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ENGINEERING STUDY ON AERATION SYSTEM SUITABLE FOR FISH FARMS

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ABSTRACT

This research was carried out in the research fish farm – Faculty of agriculture – Mansoura University during season 2011 in order to study the effect of controlling the water temperature and the quantity of pumping air on tilapia fish growing dissolved oxygen quantity and power consumption in fish farm to reach the study goal the tilapia fish were cultured in two cement ponds (experimental and the traditional pond). The cement experimental pond was built as a cuboid-shaped with dimensions of 1500 × 1000 × 1800 mm length, width and height respectively. The pond has been equipped with Adding air compressing unit provided with perforated pipe, heating unit and water supply source. On the other hand the traditional pond with cylindrical shape has diameter of 1500 mm and height of 800 mm. Air was added with a hose in the traditional pond at the center of the pond bottom. The aeration system was evaluated in the two ponds by measuring the dissolved oxygen concentration, determine the uniformity of the dissolved oxygen, calculate the air quantity and measure the fish growing rate. From the prior results it can be concluded that the fish pond aerator using the perforated pipe is suitable for the tilapia fish at perforated pipe depth of 1200 mm, distance between holes of 150 mm and air pressure of 0.2 bar which obtain the suitable dissolved oxygen uniformity (the difference between the maximum and the minimum dissolved oxygen value) of 1.5 mgl^{-1}, with average of 6.92 mgl^{-1}, the highest growth rate in the experimental pond was higher than the traditional system about 60.74 % and keep the dissolved oxygen higher than the low limit to fish good life about 1.92 mgl^{-1}. This experimental pond conditions with the perforated pipe may give a chance to more perfect diffusion for fish along the all pond size.

INTRODUCTION

Fish is one of the most important sources of protein food. This is characterized by many health benefits that make it first major food for people eat. Fish is also characterized by the short life cycle to reach commercial size and weight. Because fish production in Egypt resulting from lakes and sources of fresh water, which is estimated at about 387 thousand tons (Central Agency for Public Mobilization and Statistics, 2011) does not meet domestic consumption, which leads to import about 220 thousand tons/year . So tended to encourage state aquaculture, producing about 668 thousand tons/year (Central Agency for Public Mobilization and Statistics, 2011). The good environmental conditions for fish mean high production quantity. Hence, many researches considered to determine the imperative environmental element for fish life and its required and applied it (Tsadik and Kutty, 1987; Blom *et al.*, 1993 and Lyon *et al.*, 1993). The most vital elements are water temperature, dissolved oxygen and ammonia concentration, beside that a good fodder (Lyon *et al.*, 1993). Diana (1995) indicated that oxygen consumption by fish and DO requirement increase with temperature and food consumption. Therefore, fish need oxygen for aerobic generation of energy for body maintenance locomotion feeding and biosynthesis. Brungs (1971) concluded that concerned the provision of the appropriate ratio of dissolved oxygen to the tilapia fish growth and which should not be less than 3 mg/L. Itazawa (1971) recommended that the minimum level of (DO) for maintaining maximum feeding, growth and efficiency of food conversion is 4-4.5 mg/l for rainbow trout (*salmo gairdneri*) at 10.5 ˚C. Taparhudee (2002) mentioned that high rates of aeration can not only cause excessive water currents and erode pond bottom badly but also increase power cost. At compared the performance of paddle wheel aerators and diffused-air systems with a polyethylene pipe. He found that using the diffused-air system network proved to be most effective and convenient. This aeration system provided suitable dissolved oxygen concentrations to the water body and the pond bottom, which could stimulate decomposition at the pond bottom. In addition, this system had low operating costs. It is suitable to be applied in low water exchange culture systems and it can also reduce problems of pond bottom erosion, a typical problem, when using large numbers of paddlewheels. Khouraiba (1997) reported that tilapias are constantly gaining importance in aquaculture, especially in the tropics and subtropics. In Egypt, tilapias constitute approximately 45% of inland water fishery production.

