

AERATION REQUIREMENTS IN BIO FLOC BASED SHRIMP CULTURE SYSTEMS

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Adequate dissolved oxygen is a very important parameter for successful intensive aquaculture as it affects the quality and quantity of growth. Artificial aeration is provided to increase the oxygen concentration and also to remove the anoxic gases such as nitrogen and carbon dioxide. The higher crop biomass and feeding rates of intensive shrimp culture systems require supplemental aeration to maintain adequate dissolved oxygen levels (above 4 ppm). Farmers adopting high-density culture are in constant fear of low DO instances and tend to use more aeration as there is no available information on optimum aeration requirement at different stages of culture and different stocking density. Too little aeration leads to a hypoxic condition in ponds resulting in mass mortalities and more aeration results in excessive operating expenses and wastage of energy. Shrimp die when DO concentrations fall below 1mg/L for more than few hours and also if DO level goes below 4 mg/L for several hours, it will create severe stress on animals. Less than the optimum levels of DO can lead to poor water quality, feed conversion ratios (FCR), reduced growth or survival.

Aeration requirements for different density systems

Extensive /traditional systems do not need any artificial aeration as the DO in the pond or waterbody is sufficient to meet the animal requirement. When the stocking density goes high, the bottom layer of the pond water becomes hypoxic or anoxic especially at night hours due to higher respiration rate and decomposition of accumulated organic matter

Aeration is the mechanism to maintain the aquatic animal free from oxygen deficiency stress and helps to maintain water circulation. It is the mass transfer phenomena between air and water, of which the variation of the oxygen concentration in the water as a function of time. Hypoxia or low DO (less than 2.8 mg/L) can certainly threaten shrimp life. DO values higher than 5 mg/L have been recommended in intensive culture practices. It has been reported that the lethal DO levels ranged from 0.2 to 1.27 mg/L for several penaeid shrimps.

In high-density biofloc based farming, intensive turbulent mixing is very much essential for biofloc systems as solids must be suspended in the water column at all times to make the system function. Important requirement in the bio-floc system is to meet high oxygen demand. Typical aeration requirements are 1 HP/300-350 kg shrimp biomass. The bio-floc system requires high aeration/mixing with aerators, and blowers not only to provide DO and remove CO₂ (70-90ppm) but also to keep bio-floc in suspension and prevent the production of nitrogenous metabolites,

sulfides and organic acids. Also, direct an aspirator type aerator at the sludge pile to re-suspend it. Optimum uninterrupted aeration is essential to maintain high DO whereas less turbulence will lead to the production of hydrogen sulfide, methane, and ammonia and more turbulence will make it difficult for shrimp to locate feed or can lead to pond dike aeration. Water respiration in indoor biofloc systems is normally about 6 mg O₂/L per hour. It is believed that aeration requirement of 1 HP of every 200-250 kg of biomass.

Aeration methods

There are three categories of aeration methods, viz., surface or mechanical aeration, diffused aeration, and combined or turbine aeration method. Mechanical aerators such as paddle wheels, vertical pumps, pump sprayers, propeller aspirator pumps, and diffuser air systems are widely used because of better efficiency and convenience of operation. Stationary paddlewheel aerators are commonly placed parallel to the dikes of the pond, creating a radial or elliptical water flow regime with rapid water flow in the periphery and stagnant conditions in the center.

Estimation of aeration requirements

Estimating supplemental aeration needs to be done considering the biomass and the feeding rate. Early attempts in *L.vannamei* ponds were based on "Taiwanese rule of thumb" for intensive *P.monodon* culture. This indicates that one horsepower of aeration per 650 kg of anticipated harvest biomass. There is a real danger in basing the aeration rates on anticipated harvest mass. If higher than the normal feed rates for given projected biomass is used, critically low oxygen levels can be experienced.

