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Integrated Aquaculture or Integrated Multitrophic Aquaculture: Same or Different Concepts

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Summary

By constituting a material of enormous importance in the sustainability of aquaculture in a world where society and the environment are impacted by various productive processes, Integrated Aquaculture, or currently called Integrated Multitrophic Aquaculture, it comes to save the polluting effects of waste, the misuse of water and land, and the social impacts that are generated, when these productive processes act independently.

Although this modality of aquaculture in inland water is an ancient practice in China, it has now been renamed Integrated Multitrophic Aquaculture, including proving its beneficial effects on economic and ecological effectiveness, forgetting the proven Asian experience in this aquaculture modality. Apparently, the concept has not been fully understood, confusing the polycultures of fish or the symbiotic relationships between the species that occur in nature, with the integration. The present work aims to establish the conceptual differences between the two definition and to show concrete examples of models of aquaculture integration, with the intention of clearing doubts and providing a broader approach to it.

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Introduction

Integrated Aquaculture, which has been practiced in China for over a thousand years, has been resumed by the present aquaculture, to solve the effluent problems, the reuse of nutrients generated in the commercial exploitation of fish and other organisms cultivated in intensive conditions.

They maintain in common that the integrated crop is the one where the by-products of a monoculture, which would otherwise be discarded, are used as input for another that accepts it as an energy resource for its development. This results in more productive efficiency in the area managed by the producer [1-5].

The reuse of waste by integrated organisms is established in a univocal, biunivocal or multilvocal way, between macroscopic and microscopic organisms, inside and outside the aquatic environment where the fish are found (Remedios and López, 2000) [6].

Chopin [7] argues that polyculture of fish with integrated aquaculture is sometimes confused. This author cites the example that three species of fish undergoing a polyculture process, share common biological, physical and chemical processes, and their culture activities could modify the properties of the ecosystem. However, there is no direct trophic interdependence between them, nor can it be attributed that other organisms present in the reservoir, which naturally live there, are part of an integration crop. The multitrophic approach refers to the fact that the prioritized organisms in the crop, whether fish orshrimp, are integrated with organisms that form part of a programmed and controlled intentional existence that operate close to each other and use the waste of some for the benefit of others, and not necessarily in the same place.

Confounding with the introduction of the term multitrophic in the classical concept of integrated aquaculture has been created. The introduction of the multitrophic concept in integrated systems is not necessary, since the concept of integration presupposes the multitrophic nature of the biotic components that support the system. The term trophic refers to the nutritional reasons of the components of the system, and according to Chinese interpretation, integration not only addresses these reasons, but others that will be seen later. Its positive effects are more than tested and demonstrated by a thousand-year-old practical application of Chinese aquaculture.

Since its creation, this type of aquaculture has been named integration, which has evolved in its different modalities due to a process of historical adjustments of efficiency [6]. Any "new definition" is trying to figure out what has already been discovered. The versatility of the concept, in the vast universe of integrated aquaculture, as the Chinese conceived, is not yet clear [8] to have clarear idea of the scope of the concept, then we show some of the various variants applied.

Fish Biological Bases in the Integrated Farm

This activity is essentially an ecological system under human control, and considering that fish culture is the main activity should be known the dynamics that develops in the pond, as well as in all its area of action, before and after the cultivation process. Knowledge and control of the dynamics of the biological interrelation of the system is essential to achieve the objectives pursued. In relation to the contribution to the manure pond from the raising of pigs, ducks or

chickens, this does not constitute the direct food of the fish; (although sometimes they can be consumed), their first step is to travel through a process of degradation in bacterial action, causing the formation of nutrients for the production of plankton [9]. In turn, plankton-feeding fish carry out their excretions and they will also produce the above elements. In this way a balanced system is established in the cyclical use of energy [10].

The problem is to maintain the necessary substrate according to the energy consumption. For example: nutrients contributed by animal manure whether in default as in excess to primary producers (phytoplankton, zooplankton and benthos) cannot limit their reproduction, so that the densities of these organisms in the pond are the favorable for a Good development fish. The above presupposes that the balance between supply and energy demand is the cornerstone of the system's success [6].

This ecological system in equilibrium is established by the nutritional characteristics of the cultivated species, without interference between them, those that make a total consumption of the food possibilities that sustain the system itself and contained in the biotopes in question [6]. (Table 1) shows the most commonly used fish species in polyculture.

