Interrelationship of Temperature, pH, Dissolved Oxygen and Nitrogenous Wastes in Fish Culture Systems

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ABSTRACT

Frequent monitoring of water quality in fish culture systems is important to profitable operation of fish farming ventures. This study investigated how water quality parameters such as Temperature, pH, Ammonia, Nitrate and Dissolved Oxygen interrelate in fish culture systems. Water samples were collected from a concrete tank and an earthen fish pond in a commercial fish farm in Ibadan over a period of six weeks. Water source for fish culture, fish feeding rate and frequency were the same. Temperature, pH, Ammonia, Nitrate and Dissolved Oxygen (D.O.) were all analyzed in the water samples using standard methods. Relationships exist among the water quality parameters examined. There were variations of each water quality parameters among the weeks in the fish culture systems. The levels of the parameters determined were within the acceptable ranges for fish culture. Temperature had a negative correlation with pH and D.O. at r values of -0.61 and -0.53 respectively. Ammonia had a weak negative correlation with pH at -0.41 r value. Interrelationship between temperature and dissolved oxygen gave an equation which predicts D.O. as -0.911T + 32.57 with R^2 value of 0.373. A multiple relationship among ammonia, temperature and pH is such that at R^2 value of 0.58, ammonia can be estimated to be 7.42+0.31pH – 0.20T.

Keywords: *Physico- chemical parameters, Fish health, Test Kits. Water analysis*

INTRODUCTION

The aquaculture industry in Nigeria has grown tremendously in recent years with a reported production of farmed catfish of 143,207 metric tonnes (FDF, 2008) and 20% growth per year. This development has catalyzed a well developed value chain of many participants including an estimated 5,000 or more fish farmers, more than 100 small to medium hatcheries as well as four quality fish feeds of local manufacture, 12 imported quality fish feeds and an undocumented large number of small, artisanal fish feed producers. Equipment (fishing gears, laboratory needs) suppliers and consulting service providers have also grown with fairly wide coverage in the different regions of the country. Intensive fish culture ventures is a major avenue to close the present fish demand –supply gap in the country and satisfy the nutritional need of the populace with respect to provision of high quality protein in diets. The different forms of high density, intensive aquaculture systems comes with their peculiar challenges comprising the subject of water chemistry and its net result of the water quality of the culture environment.Water as a habitat for fish must carry dissolved useful gases, minerals and other substances of sorts and in such amounts that are not harmful to fish (Adeyemi and Ipinjolu 1999). Water quality criteria are scientific and technical information provided for a particular water quality constituent in the form of numerical data or narrative description of its effects on the suitability of water for a particular use or on the health of aquatic ecosystems. Water quality for the aquaculturists refers to the quality of water that enables successful propagation of the desired organisms (Boyd, 1995). Poor water chemistry leads to deterioration of water quality, which causes stress to the cultured organisms. Efficient feed conversion, growth and marketability of the final product cannot be guaranteed unless the culture system is balanced or in harmony with nature. Water quality parameters affect respiration, feeding, metabolism, reproduction, and waste removal from the environment. Maintenance of good water quality is essential for both survival and optimum growth of culture organisms. The levels of metabolites in pond water that can have an adverse effect on growth are generally an order of magnitude lower than those tolerated by fishes for survival. Water quality of the culture environment determines the ultimate success or failure of an aquaculture operation. The paramount concern of the fish farmer therefore is to maintain, equilibrium conditions with respect to water chemistry thereby ensuring good water quality. The information gathered from monitoring activities is critical to protect the beneficial use of the water to support aquatic life.

The fish farmer is expected to measure, record, and manage the water quality all through the growing season. This serves as guide for managing the fish culture systems so that conditions that can adversely affect the growth of fish can be avoided. In cases where problems are encountered, these parameters can help in the diagnosis, so actions to remedy the situation can be taken. Parameters such as Dissolved Oxygen (D.O), Temperature, pH, Salinity, Turbidity, Nitrogenous wastes indices like Ammonia, Nitrite and Nitrate among others are considered basic to life within aquatic systems.. Individual parameters usually do not tell much, but several parameters put together can serve as indicators of the dynamic processes occurring in the culture medium. Monitoring of these physico –chemical parameters, involves a variety of methods including titrimetric procedures requiring chemical reagents, bottles and glassware like beakers, burette, pipette, conical flasks, D.O bottles ,calorimeters as well as the use of meters like digital thermometer, pH meter, D.O. meter, Spectrophotometer and portable test kits. Whichever method or equipment is employed, measurement of these physico–chemical parameters, are most times cumbersome and usually very expensive, especially for peasant farmers in the rural areas of Nigeria. Theoretical, empirical or numerical studies and analysis that may result in the use of easily measured parameters (e.g pH, temperature) to reveal the level of other water quality parameters would be welcome. Moderately trained poor peasant farmers can thus spend less time and money on water analysis procedures and test kits. The present study was considered to investigate the interrelationship and possibly develop predictive equations between temperature, pH, dissolved oxygen, ammonia and nitrate in fish culture systems.