Aeration requirements depend on the stocking density, feeding rate, and early morning dissolved oxygen in shrimp ponds, and it is related as:

$$F/A = 28.83 - (4.31 \times DO)$$

where F = 5-day average feeding rate (kg/ha/day); A = aeration rate (hp x day/ha); DO = dawn DO concentration (mg/L). These relationships will facilitate economic optimization based on capital equipment expenses for electricity, seed, and feed. Supplemental aeration may be needed in shrimp ponds at feed rates above 40-50 kg/ha. day. *L.vannamei* shrimp is cultured under intensive culture, and it is column dwelling species, so the oxygen has to be distributed throughout the pond.

Aerators use in shrimp farms

Aeration with better oxygen transfer rate is very much essential to reduce the production cost and maintain the good shrimp culture. The placement of aerators in the pond assumes greater importance given the need to maintain proper water circulation for maintaining feed and biofloc in

suspension and also concentrate the waste in one place. While feed accounts for nearly 50-60% of the total recurring cost, the electricity and diesel charge nearly take away 25 to 30% of the recurring cost. The electrical power supply has become very erratic and costly. Diesel engines are commonly used to run aerators that further add input cost.

Different types of paddle wheel aerators with custom made the design are widely used in shrimp ponds with different length, capacity, No. of blades, source of power, and placement. In some places, small farmers have changed the paddle wheel aerators to custom made one and operated using the diesel engine due to non-availability of electricity. The efficiency and energy consumed per kg of production using different types of aerators are either not known or not evaluated to optimize the best design to produce maximum oxygen transfer rate with less energy. Few other types of aerators such as injector types, diffuser types are also being tried by a few farmers. Monitoring the efficiency of the aerators in farmer's ponds will pave the way for optimum design criteria that can deliver maximum oxygen transfer rate with less energy in another way with a reduction in operation cost.

Oxygen demand and aeration requirement increase with culture period, but there is no system adopted by the farmers to gradually increase the aeration hours. Operation costs demand the correct calculations to optimize the type of management used and the region of culture. Estimation of aeration requirement for each week of culture can bring substantial savings with electricity and consequently production costs. The study from CIBA indicated that energy used per kg of shrimp production varied widely and too little or much aeration is given in many ponds as no information on exact aeration requirement is available for different stocking densities of different species and pond conditions. In the shrimp farms, the hours of operation of aerators vary from farms, and there is no standard procedure or mechanism adopted based on the biomass.

Different aerators in shrimp ponds

Paddlewheel aerators: Semi-intensive / intensive ponds are commonly aerated by placing the paddle wheel aerators parallel to the pond dikes, creating a radial or elliptical water flow regime with rapid water flow in the periphery and stagnant conditions in the center. Water is pumped into the air by pushing into the air with the standard water transfer efficiency of 1.7 kg and consumes the energy of 1HP /hr for 2PW aeration. Normally 1hp aeration is given for 300 to 400 kg of biomass. The aeration requirement is more when the level of water exchange is reduced, which has become common as a means to reduce the probability of pathogen transfer. Normally 2, 4 or 6 wheel aerators are used. Paddlewheel, long arm and spiral were three kinds of aerators found adopted by the farmers. In some places, small farmers have changed the paddle wheel aerators to custom made one and operated using the diesel engine due to non-availability of electricity.



Custom made 7 wheel and 6 wheel PWA with diesel engine and modified car engine



Aero tubes



Round flow pond aerator

Fig. 1 Types of aerators

Different types of two, four, seven, eight wheels operated with 3 phase electric motor or customized car engines (Diesel) were used in the farms. Motors for paddle wheel aerators usually turn at 1750 rpm, but this speed is reduced so that the paddle wheel rotates at 70–120 rpm. There is considerable variation in the design of the paddle wheel and in the mechanism for reducing the speed of the motor output shaft. Many studies indicated the variation in aerator efficiency at varying salinities.

Water circulation may cause soil erosion in intensive shrimp ponds unless banks are protected. Aeration of marine shrimp ponds should be arranged in such a way as to sweep the feed area of the pond. Each 1 kW of aeration will support an additional 500 kg shrimp production, beyond a base of 2000 kg/ha that may survive by natural re-aeration. Square ponds are easier to manage because four paddlewheels can be arranged to wash out the corners.

