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-An International Journal of Agriculture

Popular Article

ADVANCED FARMING SYSTEMS IN AQUACULTURE: STRATEGIES TO ENHANCE THE PRODUCTION

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KEY WORDS:

Fish farming, Water quality, Water recirculation, Ecological aquaculture

ARTICLE INFO:

Received on:
02.02.17
Revised on:
18.03.17
Accepted on:
19.03.17

ABSTRACT

Aquaculture is one of the most emerging sectors growing like industries, providing an ultimate livelihood option to a millions of peoples of India. The current aquaculture production is not able to meet the growing demand for fish due to intensification of human population. Aquaculture must have to move towards intensification to meet the rising demand, to contribute more effectively to the reduction of poverty and malnutrition, and to become ecologically more sustainable. New technologies will make it possible for sustainable aquaculture to become the new global standard. In order to improve the socio-economic condition of the farmers, this expansion of aquaculture production needs to take place in a sustainable way through the applications of new farming interventions *viz.* integrated farming, Aquaponics, Recirculatory aquaculture system (RAS), Neo-female Technology, Biofloc technology (BFT), Compensatory growth Technology etc.

Introduction

The world's appetite for fish is steadily growing. The aquaculture industry has greatly improved performance over the past 20 years, producing more farmed fish per unit of land and water, lowering the share of fishmeal and fish oil in many aquaculture feeds. However, doubling aquaculture production without further increasing the industry's efficiency could lead to a doubling of environmental impacts. Unless the aquaculture industry is able to boost productivity, the limited availability of land, water, and feed may constrain its growth. The present aquaculture systems faces many challenges, mainly, water-quality management, harmful diseases and epizootics, development of appropriate feeds and feeding practices, hatchery as well as grow-out technologies. These all provides considerable scope for the development of new aquaculture systems or technologies to face these challenges. It has wide range of approaches that can improve subsistence and commercial aquaculture production and management. Some of the new development in aquaculture systems for enhancing the aquaculture productions are discussed in the paper viz. integrated farming, aquaponics, recirculatory aquaculture system (RAS), neo-female technology, biofloc technology (BFT), Compensatory growth Technology, etc.

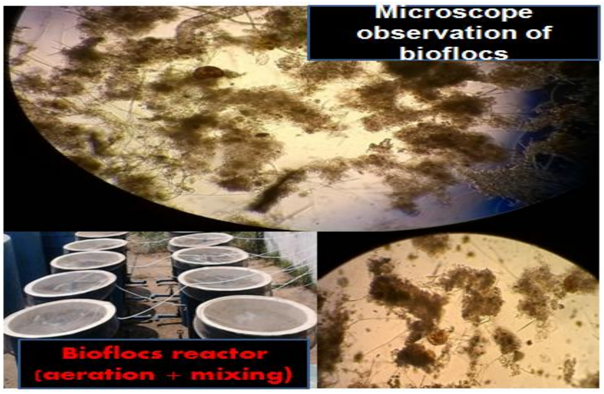

Fig. 1. Observation of bioflocs under Microscope

Biofloc technology (BFT)

Biofloc technology is a technique of enhancing water quality in aquaculture through balancing carbon and nitrogen in the system (Crab *et al.,* 2012). It is the retention of waste and its conversion to biofloc as a natural food within the culture system (Avnimelech, 2009). Bioflocs are the aggregates (flocs) of algae, bacteria, protozoans, and other kinds of particulate organic matter such as faeces and uneaten feed. Each floc is held together in a loose matrix of mucus that is secreted by bacteria.

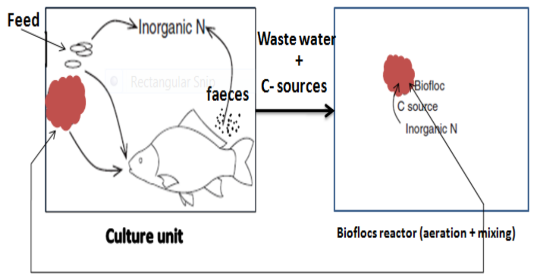

Fig. 2. Flow diagram of Bioflocs based aquaculture

In this system, the addition of carbohydrates to the pond, heterotrophic bacterial growth is stimulated and nitrogen uptake through the production of microbial proteins takes place (Avnimelech, 2009). If carbon and nitrogen are well balanced in the solution, ammonium with organic nitrogenous waste excreted from fish will be converted by the bacterial biomass.