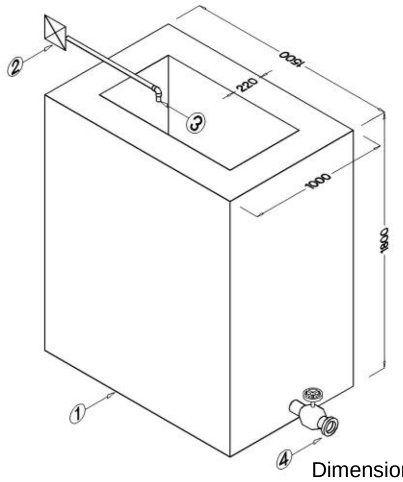
The aim of this study is evaluate the experimental system for pumping air in aquaculture under constant water temperature (25 °C), (Balarin and Haller, 1982 and Chervinski, 1982), and comparing this system with traditional pond.

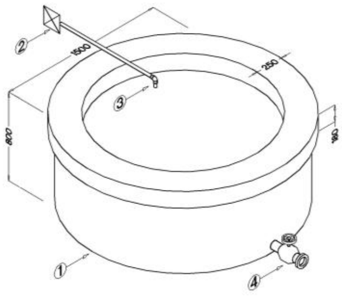
MATERIALS AND METHODS

The experiments were carried out in the research fish farm – Faculty of agriculture – Mansoura University during season of 2011. In order to reach the study goal the tilapia fish were reared in two cement ponds (experimental and traditional pond). The cement experimental pond (Fig. 1) was built as a cuboid-shaped with dimensions of 1500 × 1000 × 1800 mm length, width and height respectively. The pond has been equipped with:

1 - Air compressing unit; which consists of: air pump – air hose - stopcock - pressure gauge - perforated pipe - timer.
2 - Heating unit consists of: Control board (thermostat, contactor and automatic keys) - electric heaters - electric cable to adjust the water temperature at 25 °C.
3 - Source of water.
4 - Pipe to discharge water.

On the other hands, the traditional pond (Fig. 2) with cylindrical shape has diameter of 1500 mm and height of 800 mm. The traditional pond without water temperature controlled and air supply through rubber hose at the center of its bottom.





Dimensions in mm

Fig. 1: Scheme of experimental fish pond isometric.
1- Fish pond walls 2- Water source
3- Stopcock 4- Water outlet

Fig. 2: Scheme of traditional fish pond isometric.
1- Fish pond walls 2- Water source
3- Stopcock 4- Water outlet

The experimental procedure:

Primary experiments were carried out in the experimental pond to determine the level of air pressure, distance between holes and perforated pipe depth which gained the best air quantity. These experiments consist of the following studied variables:

- Perforated pipe depth 900, 1200, 1500 and 1800 mm from the water surface in the upper end of the pond.
- Distance between holes 150, 200 and 250 mm.
- Air pressure 0.1, 0.2 and 0.3 bar.

In this experimental group the experiments were done in the two ponds, the first one was the conditioned pond after choosing the optimum factors from the first experimental group, which gained the enough dissolved oxygen with the least electric power consumption attended to pumping air in pond water, these experimental factors can be summarized as follows:

1-Water pond temperature was 25 °C in all experiments under study.
2-The optimum distance between holes of perforated pipe was 150 mm, these holes have a circular shape with 4mm diameter.
3-The optimum perforated pipe depth from upper surface was 1200 mm.
4-The optimum pumped air pressure was 0.2 bar.

While the second one was the traditional pond cleared in (Fig. 2). The temperature in this pond was not under control.

The main experimental tests:

It was carried out using both ponds were reared with tilapia fingerlings fish at the same fish density (20 fry/m^3) and fed with the same food 25% protein by rate of 5% from fish mass per day. The fish food divided into two meals, the first one in the morning while the second was added in the afternoon. The rate of changing water was 20% daily for both ponds.

