrations of 5.0 milligrams per liter (mg/L) (equivalent to 5 parts per million (ppm))l or higher can support a well balanced, healthy biological community. As dissolved oxygen drops below 5.0 mg/L, aquatic life is put under stress (Hach Company 2001).

II. MATERIALS AND METHODS

The study was conducted at the Nigerian Institute for Oceanography and Marine Research Sapele out station Sapele Local Government Area of Delta State, Nigeria (N50° 54’5.5” E005° 39’56.4”). six circular fibre glass tanks were used in the experiment. All experimental tanks were identical in shape and size. Tanks capacities were 3.08m³ and depth of 60.5cm each and diameter 176.78cm. Sex reversed Nile tilapia (Oreochromis niloticus) of 0.80g average size was stocked.

The tanks were divided into three culture systems that is intensive, semi intensive culture and extensive culture in triplicates for each culture system. The treatments were dried chicken manure only, dried chicken manure plus commercial diet (coppens) and commercial diet (coppens) only. These treatments was used to determine the dissolved oxygen dynamics in each culture system and to predict the effect of pH and survival of fish culture in fibre glass tank. Three hundred (300) fish were stocked in each tank.

The fish used for this experiment were fingerlings of all male Nile tilapia (O. niloticus). Fish were fed at 800hr and 1600hr with dried chicken manure, chicken manure plus commercial feed (coppens) and commercial feed (coppens) only. The feeding rate was 5% of the total fish biomass presented in each tank and the feed amount was adjusted every two weeks for each tank separately according to the biomass available which was determined during sampling. Random samples of 75 fish were taken biweekly from each treated tank during the experimental period. Fish samples were obtained in the early morning (between 7.00hr to 9.00hr)

From the measurements, the following parameters were determined:

ISSN: 2456-1878
https://dx.doi.org/10.22161/ijeab.63.18
\[ \text{Specific growth rate (SGR\% day)} = 100 \times \frac{\ln \text{Final bodyweight} - \ln \text{Initial body weight}}{\text{Rearing period in days (t)}} \]  

(3)

where

\[ \ln = \text{natural log} \]

\[ \text{Feed Conversion Ratio} = \frac{\text{Total weight of feed consumed}}{\text{Total weight of fish produced}} \]

(4)

\[ \text{Fish Survival Rate (SR\%)} = \frac{\text{Total fish number harvested}}{\text{Total fish number stocked}} \times 100 \]

(5)

\[ \text{Fish Yield} = \frac{\text{Total weight of fish harvested over culture}}{\left( g / 180 \text{ days} / 3.08 \text{m}^3 \right)} \times 100 \]

(6)

The water quality was monitored using the following water testing meters: At the end of the hand picking. Total weight of the fish was taken. Random fish samples 50 from each treatment were taken to determine the final mean weight. Harvested fish were kept in plastic containers for marketing.

From the foregoing the primary data collected were used for modeling the dissolved oxygen in the fibre glass tanks with respect to the treatments administered to them vis-à-vis Chicken manure, Chicken manure plus coppens and Coppens only. The average (mean) for each parameter per two weeks was computed, considering the values from three treatments. Their interrelations of twenty four weeks were determined by the analysis of variance (ANOVA) using the MiniTab 17 software. All test were carried out at 5% probability level (P <0.05).

III. RESULT AND DISCUSSION

Treatment I

| Bi Weekly | pH  | Yield | Dissolved oxygen |
|-----------|-----|-------|------------------|
| 2         | 6.77| 0.83  | 3.577            |
| 4         | 9.246| 1.07  | 12.797           |
| 6         | 9.826| 4.5   | 14.642           |
| 8         | 10.206| 9.14  | 16.425           |
| 10        | 10.088| 14.05 | 16.736           |
| 12        | 9.47 | 19.74 | 17.094           |
| 14        | 8.704| 26.57 | 15.842           |
| 16        | 8.924| 40.38 | 16.603           |
| 18        | 8.598| 59.38 | 16.875           |
| 20        | 8.577| 79.27 | 17.222           |
| 22        | 8.463| 111.48| 17.211           |
| 24        | 8.314| 143.47| 16.481           |
| Total     | 107.186| 509.88|                  |

Table 1: Water quality parameter in time-weeks for Treatment I
Table 2: Water quality parameter in time-weeks for Treatment II

| Bi-Weekly | pH  | Yield | Dissolved oxygen |
|-----------|-----|-------|------------------|
| 2         | 6.77| 0.77  | 4.581            |
| 4         | 8.563| 1.39  | 8.058            |
| 6         | 8.66 | 6.63  | 10.521           |
| 8         | 9.202| 13.64 | 12.978           |
| 10        | 9.149| 20.55 | 14.114           |
| 12        | 8.326| 27.84 | 11.718           |
| 14        | 8.135| 35.79 | 11.397           |
| 16        | 7.847| 58.04 | 10.792           |
| 18        | 7.809| 85.04 | 10.561           |
| 20        | 7.743| 107.67| 10.567           |
| 22        | 7.651| 139.87| 10.461           |
| 24        | 7.611| 171.97| 10.706           |
| Total     | 97.466| 669.2 |                  |