MATERIALS AND METHODS

Water samples were collected from two fish holding structures, concrete tank and earthen pond in a commercial fish farm located at Olodo village, Ibadan, Oyo State. Water source to the farm is from a stream; the fish in the culture systems were twelve weeks at the onset of water sampling. The species stocked in both fish holding structure was *Clarias gariepinus*. The fish were fed with locally compounded feed pelleted on the farm and are fed twice daily.

Water samples were collected over six week duration at depth 10cm-15cm below the water surface and from two points (inlet and outlet) in each of the holding structure with a sampling bottle in the morning (9.00am-10:00am) and evening (6.00pm-7:00pm). Temperature and pH were determined at the site of water collection. Dissolved Oxygen (D.O.), Ammonia and Nitrate, were analyzed in the water samples taken to the laboratory. Temperature was determined with the use of simple mercury –in- glass thermometer; the thermometer was dipped into the water consistently at surface depth of 10cm-15cm throughout the period of the experiment. It is measured in ^{o}C .The pH was measured with an electric pH meter; the meter was dipped into water for few seconds and the reading was taken. Dissolved oxygen (DO), measured in mg/l., was determined using Winkler's method .Merck Ammonia -Nitrogen test kit was used to analyze the water sample to determine the level of ammonia. Nitrate was determined using the Kjeldahl digestion method. All analyses were done in line with standard methods (APHA 1995).

The data obtained were analyzed using descriptive statistics. Average values for each parameter was computed considering the values from the two culture systems. The significant difference in the mean values of each parameter was determined by one way ANOVA. Correlation analysis was carried out to determine the interdependence among the parameters and regression analysis was also carried out to determine the interrelationship among the parameters. The regression equation is expressed as; $Y = a + bX$ where Y = independent variable, X= independent variable, a = intercept and b= slope. . Temperature and pH are considered as independent variables because their measurement and determination are less cumbersome and least demanding relative to others (dissolved oxygen, ammonia and nitrate) which are thus treated a dependent variable.

RESULTS AND DISCUSSION

Temperature and pH

Mean temperature value obtained in concrete tank was 29.17±0.34°C. The range of temperature value did not show wide deviation from the mean value which indicate that temperature obtained in the concrete tank are almost stable, while the mean temperature obtained in earthen pond was 30.06±0.30°C(Table 1). Temperature obtained in both culture systems are in line with study of Boyd, (1995) that reported 26-32°C for freshwater fish.

The pH value obtained in concrete tank during the study was 8.84±0.41, while value obtained in earthen pond was 8.08 ±0.28 (Table 1). The pH value obtained during the study in both culture systems was in line with study of Stone and Thomforde (2003), who obtained a desirable range for pond pH as 6.5 - 9.5 and acceptable range is 5.5 - 10.0 for good productivity and fish health .

Dissolved Oxygen, Ammonia and Nitrate

The mean D.O. value recorded in concrete tank is 6.08±0.63mg/l, while the mean dissolved oxygen obtained in earthen pond is 4.99 ±0.63 mg/l (Table 1).The mean values of D.O. measured in the two culture systems differs significantly (P<0.05).

TABLE 1
Mean values of selected quality parameters and ranges for fish culture.

Parameters and units	Concrete tank	Earthen pond	Optimum level for freshwater fish culture
Temperature, °C	29.17±0.34	30.06±0.30	26-32
pH	8.84±0.41	8.08 ±0.28	6.5- 8.5
Dissolved Oxygen, mg/l	6.08±0.63^a	4.99 ±0.63^b	>5.0 mg/l
Ammonia, mg/l	4.61±0.42^c	5.90±0.51^d	<8.0 mg/l
Nitrate, mg/l	2.30±0.08	2.60±0.11	< 250 mg/l

Means in the same row differently superscripted differ significantly (P<0.05)

The relatively low dissolved oxygen recorded in the earthen pond can be attributed to the slightly higher mean temperature .This is in agreement with the work of Fakayode, (2005), who observed that high temperature will cause decrease in the dissolved oxygen. The dissolved oxygen in the water body is at its lowest in the morning because of respiratory activities that occurs over the night and is at its peak in the evening when the sun is just set because of photosynthetic activities (King and Nkanta, 1991).Values obtained in this study follows this trend.