Experimental measurements:-

There are four measurements in the main experimental group were done as follows:-

1- Measuring the dissolved oxygen concentration within the ponds at depths of 0 - 900 - 1800 mm for cement pond and 0 - 700 mm for the traditional pond once a week using the dissolved oxygen meter.

2- Determine the uniformity of the dissolved oxygen distribution.

3- Calculate the air quantity according to (Wasef, 1994) using the common following formula:

$$q = \frac{\pi \times R^4 \times P}{8 \times \eta \times l}$$

Where: q : air flow for one hole, (m^3/sec)

π : constant, (3.143)

R: Radius of hole, (2×10^{-3} m)

P: Air pressure, (0.2×10^5 N/m^2)

η: Air viscosity factor, (19×10^{-6} N.s/m^2)

l : Path length, (m)

4- Measuring the fish growing rate by weighing samples of fish (7 fishes) in both ponds every 14 days using the digital balance has ±0.01 accuracy.

The all measuring were replicates three times and the statistical analysis as a simple regression coefficient to present the effect of adding air on the dissolved oxygen uniformity and the fish growing rate.

RESULTS AND DISCUSSION

1- Dissolved oxygen concentration

Fig. (3) shows the dissolved oxygen values (mgl^{-1}) over the experiment from 15/10/2011 to 03/12/2011 for the experimental and the traditional ponds. From Fig. (3) it can be seen that the behavior of dissolved oxygen concentration recorded decrease in both of the experimental and the traditional ponds. It can be observed from Fig. (3), declines the dissolved oxygen concentration over the experiment from 15/10/2011 to 03/12/2011, where recorded 5.563, 5.470, 5.400, 5.252, 5.159, 5.067, 4.959 and 4.796 mgl^{-1} obtained from 15/10/2011 to 03/12/2011 once a week respectively for the experimental pond. The trend was the same for the traditional pond where recorded slightly decreasing 4.675, 4.600, 4.575, 4.500, 4.475, 4.450, 4.425 and 4.400 mgl^{-1} respectively obtained for the same period.

Generally, the trend of above results is that decreasing the dissolved oxygen over the experiment for the two ponds, this trend may attribute to fish growth which consequent more oxygen consumption especially for the experimental pond which recorded more regression in decreasing of dissolved oxygen.

2- Dissolved Oxygen Uniformity

Figures from (4 to 11) show the dissolved oxygen uniformity in the experimental pond at different latitude and longitude pond sides at three depths.

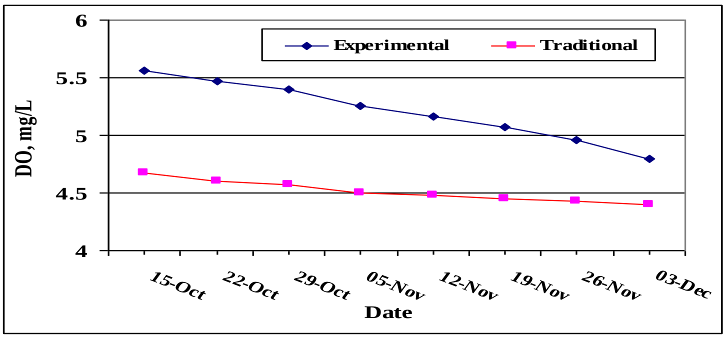


Fig. 3: The mean values of dissolved oxygen concentration in the experimental and traditional ponds every week over the experiment.