Table 3: Water quality parameter in time-weeks for Treatment III

| Bi-Weekly | pH  | Yield | Dissolved oxygen |
|-----------|-----|-------|------------------|
| 2         | 6.77| 0.8   | 3.767            |
| 4         | 9.163| 1.98  | 10.525           |
| 6         | 8.921| 15.53 | 9.662            |
| 8         | 8.831| 33.17 | 9.733            |
| 10        | 8.065| 51.57 | 10.7             |
| 12        | 7.8  | 72.09 | 7.625            |
| 14        | 8.009| 103.81| 9.439            |
| 16        | 8.237| 135.35| 10.125           |
| 18        | 8.316| 174.63| 10.461           |
| 20        | 8.109| 206.73| 10.339           |
| 22        | 7.981| 239.1 | 10.428           |
| 24        | 7.904| 272.1 | 10.45            |
| Total     | 98.106| 1306.86|           |

The model intended to be developed is of the form

\[ Y = b_0 + b_1y_1 + b_2y_2 \]  \hspace{1cm} (1)

The Table below show the result of the experimental Do and model DO

For Treatment I
Table 4: Percentage error of Model and Experimental DO for Treatment I

| WEEK | DOM   | DOE   | %error |
|------|-------|-------|--------|
| 2    | 3.644 | 3.577 | -0.0187|
| 4    | 14.544| 12.797| -0.1365|
| 6    | 15.134| 14.642| -0.0342|
| 8    | 16.997| 16.425| -0.0348|
| 10   | 18.392| 16.736| -0.0994|
| 12   | 18.765| 17.094| -0.0978|
| 14   | 19.930| 18.842| -0.2581|
| 16   | 17.862| 16.603| -0.0759|
| 18   | 18.458| 16.875| -0.0938|
| 20   | 18.662| 17.222| -0.0839|
| 22   | 18.768| 17.211| -0.0905|
| 24   | 19.327| 16.481| -0.1727|

For Treatment II

Table 5: Percentage error of Model and Experimental DO for Treatment II

| WEEK | DOM   | DOE   | %error |
|------|-------|-------|--------|
| 2    | 4.5809| 4.581 | 0.0002 |
| 4    | 9.1158| 8.058 | -0.1313|
| 6    | 9.8682| 10.521| 0.0620 |
| 8    | 12.412| 12.978| 0.0436 |
| 10   | 14.322| 14.114| -0.0147|
| 12   | 11.674| 11.718| 0.0038 |
| 14   | 11.521| 11.397| -0.0109|
| 16   | 10.585| 10.792| 0.0192 |
| 18   | 10.596| 10.561| -0.0033|
| 20   | 10.462| 10.567| 0.0099 |
| 22   | 10.666| 10.461| -0.0199|
| 24   | 10.662| 10.706| 0.0041 |

For Treatment III

Table 6: Percentage error of Model and Experimental DO for Treatment III

| WEEK | DOM   | DOE   | %error |
|------|-------|-------|--------|
| 2    | 3.8045| 3.767 | -0.01  |
| 4    | 10.569| 10.525| -0.0042|
| 6    | 9.2522| 9.662 | 0.0424 |
| 8    | 10.204| 9.733 | -0.0484|
| 10   | 10.148| 10.7  | 0.0516 |
| 12   | 8.0575| 7.625 | -0.0567|
| 14   | 9.0996| 9.439 | 0.0359 |
The results presented in Tables 7, 8 and 9 shows that for the models representing all three treatments, the model p-value was less than 0.05. This suggests that the response models were significant and can be used for predictive purpose.

### Table 7: ANOVA results for Treatment 1

| Source   | Sum of Squares | Degree of freedom | Mean square | F value | P value |
|----------|----------------|-------------------|-------------|---------|---------|
| Model    | 159.770        | 7                 | 22.8243     | 24.34   | 0.004   |
| $x_1$    | 14.449         | 1                 | 14.4491     | 15.41   | 0.017   |
| $x_2$    | 22.032         | 1                 | 22.0321     | 23.50   | 0.008   |
| Error    | 3.750          | 4                 | 0.9376      |         |         |
| Total    | 163.520        | 11                |             |         |         |