Common Name	Scientific Name	Food
Silver carp	*Hypophthalmychthys molitrix*	Phytoplankton
Bighead carp	*Aristichthys nobilis*	Zooplankton
White grass carp	*Ctenopharyngodon idella*	Aquatic and terrestrial grass
Black grass carp	*Ctenopharyngodon nitidus*	Small crustaceans, snails
Common carp	*Cyprinus carpio*	Detritus
Colossoma Tambaqu	*Colossoma macropomum*	Seeds, fruits
Tilapia aurea T. nilótica	*Oreochromis aureus; Tilapia niloticus*	Omnivorous

Table 1: Fish species commonly used in freshwater polyculture. Taken from: Apuntes of the aquaculture in China [6].

Fish farms integrated into agriculture

a. Integrated aquaculture with agricultural system.
b. Integrated aquaculture with poultry system.
c. Integrated aquaculture with agriculture and poultry system.
d. Integrated aquaculture with industry and trade system

In each system there are different models of farms:

a. The integrated aquaculture with agricultural system:

- Fish-Crops and agricultural herbs.

There are good economic benefits in this system. This type of integration includes pasture crops in the dykes and ponds when there are no fish. Different types of trees, herbs and fish are used, and according to these, different models of farms are established. Example: The traditional model with sugar cane and herbivorous white carp, is the most efficient and economical, so it is the most used. Tilapia and colossoma, which are cultivated in warm and warm climates, are usually integrated with plantain crops, cassava, maize, cocoa, citrus, pastures, forage and the development of small live stocks [11].

Agriculture is linked in the integrated system from all possible angles, since the contributions between the two elements, agriculture and aquaculture, benefit each other. Nutrient-enriched water for orchard irrigation, vegetable planting, fruit plantations, etc., as fertilizer, when fish are harvested in retribution, seeds, fruits, herbs, etc., are used for feeding fish in cultivation.

- Fish-Rotating herb crops.

It is the type of integration where the pond is used for the cultivation of vegetables. It is a more simplified agricultural-aquaculture relationship, because the purposes can be considered as less complex. During the growth of fish, dikes and pond area are used in planting smaller agricultural products, such as rice, sorghum and other grass. At the end of the fish harvest, the pond is based on a short cycle for the planting of relevant species with the degree of humidity and nutritional possibilities of the pond bottom until the restart of the fish planting operations. In this way, a more rational exploitation of the land is achieved.

b. Integrated aquaculture with poultry system:

- Fish-Ducks, geese and chickens.
- Fish-Pigs (the most used).
- Fish-Cattle, horses.
- Fish-Rabbits, sheep and goats.

In all these models aquaculture is always the fundamental activity and from which the proportions taxed by the other crops are established.

This subsystem is one of the most relevant of the farm, as it focuses on the main activity of fish farming. The rest of the animals involved in the system contribute in some way (directly or indirectly) to the growth of the fish. It is a more widespread subsystem is the relationship between all elements of integration, referring to animals and may well be dismembered in turn into more specific subsystems. The manure of the animals linked to fish farming is used for the fertilization of the pond. In the case of pork, they can provide 4500 kg of fertilizer per year. This fertilizer can be directly applied or fermented [6].

c. Integrated aquaculture with agriculture and poultry system.

- Fish-Animals agriculture

This model combines the previously-seen subsystems. The farm is more complex by qualitatively increasing the components of the system. Here are three components. Example: vegetables - pork - fish. As is supposed to be, these three components can vary in correspondence with species to link with fish farming.

- Fish-Herbs-Pig.
- Fish-Agricultural Farms-Ducks.
- Fish-Pig-Chickens. (This is the vertical integration model) Vegetables-Fish-Pigs.
- Fish-Silk-worm crops-Agricultural crops. Fish-Cultivated worms-Mushrooms-Cattle.

d. Integrate aquaculture with industry and trade system

An integrated aquaculture farm reaches its highest efficiency expression, when intermediaries are eliminated (fish market and other products obtained in the system). By owning all the integrated elements, the farm is by virtue of marketing them, and when this happens, the industrialization of the products and services is complemented. This is where the character of integration has no dependence on the residues produced by some, to be exploited by others and therefore, the character of multitrophic as definition, is broken. Here flows, money, investment and therefore is the most advanced.

Technical and Economic Feasibility of the Integral Agricultural

In every productive process where many factors are involved, there are advantages and disadvantages that need to be weighed before the implementation of integrated aquaculture projects.

Advantages

Use of waste materials, such as animal manure. Example: A cow can produce from 10,400 kg to 11,800 kg of fresh manure in one year. A pig can produce from 4,100 kg to 4,700 kg and a duck from 40 to 70 kg [6]. These figures, in the possibilities of excreta as fertilizing material are very important, if we want to achieve an efficient integrated fish farm. Abundant and diverse supply products: There is a diversification of the food products that can be offered to the population as fish, eggs, milk, meat, fruits, vegetables, etc., all obtained ecologically.