Each depth act as a contour curves to clear the dissolved oxygen uniformity. The figures illustrate that the dissolved oxygen uniformity via the optimum treatments concluded from the first experimental group at measured points for air pressure of 0.2 bar, distance between holes of 150 mm and pipe depth of 1200 mm. Therefore, Fig. (4) shows that the dissolved oxygen in the experimental pond uniformity which slightly varied from bottom to top of the pond. The figure shows no difference in uniformity for the three layers where the change in dissolved oxygen value for each layer was 0.2 mgl^{-1}. While the variation in dissolved oxygen value between the three layers fluctuated from 0.2 to 0.3 mgl^{-1} for figures from (5, 6, 7, 10 and 11) and changed from 0.2 to 0.4 and 0.1 to 0.3 for the figures (8 and 9) respectively. At the all measured layers the differences between the maximum and the minimum dissolved oxygen values were 1.6, 1.6, 1.5, 1.4, 1.4, 1.3, 1.2 and 1.1 mgl^{-1} for the figures from (4 to 11) respectively.

From figure (4) it can be seen that the data at contour curve of zero layer were ranging from 6.2 to 6.4 mgl^{-1} but at layer depth of 900 mm it were less which it ranging from 5.4 to 5.6 mgl^{-1} and at layer depth of 1800 mm it were the lowest value as it ranging from 4.8 to 5.0 mgl^{-1}. The same trend found in Figs. From (5 to 11) which show that the data at contour curve of zero layer were ranging from 6.1 to 6.3, 5.9 to 6.2, 5.7 to 6.0, 5.5 to 5.9, 5.5 to 5.8, 5.3 to 5.6 and 5.1 to 5.4 mgl^{-1} respectively. While at layer of 900 mm depth it ranging from 5.2 to 5.5, 5.2 to 5.5, 5.1 to 5.4, 5.0 to 5.3, 4.9 to 5.2, 4.8 to 5.1 and 4.7 to 4.9 mgl^{-1} respectively for Figs. From (5 to 11). Therefore at layer of 1800 mm it was ranging from 4.7 to 4.9, 4.7 to 4.9, 4.6 to 4.8, 4.5 to 4.7, 4.5 to 4.6, 4.4 to 4.6 and 4.3 to 4.5 mgl^{-1} respectively.

Generally, at the all measurement points and layers and at the maximum fish growing period the dissolved oxygen in the experimental pond is enough to the tilapia fish physiological process higher than (3.0 $mg.l^{-1}$) "Brungs (1971)".

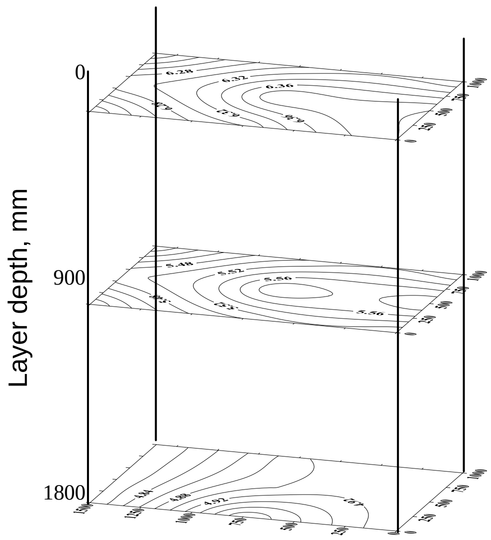


Fig. 4: The dissolved oxygen uniformity via the measured point in 15/10/2011.

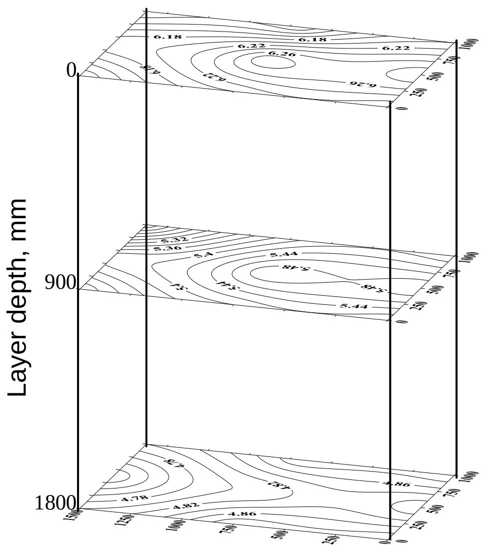


Fig. 5: The dissolved oxygen uniformity via the measured point in 22/10/2011.

