# Increasing the Economical Efficiency and Sustainability of Indoor Fish Farming by Means of Aquaponics - Review

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**Abstract**
This review focuses on increasing economical efficiency and sustainability of indoor fish farming. Aspects like sustainability and economical efficiency were reviewed. In order to improve man`s health we must reconsider the agricultural sciences, by this we understand that we must develop technologies friendly for the environment. Sustainable indoor fish farming is the farming of the new millennium. Combining aquaculture with hydroponics we obtain a new innovation named aquaponics which respects principles of sustainable agriculture (wastewater biofiltration by plants) and gives us the possibility to increase economical efficiency with an additional production (organic vegetables).

**Keywords**: aquaculture, aquaponics, hydroponics, organic products, recirculating aquaculture systems (RAS).

## Introduction

The increasing rate of scientific and technological innovation has kept engineers in a continuous struggle to update themselves with the latest codes of practices, technologies and scientific breakthroughs. Engineering, as an applied science, has improved the quality of life for man through the introduction of new and improved products.
This review focuses on increasing economical efficiency and sustainability of indoor fish farming. The need and urgency of sustainable development for the aquaculture is beyond the deliberation stage. Sustainable indoor fish farming is the farming of the future.
Increased productivity with reduced ecological impact, integration between production systems and reduced use of chemicals are just some of the leading principles that more sustainable fish production needs to follow [1].
The safety of food for human consumption is becoming increasingly important on a worldwide level.
Aquaponics is essentially the combination of aquaculture and hydroponics.
Aquaculture represents fish farming, one system where commercial fishes are reared in containers, ponds or tanks.
A recirculating aquaculture system (RAS) can be defined as an aquaculture system that incorporates the treatment and reuse of water with less than 10% of total water volume replaced per day. The concept of RAS is to reuse a volume of water through continual treatment and delivery to the organisms being cultured. Water treatment components used in RAS need to accommodate the input of high amounts of feed required to sustain high rates of growth and stocking densities typically required to meet financial outcomes. Generally, a recirculating aquaculture system consist of mechanical and biological filtration components, pumps and holding tanks and may include a number of additional water treatment elements that improve water quality and provide disease control within the system [2].

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Hydroponics is a term used to describe the production of plants without soil. Plant roots grow in a nutrient solution with or without an artificial medium for mechanical support [3].
Hydroponics is a plant culture technique, which enables plant growth in a nutrient solution with the mechanical support of inert substrata. Largely applied both in laboratory experiments and in commercial crop production, hydroponics is considered as a promising technique not only for plant physiology experiments but also for commercial production [4].
Both aquaculture and hydroponics have some negative aspects, hydroponics requires expensive nutrients to feed the plants, and also requires periodic flushing of the systems which can lead to waste disposal issues. Recirculating aquaculture needs to have excess nutrients removed from the system, normally this means that a percentage of the water is removed, generally on a daily basis. This nutrient rich water then needs to be disposed of and replaced with clean fresh water. While re-circulating aquaculture and hydroponics are both very efficient methods of producing fish and vegetables, when we look at combining the two, these negative aspects are turned into positives [5].

**Nitrogen compounds in RAS**

The natural feeding strategy of fish species (i.e., herbivore, carnivore, omnivorous, and filter feeder etc.), fish stocking density, total fish biomass, input feed rate (fertilizer/feed used quantity and application method), water quality, and water management influence the assimilation of nutrients by fish and wastewater production [6]. discharged from the culture system in the form of sludge [10].
Some of the effects of excessive ammonia include:

- Extensive damage to tissues, especially the gills and kidney
- Impaired growth
- Decreased resistance to disease
- Death

Fortunately nature give us solutions for the bigest problem in the systems - toxic levels of ammonia and for that *Nitrosomonas sp.,* in metabolic process of their growth, consume ammonia and converts it to nitrite.