### Table 8: ANOVA results for Treatment II

| Source   | Sum of Squares | Degree of freedom | Mean square | F value | P value |
|----------|----------------|-------------------|-------------|---------|---------|
| Model    | 60.6163        | 7                 | 8.65947     | 17.39   | 0.008   |
| $x_1$    | 6.4582         | 1                 | 6.45815     | 12.97   | 0.023   |
| $x_2$    | 0.1662         | 1                 | 0.16622     | 0.33    | 0.594   |
| Error    | 1.9919         | 4                 | 0.49798     |         |         |
| Total    | 62.6082        | 11                |             |         |         |

### Table 9: ANOVA results for Treatment III

| Source   | Sum of Squares | Degree of freedom | Mean square | F value | P value |
|----------|----------------|-------------------|-------------|---------|---------|
| Model    | 41.2256        | 7                 | 5.8894      | 16.05   | 0.009   |
| X1       | 0.3885         | 1                 | 0.3885      | 1.06    | 0.362   |
| X7       | 7.7167         | 1                 | 7.7167      | 21.03   | 0.010   |
| Error    | 1.4676         | 4                 | 0.3669      |         |         |
| Total    | 42.6932        | 11                |             |         |         |

The results presented in Tables 7, 8 and 9 shows that for the models representing all three treatments, the model p-value was less than 0.05. This suggests that the response models were significant and can be used for predictive purpose.

### Table 10: Coefficient estimate for model representing Treatment 1

| Source | Coefficient estimate | Standard error | T value | VIF |
|--------|----------------------|----------------|---------|-----|
| Const  | 101.9                | 26.5           | -3.84   | -   |
| X1     | 5.65                 | 1.44           | 3.93    | 21.47 |
| X7     | 0.04841              | 0.00999        | 4.85    | 2.57 |
The variance inflation factor in all the three treatments are very large since multicollinearity exist among the variables. The coefficient estimate show that there is positive effect on the model and the response for both Treatment I and Treatment II while Treatment III show both positive and negative values. The positive value indicate positive effect on the model while the negative value indicate antagonistic effect on the response.

Growth Performance Mean Weight Gain (MWG)
Using eq. .1, the mean weight gain in treatment I was found to be 42.49 while that of treatment II recorded was 55.77 and treatment III was 108.91. Fish in treatment III showed the highest mean weight gain of 108.91 which was significantly different from all the other treatments (Table 4.11). Fish in treatment I and II recorded 42.49 and 55.77 respectively, which were not significantly different from each other.

Table 11: Coefficient estimate for model representing Treatment II

| Source  | Coefficient estimate | Standard error Coefficient | T value | VIF |
|---------|---------------------|----------------------------|---------|-----|
| Constant | 25.1                | 31.6                       | -0.79   | -   |
| x<sub>1</sub> | 4.42                | 1.23                       | 3.60    | 16.28 |
| x<sub>7</sub> | 0.010               | 0.0173                     | 0.58    | 21.95 |

Table 12: Coefficient estimate for model representing Treatment III

| Source  | Coefficient estimate | Standard error Coefficient | T value | VIF |
|---------|---------------------|----------------------------|---------|-----|
| Const   | -67.4               | 17.8                       | -3.78   |     |
| x<sub>1</sub> | -2.09               | 2.02                       | -1.03   | 47.91 |
| x<sub>7</sub> | 0.0241              | 0.00525                    | 4.59    | 7.55  |

Table 13: Bi Weekly Mean Weight Gain of All Male Tilapia for the three Treatment tanks for 24 weeks of culture

| Weeks | Chicken Manure Only (g) | Chicken Manure With Coppens (g) | Coppens Only (g) |
|-------|-------------------------|---------------------------------|-----------------|
| 2     | 0.83                    | 0.77                            | 0.80            |
| 4     | 1.07                    | 1.39                            | 1.98            |
| 6     | 4.50                    | 6.63                            | 15.53           |
| 8     | 9.14                    | 13.64                           | 33.17           |
| 10    | 14.05                   | 20.55                           | 51.57           |
| 12    | 19.74                   | 27.84                           | 72.09           |
| 14    | 26.57                   | 35.79                           | 103.81          |
| 16    | 40.38                   | 58.04                           | 135.35          |
| 18    | 59.38                   | 85.04                           | 174.63          |
| 20    | 79.27                   | 107.67                          | 206.73          |
| 22    | 111.48                  | 139.87                          | 239.10          |
| 24    | 143.47                  | 172.97                          | 272.10          |
| X     | 42.49b                  | 55.77b                          | 108.9a          |
Growth Performance

Survival Rate

Treatment III fed with coppens only perform better in terms of growth performance while Treatment I has the lowest performance. Survival rate exceeded 90% in all treatments. Treatment I recorded 77%; treatment II 99% and treatment III 99.33% which is the highest survival rate. Table 14 gives the values and this was estimated using eq. 5.