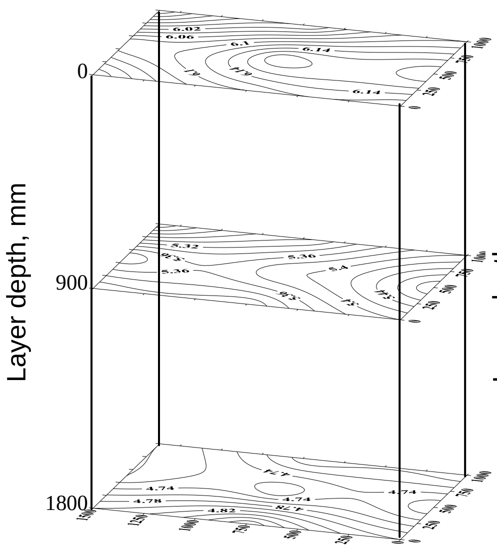


Fig. 6: The dissolved oxygen uniformity via the measured point in 9/10/2011.

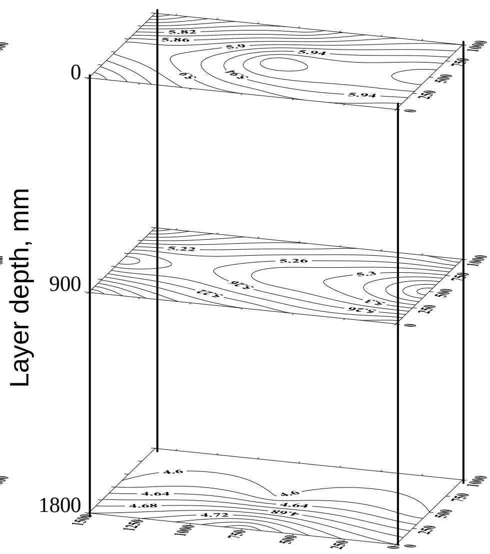


Fig. 7: The dissolved oxygen uniformity via the measured point in 05/11/2011

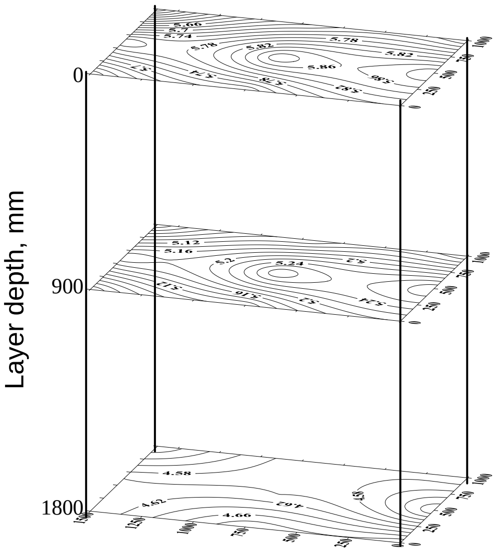


Fig. 8: The dissolved oxygen uniformity via the measured point in 12/11/2011.

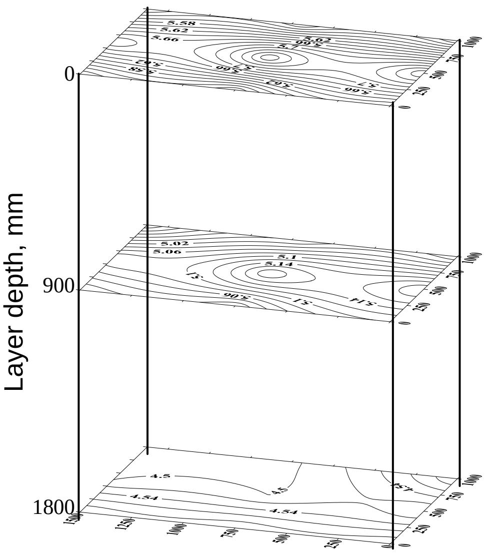


Fig. 9: The dissolved oxygen uniformity via the measured point in 19/11/2011.