This system requires the addition of extra carbon to the aquaculture system, through an external carbon source or elevated carbon content of the feed. This system promoted nitrogen uptake or Immobilization of ammonium by heterotrophic bacterial growth decreases the ammonium concentration more rapidly than nitrification. Thus, the BFT provides a new farming approach to increase the food production in a sustainable ways.

Advantages

- Bioflocs as a feed for aquaculture species.
- Bioflocs as a bio-control measure.
- Maintaining water quality by reducing toxic ammonia.
- Minimum or zero water exchange.
- Reducing feed conversion ratio and a decrease of feed costs.
- Nutrients could be continuously recycled and reused.
- Control pathogens in aquaculture.

Recirculation aquaculture system (RAS) technology

Recirculation aquaculture system (RAS) technology is the land-based closed systems in which aquatic organisms are cultured through the minimal use of water which is serially reconditioned. This land-based closed-containment system improves food security and reduces environmental impacts. RAS is consists of a series treatment processes removes organic and other oxygen demanding materials such as suspended solids, nutrients, fats, oil and pathogens from the waste water so that the water can be safely reused. The larger solid suspended solids, debris and floating materials (wood, paper rags and plastics) are removed by passing the waste through Mechanical filers *viz.* settlement tanks, sand filter, drum filter, screen filter, etc where most of the solid materials removed.

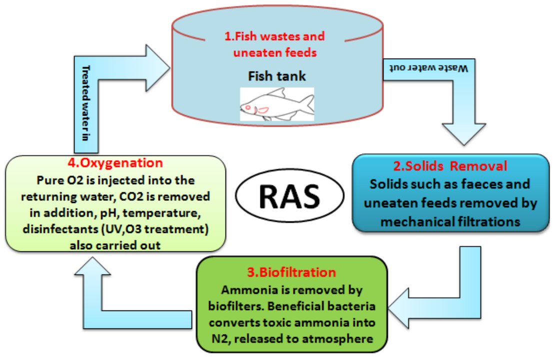

Fig. 3. Flow diagram of Recirculation aquaculture system

Then it is treated through a biofilters where the liquid waste is passed through a film of microbial growth develops on the filtering medium (Zoological film) which may be of 0.2-2.0 mm thick. The film consists of bacteria, fungi, protozoa and algae. The naturally occurring microorganisms on the films break down organic the material and purify the liquid (converts ammonia NH_{4+} and NH_3 excreted by the fish into nitrate).

Re-oxygenating the system water is crucial to obtain high production densities. Fish require oxygen to metabolize food and grow. Dissolved oxygen levels can be increased through two methods aeration and oxygenation. In aeration air is pumped through an air stone or an air stone that creates small bubbles in the water column, this result in a high surface area where oxygen can dissolve into the water.

In all RAS, pH must be carefully monitored and controlled. Desirable pH is typically controlled by the addition of lime ($CaCO_3$) or sodium hydroxide (NaOH) etc. A low pH will lead to high levels of dissolved carbon dioxide (CO_2), which is toxic to fish. Desirable pH can also be controlled by degassing CO_2 with an aerator. All fish species have a preferred temperature above and below which that fish will experience negative health effects and eventually death. Temperature also plays an important role in dissolved oxygen (DO) concentrations so; it can be controlled through the use of submerged heaters or heat pumps or chillers or heat exchangers. Finally it is disinfected using UV radiation or Ozone treatments before reused in the culture units.

Advantages

- Low water requirements.
- Low land requirements.
- Water quality parameters can be easily rectified.
- Independence of adverse weather conditions.

- High stocking density of desired species and productions.
- Most efficient; feed conversion is near 1:1.
- Reduce or eliminate vaccine, antibiotic and pesticide uses.
- Consistent production.
- Eco-friendly.
- Improve health and performance of the fish species

Aquaponics systems

Aquaponics is a modern food production system combines aquaculture and hydroponics (Raising of plants without soil beds) together symbiotically in a balanced recirculatory environment (Azad *et al.*, 2016).