The most common water quality problems in re-circulating aquaculture systems are oxygen depletion and accumulation of organic matter, inorganic nitrogen, particularly ammonia, and CO [7], this problems for the recirculating aquaculture has traditionally been reduced by water exchange [8].
While feed is continuously added in a fish culture system, the wastewater it accumulates in dangerous quantity. Wastewater effluent is rich in nutrients because it comprises mainly faeces, uneaten food, and bacterial biomass. Decomposing food creates ammonia.
Fish, in metabolic processes of theirs growth, excrete ammonia at the gills. In a lake or ocean it’s all good because the vast volume of water dilutes this ammonia. When you’re keeping fish in containers, ponds or tanks it needs to be managed as it is very toxic to the fish.
A major concern in aquaponic systems is the removal of ammonia, metabolic waste product excreted through the gills of fish. Ammonia will accumulate and reach toxic levels unless it is removed by the process of nitrification (referred to more generally as biofiltration), in which ammonia is oxidized first to nitrite, which is toxic, and then to nitrate, which is relatively non-toxic. Two groups of naturally occurring bacteria (*Nitrosomonas sp.* and *Nitrobacter sp.*) mediate this two-step process [9].
The total dissolved solid (TDS) generates (produces) due to feed leaching and bacterial degradation of faecal materials. Total suspended solid (TSS), including faecal materials and biomass of bacteria, is typically separated from water by the solid separation unit, which is then We know that nitrite is much less poisonous to the fish than ammonia, but it`s by no means a good thing. The nitrite attach to the hemoglobin and results metehemoglobine which it is not capable to transport the oxygen [11].
Again nature helps us, with *Nitrobacter sp.* These good bacteria, in metabolic process of their growth, consume nitrite and convert it to nitrate. Nitrates are not a big problem for the fish, but for the good health of the fish we must keep nitrates at a low level.
This is a good thing for us because nitrate happens to be the favorite food of plants. Also the fish will tolerate a much higher level of nitrate than ammonia or nitrite [11].

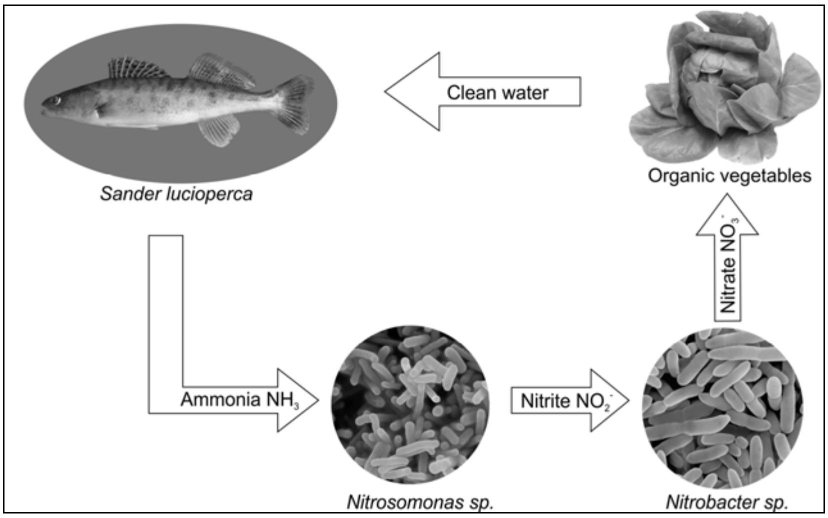

**Figure 1**. Nitrogen compounds in RAS integrated with aquaponics cultures

Plant uptake is one of the most widely recognized biological processes for contaminant removal in wastewater treatment wetlands [12, 13].

Ammonium nitrogen removal efficiencies of 86% to 98% were reported from a constructed wetlands system receiving aquaculture wastewater [14].

Over the past 3 decades, in aquaculture practices, the hydroponic(s) plant compartments with different experimental design were integrated in the aquaculture systems in both warm and moderate climates to alleviate the accumulation of nutrients especially, N compounds in the culture system [15-18, 10].

Recirculating aquaculture systems appeared to be the most recommended aquaculture system for integration with hydroponics since nutrients can be maintained at the concentrations which are sufficient for hydroponics plant culture [19, 20].

In hydroponic greenhouse plant production systems receiving aquaculture wastewater, Adler (1996) found that differences in nutrient removal rates of nitrate nitrogen and phosphorus were dependant on plant numbers and effluent flow rate. If plant numbers are increased sufficiently, nutrient concentration can decrease to levels that may be too low to sustain plant growth. Aquaponic wastewater cleanup cost abatement alone can be a major factor in integrating hydroponic and aquaculture systems [21, 22].