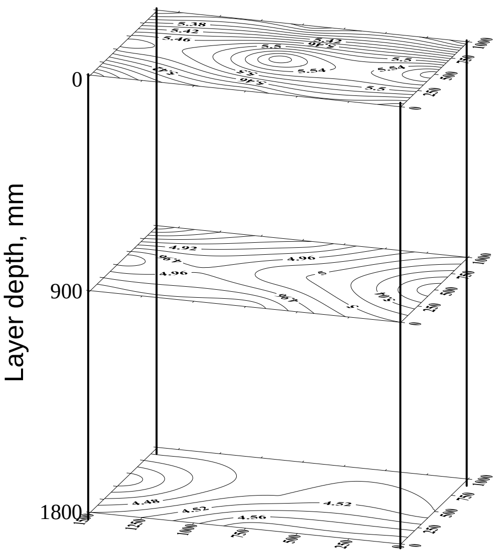


Fig. 10: The dissolved oxygen uniformity via the measured point in 26/11/2011.

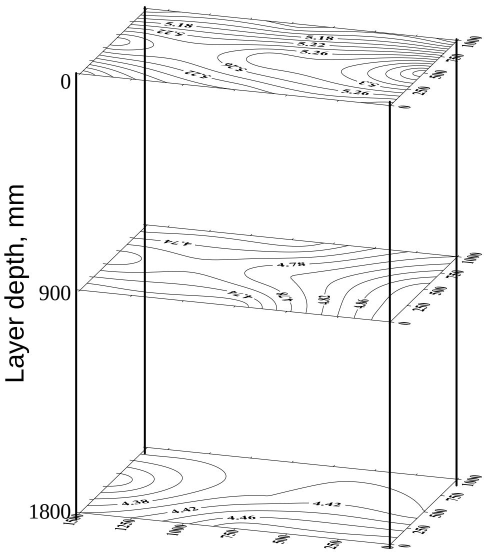


Fig. 11: The dissolved oxygen uniformity via the measured point in 03/12/2011.

The simple regression analysis shows that the best fit equation to explain the correlation between the dissolved oxygen (DO) and the time period after frys rearing indicated as follows:-

$$DO_E = 5.6906 - 0.01533\ T \qquad R^2 = 0.9924$$

$$DO_T = 4.683929 - 0.0544\ T \qquad R^2 = 0.9561$$

Where: DO_E: Dissolved oxygen in experimental pond, (mgl^{-1})

DO_T: Dissolved oxygen in traditional pond, (mgl^{-1})

T : Time period after rearing of frys, (day)

The regression equation clear that the dissolved oxygen has an inversely proportion to the time after rearing.3- Air quantity

Fig. (12) cleared that the air quantity in the comparing ponds. The experimental pond has about 0.022 m^3s^{-1} while the traditional pond has about 0.000797 m^3s^{-1}. From the figure it can be seen that the air quantity in the traditional pond decrease about 0.021203 m^3s^{-1} from the experimental pond.

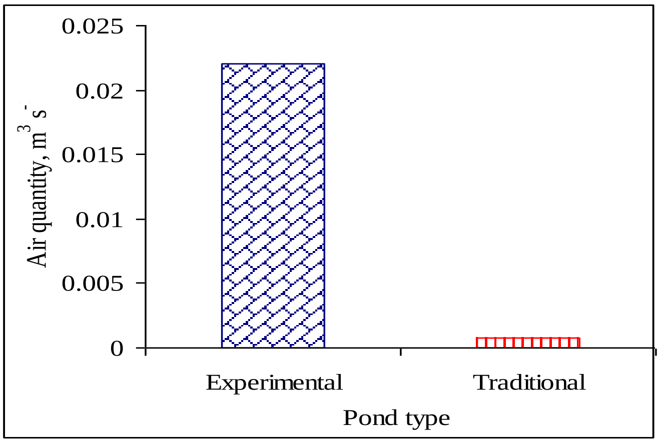


Fig. 12: Air quantities in both ponds under study.