Table 14: Growth performance of all male Tilapia fed with chicken manure only, chicken manure with coppens and coppens only in a fibre glass tank.

| Parameters                  | Treatments                      |
|-----------------------------|---------------------------------|
|                             | I (Chicken manure only)         | II (Chicken manure with coppens) | III (Coppens only)  |
| Initial mean weight (g)     | 0.83                            | 0.77                             | 0.80                |
| Mean weight gain (g)        | 42.49b                          | 55.77b                           | 108.91a             |
| Final mean weight (g)       | 143.47c                         | 171.97b                          | 272.10a             |
| Specific growth rate (%/day)| 4.96a                           | 5.14a                            | 5.60a               |
| Survival rate (%)           | 77a                             | 99a                              | 99.33a              |
| Feed intake (g feed/fish)   | 584.50c                         | 823.70b                          | 1596.30a            |
| Feed Conversion Ratio       | 1.95                            | 2.75                             | 5.32                |

Mean with different superscripts in the same row are significantly different

Water quality analysis

Table 15: Water quality parameters during the experimental period

| Parameters                   | Treatments                        |
|------------------------------|-----------------------------------|
|                              | Chicken manure only | Chicken manure + coppens | Coppens only |
| Dissolved Oxygen             | 15.164                           | 10.539                    | 9.417        |
| pH                           | 8.860                            | 8.073                     | 8.108        |
| Temperature °C               | 28.517                           | 28.191                    | 29.044       |
| Electrical Conductivity      | 293.10                           | 314.30                    | 313.40       |
| Unionized ammonia (NH₃)      | 0.50                             | 12.80                     | 0.20         |
| Total Dissolved Solid        | 147.09                           | 157.19                    | 156.55       |
| Transparency (cm)            | 32.50                            | 25.20                     | 16.42        |

IV. CONCLUSION

The water quality parameter table show suitable environmental conditions for rearing All Male Tilapia during the experimental period.

It was observed that dissolved oxygen interact with pH, the yield increase as the dissolved oxygen increase, also the lower the pH the better the dissolved oxygen for the survival of the fish.

It was observed that the response model is significant (p < 0.05).
REFERENCES

[1] Araoye PA, Adedeji RA, Dada JO, Adebiyi GO (2007). Relationship between the rainfall water levels flooding and fish supply from Asa dam Ilorin, Nigeria. In: Proceedings of the Fisheries Society of Nigeria. Eds. Araoye PA, Adikwu IA, Banke ROK. Publ. Fisheries Society of Nigeria. pp. 236-239.

[2] ANZECC & ARMCANZ (2000). (Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand): Australian and New Zealand guidelines for fresh and marine water quality National Water Quality Management Strategy Paper No4, Canberra.

[3] Beigum A., Mondal S., Ferdous Z., Zafar M. A. And Ali M. M. (2014). Impact of water quality parameters on monosex tilapia (Oreochromis niloticus) production under pond condition. IJAFS: ISSN 2308-4715, Volume 2 Issue 1.

[4] Boyd CE (1982). Water quality management for pond fish culture. Elsevier Scientific Publishing Co. New York. p. 318.

[5] EIFAC (1969). European Inland Fisheries Advisory Commission. Working Party on Water Quality Criteria for European Freshwater Fish. List of literature on the effect of water temperature on fish. EIFAC Tech.Pap., (8):8 p.

[6] Hach Company. (2001). Important water quality factors. H2O University. http://www.hach.com/h2ou/h2wtrqual.htm. (April 2001).

[7] Klonz, G. W. (1993): Producing a marketable fish. Part V. Inventory techniques. Northern Aquaculture 10, 21–25.

[8] Kemker, C. (2013). Dissolved Oxygen." Fundamentals of Environmental asurements. Fondriest Environmental, Inc. Web. http://www.fondriest.com/environmental-Measurements/parameters/water-quality/dissolved-oxygen.

[9] Meade, I. W. (1989): Aquaculture Management. Van Nostrand Reinhold, New York.

[10] Mitchell and Stapp, 1992. The effect of rain water on stream erosion and total suspended solid levels.

[11] Swingle, H. S. (1969). Methods of Analysis for waters, organic matter and Pond Bottom Soils Used in Fisheries Research. Auburn Univ. Auburn, Ala, 119pp.

[12] Tomasso, J. R. (1993). Environmental requirements and diseases of freshwater and estuarine temperature fishes. Pages 240-246 in M stoskopf (Editor). Fish Medicine. WB Saunders, Philadelphia.

[13] UNEP (2007). Water Quality monitoring programme in the Iraq marsh lands. Report from United Nation Environment programme support from the environmental Management of The Iraqi Marsh lands, pp. 1-24.

[14] Wetzel, R. G. (2001): Limnology: Lake and River Ecosystems (3rd ed.). San Diego, CA: Academic Press.

[15] Whitney RJ (1942). Diurnal fluctuations of oxygen and pH in two small ponds and a stream. J. Expt. Biol. 19: 92-99.