In closed growing systems, the drainage nutrient solution resulting from surplus fertilization is recycled, thus reducing the use of water and production systems. The environmental impacts of aquaculture vary according to the species being limiting the leakage of fertilizers to the environment [23].

**Sustainability**

Intensive fish culture systems can be classified as flow-through or recirculating. In the former, clean water is typically directed in a single pass through the production unit and discharged or dispersed thereafter. Freshwater flow-through or open systems are found in regions with an ample supply of clean water the biggest disadvantage for this system is that they may contaminate recipient water bodies and may therefore become limited by environmental constraints [7]. To the opposite side, recirculating systems incorporate facilities for maintaining adequate water quality. These systems have the potential to be more environmentally sound as water input is minimized, little water is discharged and this can itself be treated.

However, the trends of new millennium in environmental regulation, are limiting the amount of water which may be consumed or discharged, reducing the ability to use large influxes of water to remediate excess nitrate [8], this issue can be remediate by introducing vegetable crops as a bio-filter for the aquaculture wastewater.

In animal food-producing sector we know that aquaculture is the sector that grows most fast. Hundreds of different species of finfish, shellfish, and aquatic plants are farmed globally in a variety of culture environments and cultured and the production system employed [24].

Rising environmental concerns and growing demand for different uses of production inputs set new challenges for aquaculture development. Increased productivity with reduced ecological impact, integration between production systems and reduced use of chemicals are just some of the leading principles that more sustainable fish production needs to follow [1].

Merging the two disciplines, wastewater treatment and crop production, requires moving the focus from optimizing the degradation, nitrification, denitrification and absorption rates to maximizing the recycling rates of phosphorus and nitrogen and to fulfilling the quality requirements of the resulting products such as plant biomass and effluent water [25].

Nitrification activity runs optimal at pH levels near by 7, combining hydroponics and aquaculture into aquaponic systems requires reconciling water quality parameters for the survival and growth of plants, fish, and nitrifying bacteria [26].

Sustainable farming is the farming of the new millennium. A lot of people see the sense in doing things sustainably, whether it will be the way we build our houses or the way we run our farming enterprises. Sustainability means that we squeeze as much as we can out of a resource because these resources are limited and it is best to use them as efficiently as we can. It also means that we take the surrounding environment and ecology into due consideration. We protect it and care for it, because we understand that many of our resources come from this environment or ecology and, if we abuse it, we may eventually run out of those very resources we depend on [27].

The dual objective of sustainable aquaculture, to produce food while sustaining natural resources is achieved only when production systems with a minimum ecological impact are used. Recirculating aquaculture systems (RASs) provide opportunities to reduce water usage and to improve waste management and nutrient recycling. RAS makes intensive fish production compatible with environmental sustainability [28].

One of the great things about advances of knowledge from research is that a discovery in one field can have significant benefits in another. This innovation in Agriculture it can also be used for urban rooftop production of food using intensive aquaculture in basements and organic hydroponics in rooftop greenhouses [29]. Given the reduced access to water and green spaces in over-populated urban areas such as the Middle East, an aquaponics system has numerous benefits. Using aquaponics as a rooftop production can be a solution for families with no land from urban areas [30]. Pedersen et al. (2008) [31] also showed a reduction on the environmental impact from converting flow-through trout farms into RAS including waste management. In a recirculating aquaculture system, removal efficiencies were between 85% and 98% for organic matter and suspended solids and between 65% and 96% for phosphorous.

This is a recirculating system, a small scale ecosystem, no wastes going out into the environment. There is a limited need for supplements. This is a soiless culture so many of diseases of conventional soil based farming are not a concern. Natural methods such as aphid are used for pest control.

Tyson (2007) [32] presents that Aquaponics fits closely into the definition of sustainable agriculture.

“an integrated system of plant and animal production practices” using vegetables with aquaculture species,

“having a site specific application” in greenhouse production units.

“over the long term satisfy human food needs” and “enhance environmental quality” by producing crops using environmentally friendly practices that minimize water and nutrient waste discharges to the environment.