4- Growing Rate

Fig. (13) shows the fish growth rate (g) every 14 days from the planting fish in pond from "9/10/2011" to 04/12/2011 for the experimental and the traditional ponds. The fish growth rate recorded 17.00, 24.90, 30.90, 35.87 and 50.60 g obtained from 09/10/2011 to 04/12/2011 every two weeks respectively for the experimental pond. The same trend was observed with the traditional pond where recorded 17.00, 24.52, 27.95, 30.19 and 31.48 g respectively at the same dates.

Commonly, the trend of above results is that increasing the fish growth rate over the experiment for the two ponds. It was observed that the fish in the experimental pond was higher in growth rate than the fish in the traditional pond about 1.55% in 9/10/2011 to 60.74% in 4/12/2012; this trend may be due to the high uniformity of distribution of the dissolved oxygen all over the pond measuring points as well as the conditioning of the experimental pond especially with temperature stabilization and uniformity of water supply and water exchange. These results may be due to the food conversion depended on oxygen concentration about 5-8 mg/l it's required for normal activities fish (Boulanger, 1983).

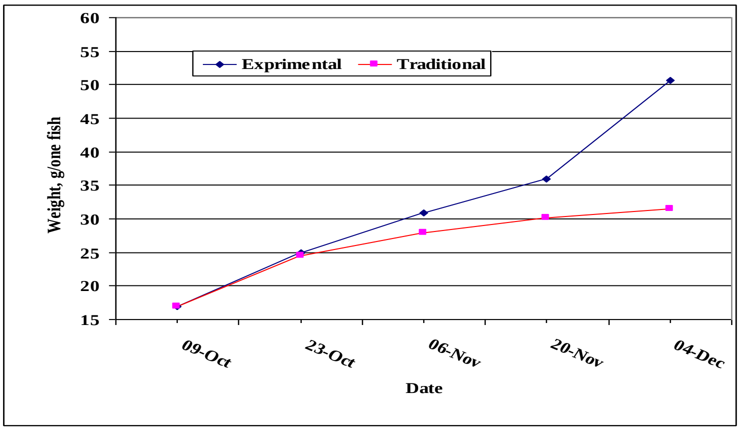


Fig. 13: Tilapia fish growing rate in both ponds.

The simple regression analysis shows that the best fit equation to explain the correlation between the fish growing rate and the time period after frys rearing indicated as follows:-

$$G_E = 16.22 + 0.558357\ T \qquad R^2 = 0.9586$$

$$G_T = 19.32 + 0.247357\ T \qquad R^2 = 0.8928$$

Where: GR_E: Fish growing rate in experimental pond, (g/day)

GR_T: Fish growing rate in traditional pond, (g/day)

T : Time period after rearing of frys, (day)

The regression equation clear that the fish growing rate has a directly proportional to the time period after rearing.

CONCLUSIONS

The fish pond aerator using the perforated pipe is suitable for the tilapia fish at perforated pipe depth of 1200 mm, distance between holes of 150 mm and air pressure of 0.2 bar to obtain the suitable dissolved oxygen uniformity of 1.5 mgl^{-1}, average air value of 6.92 mgl^{-1}, the highest growth higher than the traditional system increased about 60.74 % and keep the dissolved oxygen higher than the low limit to fish good life about 1.92 mgl^{-1}.

This experimental pond conditions with the perforated pipe may give a chance to more diffusion for fish along the all pond size. That means the possibility of coexistence of the tilapia fish dissident of the favorite's layer levels for tilapia between depths of 1000 to 1500 mm under the water surface if the optimum pond conditioning is available.