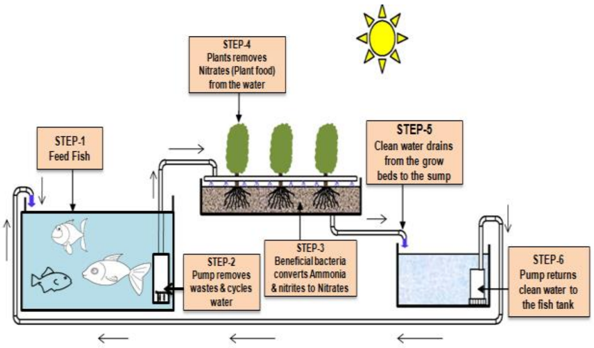

Fig. 4. Flow diagrammatic representation of Aquaponics system

In Aquaponics system (Fig.4), nutrient-rich water from fish tanks is used as liquid fertilizer to fertilise hydroponic production beds. These nutrients in the water produced from fish manure, algae, and decomposing fish feed which otherwise increases the toxic levels in the fish tanks affecting the fish growth. The hydroponic beds function as a biofilter stripping off ammonia, nitrates, nitrites, and phosphorus so the freshly cleansed water can then be recirculated back into the fish tanks. The nitrifying bacteria living in the gravel and in association with the plant roots play a critical role in nutrient cycling. These nitrifying bacteria convert ammonia to nitrate, a form of nitrogen utilised by the plants. Thus when the water returns to the fish tanks, nitrogen level are tolerable for the fish. Unlike that of traditional farming, in aquaponics system there is a constant flow of water and constant supply of nutrients to the plants occurs.

Advantages

- Significant reduction in the uses of water
- No need to use artificial fertilizer
- Provide an artificial filtration system of fish culture environment.
- Does not require farmland with fertile soil.
- Naturally organic
- Tourist attractors in rural communities
- Reduced damage from pests and disease
- No weeding
- Plants grow faster
- Sustainable
- Cleaner form of gardening
- Easy to setup
- Eco-friendly

Mono sex culture or Neo-female Technology

Mono-sex culture is a farming practice based on the culture of fish by producing all males or all females' population depending upon the sex which have better food conversion ratio and growth rate. Generally monosex culture of all female population of Carp, Salmon and all male population of Giant freshwater prawn and *Tilapia* is carried out that maximize the production level.

Among freshwater shell fishes culture *Macrobrachium rosenbergii* (Scampi) is gained importance in India. In this case the males reach market size faster than females. Thus, an all-male monosex population culture of the species is desirable. So monosex culture can be carried out by identifying the correct sexual dimorphism of this species and subsequently culture and harvest when attains desirable marketable size. Now-a-days a standardize technology called "neo female technology" where females are obtained through the sex reversal of males and that yield all male progeny. In this techniques the sex of the juvenile males are changed through microsurgical removal of the androgenic gland (AG) or through androgenic gene silencing (RNA interference method) to female (termed "neo-females"- phenotypic females with male genotype) and when it mate with a normal male gives all male progenies (Amir, 2013). In India, this neo-female technology project for the production of male scampi seeds has been undertaken by RGCA, Tamil Nadu and supplies all-male scampi seeds to farmers of the country.

Advantages

- Increase production to 2-flods.
- Better food conversion ratio
- Better growth rate

Integrated fish farming (IFF)

Integrated farming is defined as the sequential linkages between two or more agri-related farming activities with one of farming as major components. When fish becomes the major commodity in the system, it is termed as integrated farming (Ayyappan, 2011). OR, integrated fish farming systems refer to the production, integrated management and comprehensive use of aquaculture, agriculture and livestock, with an emphasis on aquaculture. The linkage of fish farming with agriculture and animal husbandry is considered as sustainable farming system, which offers greater efficiency in resources utilisation, reduces the risk by diversifying crops, provides income and increased food fish production for small scale farming.

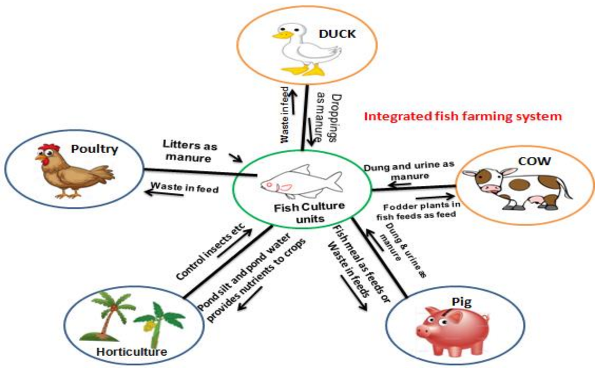

Fig. 5. Flow diagrammatic representation of IFF system

In integrated fish farming system, the wastes or by-products obtained from one system i.e. minor commodity becoming an input of fish culture systems. The by-products obtained from fodder plants, fruit plants and agriculture crops i.e. rice bran, rice polish, flour, oil cake, soybeans etc., are used in varied processed forms in aquaculture as a feed input. Besides, the wastes both urine and dung from different live stocks i.e. cows, poultries, chickens, pigs, rabbits, goats, sheep, silk warms etc., are used as a sources of manure to generate fish food organisms and helps in the sustaining of aquatic food web. There are basically two types of IFF followed by the farmers in India. The agri-based system includes paddy-fish, mushroom-fish, seri-fish, vermicompost-fish etc., with aquaculture as major component where as other agriculture practice as minor components. The livestock-fish system includes cattle-fish, pig-fish, goat or sheep-fish, duck-fish, rabbit-fish etc., with an objective to increase the farm productivity maximizing synergies between these components. Thus the IFF provides a new farming approach to increase the food production in a sustainable way which ensures better biodiversity, eco-system and integration of soil-water fertility management practices