“make the most use of nonrenewable resources” by conserving nitrogen fertilizer, produced from non-renewable fuels, and water.

“integrate natural biological cycles” by using nitrifying bacteria in the process of nitrification to convert harmful ammonia fish waste to usable, safe, nitrate nitrogen for plants.

“sustain the economic viability of farm operations” and “enhance the quality of life for farmers…and society as a whole” by producing food in a sustainable agricultural production method and in an environmentally bio-rational manner without wasteful discharge to the environment [32].

By practicing an indoor fish farming, we produce large amounts of wastewater.

Hence, aquaculture is said to be a highly polluting system due to the discharge of polluted water into the surrounding environment in order to improve water quality. However, over time many techniques have been invented to reduce the pollution, one of them is the AQUAPONIC system. Aquaponics is the combination of aquaculture and hydroponic systems whereby nutrient rich waste water from the aquaculture system is directed into the hydroponic system. Plants will absorb the nutrient from the waste water and improve or purify the water quality for the aquaculture system. This provides an eco-friendly as well as sustainable system for the agriculture sector [33].

The closed loop system mimics a natural system; the fish consume food and their waste is naturally converted to nitrate and other nutrients, the nutrients in the water are then taken up by the plants. The fish supply necessary plant supplements and the plant act as a natural water filter, a win/win situation [34].

The hydroponic beds function as a biofilter so the water can then be recirculated back into the fish tanks.

High flow rates of low concentrated effluents are the main obstacle to the economic treatment of waste water from FTS. By comparison, the flow rate of RAS waste water is 10–100 times lower and 10–100 times more concentrated [35], which allows for easier and more cost effective treatment.

Integration of aquaculture with agriculture can reduce the water requirement for the production of quality protein and fresh vegetables products relative to both culture systems operated independently [36], in aquaponics water wastage can be minimized, compared to the aquaculture system , where frequently we must change fish water from the tanks to ensure water quality, or plant cultivation on soil because in a field crop 10% of the water is absorbed by the plant, while 90% of the water is wasted. Along with saving water, the fertilizer needed for plants can be further reduced, because the food for plants is represented by the nutrients from the wastewater.

One of the several advantages of aquaculture, and by extension, aquaponics as well, as a source of food fish is that the producer can exert control over the intrinsic quality, including safety, of the product.

From the perspective of food safety in aquaponic systems, there seems to be much less likelihood of contamination of vegetable and other aquaponic crops, and fish, with pathogenic bacteria of domestic animal origin, and with microscopic parasites such as *Cyclospora sp*. of human origin, and *Cryptosporidium sp.* of domestic animal origin, in aquaponic systems, especially in indoor systems, compared with the potential of such contamination in the traditional field methods of growing such crops [37].

Polyculture of fishes (and invertebrates) in aquaponics and recirculating aquaculture is a promising way we can return advanced modern agriculture to sustainable agriculture using biological controls [38, 39].

Pesticides must not be used to control insects and plants diseases in aquaponic systems because many are toxic to fish and none have been approved for use in food fish culture. Similarly, most therapeutants for treating fish parasites and diseases should not be used in an aquaponic system because they may harm beneficial bacteria and vegetables may absorb and concentrate them. Biological control methods are the only option for controlling insects and diseases. Fortunately, biological control is the subject of intense investigation, and new methods are becoming available. The use of hardy fish species such as *Tilapia* and best management practices prevents fish disease and parasite problems [39].

**Economical increasing efficiency with vegetables productions**

Aquaponics presents an opportunity to rethink the indoor fish farming, to bring in more money at the farm gate. Two profit centers for producers: fish and plants. If fish goes through a low cycle then we have ours plant revenue to rely on and visa versa.

Estimates for production crop capabilities vary greatly. Some experts looking at the industry claim it has the potential to produce more than conventional or hydroponics other claim it produces considerably less.

The integration of fish and plants is a type of polyculture that increases diversity and thereby enhances system stability. Sale of greenhouse products generates income which supports the local economy.

Aquaponics increase economical efficiency because several key costs, such as nutrients, land and water are substantially reduced and component operating and infrastructural costs are shared. Lower resource requirements extend the geographic range of production to areas that rely heavily on food imports.