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دراسة هندسية على نظام تهوية مناسب لمزارع الأسماك

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يهدف البحث إلى تسليط الضوء على مقارنة سلوك الأكسجين الذائب فى حوضى سمك أحدهما تجريبي والآخر تقليدى عند أزمنة مختلفة لنمو السمك البلطى. ومن خلال الدراسة تم بناء حوض أسمنتي على شكل متوازي مستطيلات بأبعاد 1500 × 1000 × 1800 مم بمزرعة الأسماك البحثية التابعة لقسم الإنتاج الحيوانى بكلية الزراعة - جامعة المنصورة وقد تم تجهيز الحوض بوحدة إضافة الهواء بنظام الأنابيب المثقبة مع دفع الهواء داخلها ، وحدة تدفئة، ماسورة لصرف المياه، مصدر لإضافة المياه. تم إجراء مجموعة من التجارب المبدئية حيث تم ضخ الأكسجين إلى الحوض تحت الدراسة عند المتغيرات الآتية:

1- عمق الأنبوب المثقب من سطح الحوض 900 – 1200 – 1500 – 1800 مم

2- المسافة بين الثقوب على الأنبوب 150 – 200 – 250 مم

3- ضخ الهواء بضغوط 0.1 – 0.2 – 0.3 بار

وعن طريقها تم تحديد أفضل العوامل التي تعطي أحسن نتائج لكمية وتوزيع الأكسجين الذائب في الماء وأيضاً مع أخذ استهلاك القدرة اللازمة لضخ الهواء في الاعتبار ، وقد تم تحديد مستويات عوامل الدراسة المثالية التالية لتكون ثوابت في المجموعة الثانية من التجارب (ضغط الهواء 0.2 بار، المسافة بين الثقوب 150 مم، عمق الأنبوب المثقب 1200مم)، أما الحوض التقليدى الموجود بذات المزرعة والمخصص لتربية الأسماك فهو إسطوانى الشكل ذو قطر 1500 مم وإرتفاع 800 مم ونظام إضافة الأكسجين يتم بواسطة خرطوم فى منتصف قاع الحوض. وتمت المقارنة بين الحوضين عن طريق أخذ عدة قياسات:

1- قياس كمية الأكسجين المذاب داخل الحوضين على أعماق 0 – 900 – 1800 مم للحوض التجريبي و 0 – 700 مم للحوض التقليدي مره كل أسبوع.
2- تحديد درجة تجانس توزيع الأكسجين الذائب.
3- حساب كمية الأكسجين المضافى لكل حوض.
4- وزن عينات من السمك (7 سمكات) فى كلا الحوضين مره كل 14 يوم.

وقد أظهرت النتائج أن:

نظام التهوية بالأنابيب المثقبة مناسب لتربية السمك البلطي للحصول على أعلى معدل نمو للسمك مقارنة بالحوض التقليدي بزيادة حوالي 60.74 %، وقد لوحظ أيضاً أن كمية الأكسجين الذائب عند أقل انخفاض لها كانت أعلى من أدنى مستوى موصى به للإبقاء على العمليات الحيوية للأسماك بحوالي 1.92 مجم/لتر أيضا يتضح من النتائج إنتظام توزيع الأكسجين داخل الحوض المختبر بدرجة كبيرة.

وعليه فإن استخدام الحوض التجريبي بإضافة الأكسجين بالأنابيب المثقبة يعطى الفرصة لانتشار أكبر للأسماك خلال الحوض كله على المستويين الرأسي والأفقي نظراً لتوفر الأكسجين الذائب بمستوى جيد. وهذا يعني إمكانية تواجد أسماك البلطي على مستويات أعلى وأقل عن ما يفضله البلطي بين عمقي من 1000 إلى 1500 مم إذا ما توفر الأكسجين بدرجة مناسبة.

قام بتحكيم البحث

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