Advantages

- Offers tremendous potential for food security and production
- Optimization the use of available natural resources
- Diversification of income generating activities
- Improvement of soil-water fertilities
- Minimize the use of chemicals (pesticides, fertilizers, antibiotics) Aquatic Biodiversity conservation and sustainable use could be enhanced
- Efficient utilisation of farm space for multiple productions
- Recycling of waste or by-product
- Organic in nature
- Eco-friendly
- No need to use artificial fertilizer
- Reduces the costs of production and economically

Integrated Multi-Trophic Aquaculture (IMTA)

IMTA is a way of farming multiple marine or freshwater organisms from different positions or nutritional levels or trophic levels in the same system at the same time (Barrington *et al.,* 2009). Integrated multi-trophic aquaculture (IMTA) is the farming of aquaculture species from different trophic levels, and with complementary ecosystem functions, in a way that allows one species' uneaten feed and wastes, nutrients, and by-products to be recaptured and converted into fertilizer, feed, and energy for the other crops, and to take advantage of synergistic interactions between species.

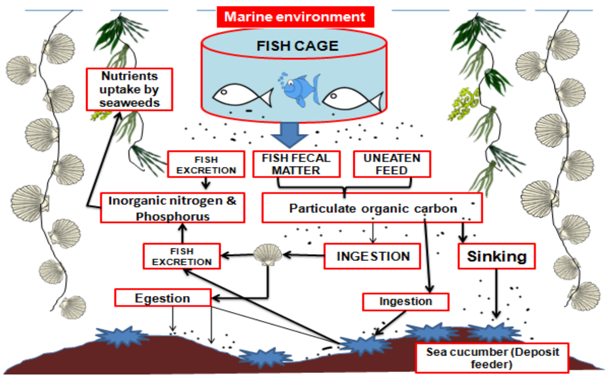

Fig. 6. Flow diagrammatic representation of IMTA

IMTA is the practice which combines the cultivation of fed aquaculture species (e.g. finfish/shrimp) with organic extractive aquaculture species (e.g. shellfish/herbivorous fish) and inorganic extractive aquaculture species (e.g. seaweed) to create balanced systems for environmental sustainability (biomitigation) economic stability (product diversification and risk reduction) and social acceptability (better management practices). Typically, carnivorous fish or shrimp occupies the higher trophic levels of IMTA's. They excrete soluble inorganic ammonia, phosphorus (orthophosphate) and particulate organic carbons (Fish faecal matter). Seaweeds and similar species can uptake these inorganic nutrients (inorganic nitrogen and phosphorous) directly from their environment. The organic nutrients (fish faecal matters and uneaten feeds, POM) are feed by shellfishes and deposit feeders and their excretory inorganic products again uptake by the seaweeds. Thus the IMTA provides a new farming approach to increase the food production by efficient utilisations of trophic levels in a sustainable way which ensures better biodiversity, biosecurity and eco-system.

Integrated Multi-Trophic Aquaculture = Fed Aquaculture (Finfish) + Extractive Aquaculture i.e. Organic (Shellfish) Inorganic (Seaweed)

Advantages

- Offers tremendous potential for food production and security
- Promotes economic and environmental sustainability by converting by-products, wastes and uneaten feeds.
- Reducing eutrophication
- Increasing economic diversification
- Reducing negative environmental impacts
- Eco-friendly.
- Efficient utilisation of all the trophic levels

Organic aquaculture

Organic aquaculture refers to the production processes and practices of ecological production management systems that promote and enhance biodiversity, biological cycles and biological activity. It is based on minimal use of off-farm inputs and on holistic management practices that restore, maintain and enhance species diversity and ecological harmony (Prein *et al.,* 2010). Moreover, the primary goal of organic aquaculture is to optimize the health and productivity of interdependent communities of soil life, plants, animals, and ensures that the production system should be socially, ecologically and economically sustainable.

Organic aquaculture based on the principles and practices of Intensive monitoring of environmental impact, use of polyculture, Integration of natural plant communities in the farm management, use of indigenous species as far as possible, without the use of hormones, irradiation and antibiotics and appropriate stocking density for food production in a sustainable way.