Dr. Mike Nichols (2008) sustains that there is a possibility to increase economical efficiency of aquaculture by selling the crop as a certified organic crop, because it is produced entirely from natural manure (fish waste). The system involves no control of root pathogens, as these are controlled biologically by the broad spectrum of antagonistic micro-organisms that develop in the natural environment [40].

Aquaponics is a bio-integrated system that links recirculating aquaculture with hydroponic vegetable, flower, or herb production and culinary or medicinal herbs [37]. Variety of crops is vast. Potential crops include: table vegetables, specialty vegetables, herbs, flowers, ornamentals, and aquatic plants. Value added potential is strong as well. Such as salad mixes, pesto, essential oils, and flower arrangements [37, 41].

This production type of fish and vegetables, is right where the market is headed- consumers are demanding safe food produced in an environmentally responsible way. The fact that aquaponic products are locally produced, and therefore, ″leaving a small footprint on earth, is an added bonus″. Terms such as ″natural″, ″ environmentally friendly″, ″pesticide free″, ″organic″ have growing attraction to consumers [42].

The selection of plant species adapted to hydroponic culture in aquaponic greenhouses is related to stocking density of fish tanks and subsequent nutrient concentration of aquacultural effluent. Lettuce, herbs, and specialty greens (spinach, chives, basil, and watercress) have low to medium nutritional requirements and are well adapted to aquaponic systems. Plants yielding fruit (tomatoes, bell peppers, and cucumbers) have a higher nutritional demand and perform better in a heavily stocked, well established aquaponic system. Greenhouse varieties of tomatoes are better adapted to low light, high humidity conditions in greenhouses than field varieties [43].

In a study of feasibility of farm direct marketing aquaponic vegetables, Eileen Kotovich, concluded that there is an array of marketing channels from which producers can connect. They include: farm direct (farm gate, farmer`s markets, agri-tourism); Hotel Restaurant, and Industrial (HRI) (white table cloth, local restaurant, restaurant chains, hospitals); specialty retail markets (health food, whole food, ethnic, organic); vegetable/herb wholesale and garden retail centers [44].

The economics of investment in expensive greenhouses in colder climates will also be improved from the greater productivity. A very real bonus will be additional revenues from sales of fish [45].

Aquaponics process, gives big advantages in earlier and faster plant crop production from cold-climate green-housses , to capture more profitable early markets. This type of agriculture might mean a stepped-up investment, but it is one that creates another revenue stream (from fish) linked with more profitable plant production. That means greater financial resiliency for a business – and maximizing dollar returns to shareholders can be a very powerful force far rapid change [46].

Many gardeners who enjoy getting their hands dirty may find the technical infrastructure of aquaponics systems, the benefits far outweigh any concerns.

Some benefits outlined by Amadis Lacheta (2010):

- Faster growth rate, crop maturity and yields
- Consistency and quality of crops
- Drastically reduced water and nutrients compared with soil-grown produce
- Crops can be grown in places where ordinary horticulture and aquaculture is impossible due to poor or contaminated soil or water
- Reduced growing area required
- Systems can be set up at a comfortable working height, excellent for people who are elderly or have disabilities
- Relative freedom from soil diseases and pests
- Weeds are virtually non-existent
- Water stress is reduced in hot conditions
- Less ongoing maintenance required
- Great for rental properties, as all the infrastructure can be moved [47].

Increasing economical efficiency of aquaculture by aquaponics, is given from the fact that by this innovation water consume is reduced to minimum and most important we obtain organic vegetable products, that means an additional product which brings to us extra cash.

## Conclusions

Sustainable indoor fish farming is the farming of the new millennium. Aquaponics is the combination of aquaculture and hydroponic systems whereby nutrient rich waste water from the aquaculture system is directed into the hydroponic system. The trends of new millennium in environmental regulation, are limiting the amount of water which may be consumed or discharged. In aquaponics, wastewater from the aquaculter is filtered and the is recirculated into the system.

Aquaponics presents an opportunity to rethink the indoor fish farming, to bring in more money at the farm gate. Two profit centers for producers: fish and plants.

Sale of additional greenhouse products generates income which supports the local economy.

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