Round flow pond aerator

This type of aeration devices can be used to increase oxygen levels during feeding. The oxygen transfer efficiency was measured as 3 kg oxygen transfer the available capacity ranged from 0.5 to 5 HP.

Injector type submersible aerator



Fig.2 Injector type aerator

This injectors are one of the best and most advanced aeration systems worldwide, and also suitable for large ponds. They work with a for an endurance run produced, maintenance free, adjustable, submerged (also seawater resistant), the motor in different power sizes (1.1-1.5 kW (1.5-2.0 HP) 230 or 380 V/50 Hz). The rotating propeller (2800 r.p.m.) produces an adjustable current, through which air is drawn from the surface and formed into fine evenly distributed bubbles. The diffused air aerate from the bottom up, and the circulation created from the fine bubbles displace the surrounding water, thus breaking up stratified water areas. This constant surge forces the pond to turn over, bringing cooler bottom water to the surface, where it picks up additional oxygen from the atmosphere. Therefore the dissolved oxygen is always as high as possible. Depending on power and depth, the air flow rate is up to 35 m³/hour and the oxygen introduction up to 3 kg/kw/h/. At an oxygen content of 6 mg O₂/L at the beginning, one 1.0 HP unit in use with air, introduce over 0.32 kg O₂/h which is the oxygen demand for over 2600 kg (table sized 250 g) trouts at a water temperature of 10 °C, for approx. 1000 kg at 20 °C or up to 3000 kg of other species

Spiral aerator

The stackable type is also developed by assembling HDPE floats discretionally, and the metal frame is avoided. It can be assembled according to local voltage and frequency. In aero tubes type, the air is pushed into the water, and less power is consumed while operation. The standard oxygen transfer efficiency is 3.7 kg. It is recommended to use with paddlewheel aerators.



Fig. 3 Spike aerator in shrimp farms

The initial investment cost is more compared to PW aerators. This method gives supplemental aeration in addition to PW aeration and currently being adopted in some shrimp farms and getting popular. However, further validation of the data from different farms is needed to be done to arrive at the exact energy saving from this method.

Blower and air tubes for biofloc



Blower and air tubes are used for aerating chambers in the biofloc system and also the ponds. Compared to the other systems it is proved to be more economical. For e.g. 3HP blower can support 6 grids, for biofloc nursery. Bio floc shrimp culture systems are gaining importance for cost-effective production where water is limited, or land is expensive. Aeration requirement in bio floc based systems was analyzed based on the primary data collected from the biofloc based shrimp culture ponds at Tamil Nadu and Andhra Pradesh. Air diffuser systems operated using air blowers have been widely used in bio floc systems, whereas different types of surface aerators are used in earthen ponds. Findings revealed that the aeration requirements in the biofloc system vary from 6.2-12 HP/m³ volume of water. Considering the high density per m³ of water, blower system is very economical per kg of shrimp production.

Economic analysis

Fixed cost includes the initial investment cost, depreciation cost, maintenance cost, and bank interest mainly for pond preparation and infrastructure development. Life of aerators can be taken like five years. Variable cost comprises seed, feed, energy, labor, and other consumables. Net profit

or loss was arrived based on the difference between the total return and total cost per crop.

$$\text{ROI} = (\text{Net Profit} / \text{Cost of Investment}) \times 100.$$

ROI, NPV, and IRR were calculated from the functions available in Microsoft Excel. NPV and IRR values of shrimp culture using different aerators can indicate the variation in profit at different salinities. NPV should be calculated based on the difference between the present value of cash inflows and cash outflows over a period and indicated the profitability of aquaculture using different aerators. IRR will help us to calculate the variation in profitability among different aerators.

In summary, high-density culture systems like biofloc require efficient aeration mechanisms for which standard aeration efficiency of the aerators at different environmental conditions should be made available. Correct calculation of aeration requirement and energy use can give substantial savings in the production cost.