The mean values of ammonia obtained in concrete tank and earthen pond are 4.61±0.46 mg/l and 5.90±0.51 mg/l respectively. (Table 1). These mean values as measured in the two culture systems are significantly different (P<0.05). The ammonia obtained in both culture systems throughout the evaluation period are almost relatively stable .These values are however considered not healthy for a freshwater body meant for fish culture . A surface water body with ammonia of 2.7mg/l is defined as grossly polluted. This high ammonia levels can arise from overfeeding. Excess protein rich feed decays to liberate toxic ammonia gas, which in conjunction with the ammonia excreted by fishes, may accumulate to dangerously high levels under certain conditions as stated by Boyd and Tucker (1998). Fortunately, ammonia concentrations are partially buffered by conversion to non toxic nitrate by nitrifying bacteria. Mean nitrate values recorded in concrete tank and earthen pond are 2.30±0.08 mg/l and 2.60±0.11 mg/l respectively (Table 1). These values are low and do not portend danger to the cultured organisms. Nitrate concentrations from 0 to 200 mg/l are reported as tolerable and acceptable.

Interdependency and relationship among parameters

The interdependence among the water quality parameters measured in the two culture systems during the period of the study is as shown in Table 2. Tables 3 and 4 show the coefficient of determination and equations obtained from the regression relationship between the water quality parameters

The correlation coefficient indicates the relationship among the parameters. Temperature and dissolved oxygen were inversely related and were negatively correlated (r= -0.61). This is in agreement with the work of Fakayode, (2005), who observed that high temperature will cause decrease in the dissolved oxygen. The relationship between the temperature and pH also shows a negative correlation (r= -0.53) and was significant. Temperature had a positive correlation(r= 0.55) with the concentration of ammonia. It can be deduced that increase in temperature will lead to increase in the level of ammonia. Correlation between temperature and Nitrate was positive (r= 0.78) and strongly significant.

TABLE 2
Interdependence among water quality parameters during the period of study.

Variables	Temperature	pH	D.O	Ammonia	Nitrate
Temperature	1.00	-0.53*	-0.61*	0.55*	0.78*
pH	-0.53*	1.00	0.74*	-0.41*	-0.69*
D.O	-0.61*	0.74*	1.00	-0.42*	-0.54
Ammonia	0.55*	-0.41*	-0.42	1.00	0.84*
Nitrate	0.78*	-0.69*	-0.54*	0.84*	1.00

*statistically significant (P <0.05)

TABLE 3
Linear regression analysis of selected water quality parameters

Y	X	Prediction equation	Coefficient of determination (R^2)
Dissolved Oxygen, D.O. mg/l	Temperature, ^{O}C	D.O.= -0.911T + 32.54	0.373
Ammonia, mg/l	Temperature, ^{O}C	Ammonia.= 0.804T -18.57	0.298
Nitrate, mg/l	Temperature, ^{O}C	Nitrate = 0.542T - 13.81	0.604
Dissolved Oxygen, D.O. mg/l	pH	D.O.= 1.130pH - 4.023	0.513
Ammonia, mg/l	pH	Ammonia.= -0.639pH+10.66	0.168
Nitrate,mg/l	pH	Nitrate= -0.55pH+6.512	0.469

TABLE 4
Multiple Regression analysis of selected water quality parameters

Y	X	Prediction equation	Coefficient of determination (R^2)
Dissolved Oxygen, (D.O.) mg/l	Temperature ,^{O}C& pH	D.O=21.12+1.08pH -0.87 T	0.67
Ammonia, mg/l	Temperature, ^{O}C & pH	Ammonia=7.42+0.31pH -0.20 T	0.58
Nitrate, mg/l	Temperature, ^{O}C& pH	Nitrate =1.10-0.06 pH+0.03 T	0. 90

Dissolved oxygen also had a strongly significant positive correlation (r = 0.74) with pH. The correlation between dissolved oxygen and ammonia was negative and not significant. The dissolved oxygen also had a negative correlation (r = -0.54) with nitrate at a weakly significant level. The pH also had an insignificant negative correlation (r = -0.41) with ammonia and a strongly significant negative correlation (r = -0.69) with nitrate.

The relationship between the ammonia and nitrate was strongly significant and positive (r=0.84). This can be attributed to the fact that decomposition of ammonia lead to the formation of nitrate, therefore when there is suitable condition (i.e. oxygen and warmth) decrease in the ammonia will lead to increase in the nitrate level in the water body.

Linear regression and single parameters prediction relationship did not yield a dependable determination as R^2 values were relatively low (Table 3) compared to multiple regression among the parameters with fairly reliable R^2 values (Table 4). Predicting dissolved oxygen with temperature values alone gave D.O. = -0.911T + 32.54 with a coefficient of determination (R^2) of 0.373.The combined use of temperature and pH readings to predict dissolved oxygen gives the equation D.O=21.12+1.08pH -0.87 T with a coefficient of determination (R^2) value of 0.67.

CONCLUSION

Findings of this study show that no single water quality parameter can be considered as important with respect to fish growth and health. There exist strong interrelationships among the selected water quality parameters. Temperature and pH readings could be used to predict dissolved oxygen, ammonia and nitrate concentration. This could serve as preemptive purposes and should not be considered as a replacement of the standard analytical methods.

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