Advantages

- Sustainable fish farming system
- Preserves the ecosystem
- Controlling supply and demand
- High nutritional Value
- Eco-friendly
- Creating more job opportunities
- Poison-free
- Food Tastes Better
- Lower Input Costs
- Disease Resistance

Compensatory growth Technology

Compensatory growth is the phase of rapid growth, greater than normal or control growth, which occurs upon adequate refeeding following a period of under nutrition (Ali *et al.,* 2003). Compensatory growth (Stunted Fingerlings) is identified by being significantly faster than the growth rate of control fishes that have not experienced growth depression, held under comparable conditions (Biswas *et al*., 2016). The fish to starvation followed by what may be termed compensatory growth once feeding was resumed. In this method, the fish that have been starved for 3 weeks and then fed for 3 weeks show a weight gain equivalent to or greater than that of fish fed normally for the 6 week period.

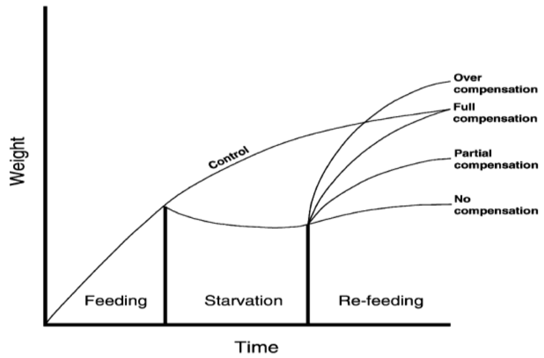

Fig. 7. Graphical representation of Compensatory growth technology

Advantages

- Carps are known to grow rapidly during the second year of their age.
- Higher survival rate in grow out ponds.
- More Immune to the diseases.
- More tolerant to environmental fluctuations.
- Require less time to reach marketable size (5-6 months).
- High growth rate & can be sold at higher prize.
- Higher production and productivity.
- Unhealthy seeds are perished during stunting periods, so we get only healthy seeds.

Conclusion

These advanced aquaculture farming systems and other technological innovations are showing a positive impact on aquaculture success, productions, investment and marketing potential. The development of these farming systems in aquaculture should provide a means of producing healthy and fast growing animals, through eco-friendly means. However, this development will largely depends on the desire, willingness, capacity building and infrastructure development of the farmers to work in collaborations with scientists and the international donor community to assist in related farming technologies.

References

Ali, M., A. Nicieza and R.J. Wootton. 2003. Compensatory growth in fishes: a response to growth Depression. *Fish and Fisheries*, **4(2):** 147-190.

Amir, S. 2013. Monosex culture of prawns through androgenic gene silencing. *Infofish International*, **10(4):** 22-24.

Avnimelech, Y. 2009. Biofloc Technology — A Practical Guide Book. World Aquaculture Society pub., Baton Rouge, Louisiana, United States, pp. 182.

Ayyappan, S. 2011. Hand book of fisheries and Aquaculture. Indian council of Agricultural Research pub., New Delhi, India, pp. 439-448.

Azad, K.N. and M.A. Salam. 2016. Aquaponics in Bangladesh: current status and future prospects. *Journal of Bioscience and Agriculture Research*, **7(2):** 669-677.

Barrington, K., T. Chopin and S. Robinson. 2009. Integrated multi-trophic aquaculture (IMTA) in marine temperate waters. In: FAO Fisheries and Aquaculture Technical Paper Number 529. FAO press, Rome, Italy, pp. 7–46.

Biswas, P., M. K. Datta, H. Saha and S. C. Mandal. 2016. Stunted Fingerlings-replacement of conventional fish seed. In: Vocational training manual on aquaculture production and its management. College of Fisheries press, Lembucherra, Central Agricultural University, Imphal, pp. 59-61.

Crab, R., T. Defoirdt, M. Wille, P. Bossier and W. Verstraete. 2012. Biofloc technology in aquaculture: Beneficial effects and future challenges. *Aquaculture*, **356:** 351–356.

Prein, M., S. Bergleiter, M. Ballauf, D. Brister, M. Halwart, , K. Hongrat, J. Kahle, T. Lasner, A. Lem, O. Lev, C. Morrison, Z. Shehadeh, A. Stamer and A.A. Wainberg. 2010. Organic aquaculture: the future of expanding niche markets. In: *Proceedings of the Global Conference on Aquaculture*, Phuket, Thailand, September 22-25, pp. 549–567.

How to cite this article?

Jena, *et al*., 2017. Advanced farming systems in aquaculture: strategies to enhance the production. *Innovative Farming*, **2**(1): 84-89.