Ease of Use: Provides stable employment to the unemployed workforce as an activity to be developed throughout the year. The integration of different crops with aquaculture reaches a universe of wide possibilities. Geese and ducks can be raised in the ponds or small reservoirs; the dykes can be used in the cultivation of fruit bushes or have corrals where to fatter pigs. The slopes of the dykes can be used for the planting of vegetables, so that this type of farm can not only produce fish using the body of water, but the surface of it, the earth and even the heavens of the pond contribute to the production of food for human consumption. Thus, a rational use of space and natural resources is achieved. without affecting, in considerable proportions the environment.

Due to this variety of functions in the pursuit of the same objective, the availability of occupations is increased, making possible the participation of other workers instead of those that only serve the fish cultivation. Because of the varied nature of an integrated fish farm, more jobs are available than on a unitary fish farm. For example, on Helei there are 149 jobs related to integrated farming of fish and other products. Among these there are 48 people involved in duck farming, 19 in cow farming, and 14 in pig farming [12].

Increases revenue and reduces production costs: Production obtained in monoculture farms is much lower than in an integrated fish farm, as the latter diversifies its products by increasing its revenue and earnings. Example: The price of manure or animal manure to produce 1 kg of tilapia is 0.41 USD, the value of the manure is half the value of the production, it is reasonable to consider that being a product of the farm itself, then it establishes a transfer between the productive purposes, without a monetary expense by the acquisition of the manure. In China's traditional monoculture, the cost of food is 80 to 90% of the production value. In integrated fish farms the cost of feeding is 40 to 60%. The general conditions of the work and the organization of the crop are improved. It has been proven to be an effective system of technical and economic angles [6].

Disadvantages

There are a lot of activities to develop. You should know how to combine all of these activities and how to control them. Example: If the amount of manure is not properly calculated on the pond, it may be too much and damage its conditions. It is a complex system and its application is not simple. It requires a knowledge of the biology of the species that are integrated and their nutritional requirements, for the good development and growth of the same.

It is not easy to gather all the knowledge of the different crops. A methodology of work is needed to support the balance of the interrelation and coexistence of various species. Ecological border. Research is required to establish direct and indirect flows of the energy involved in polyculture. For example, it cannot be considered fully efficient in the circulation of energy, because in the case of the farms that use fish+chickens, the food of the latter comes from outside the farm, on the other hand, the manure of the chickens accumulates in the lower part of the ships and there is no direct connection with another activity to use them. This could be resolved by introducing agricultural crops to feed chickens and fish, but amounts should be investigated. For this reason, the more activities exist on the farm, the more it will be the efficiency.

Types of Integrated Farms

Fish farms with pigs, (Figure 1)

Figure 1: Integrate aquaculture with pigs. (Photos taken from the Internet).

Regarding fish production, pig farming on integrated farms is a profitable crop, because fertilizers (manure) here produce an extra benefit when used in pond fertilization, as well as not incurring expenditure on disposal by treatment or transfer systems. Pigs have a high tolerance for food residues, agricultural residues, plants, etc., they also have great adaptability to extreme environments, being able to carry out young people concentrated in a closed or free area. When pigs communicate directly with the pond, fish production increases by direct fertilization. The pigs do not fully digest the food and this can be used by some species of fish that confer the optimal use of the artificial food.

Fish farms with chicken, (Figure 2)

Figure 2: Integrate aquaculture with chickens. (Photos taken from the Internet).

Chickens have a close relationship with aquaculture and agriculture, since all manure is used as organic fertilizer in these productive activities. Example: A chicken produces between 5-5.7 kg of chicken manure in one year. If we consider that 500 kg chicken manure is equivalent to 40.7 kg of nitrogen, 42.7 kg phosphorus and 8.5 kg potassium, then you can understand why farmers prefer chicken manure to pork manure. The particularities in the components of the chicken manure make it very efficient in its role as fertilizer. The chicken manure can be added to the water after being deposited for a while under the cages, or by a rinse system, going continuously to the fish ponds. The number of chickens released on an integrated farm is unlimited,

as long as there is access and control to sites where products can be damaged by an animal attack. Example: rice, vegetables, etc. For the rest, they are a control of the harmful insects and their larval forms. Chickens are an important productive line due to their easy reproduction and rapid growth. Indeed, egg production is very high when there is a considerable mass of placement.

Fish farms with ducks, (Figure 3)

Figure 3: Integrate aquaculture with ducks. (Photos taken from the Internet).

Ducks, like chickens, provide fertilizer rich in vegetable nutrients. The difference with chickens is that ducks can excrete it directly in the water. This integrated agricultural model has a long history in China and can archive high economic efficiency, as the fish pond is considered a semi-enclosed ecosystem, where duck excrements fertilize water. Some aquatic insects are detrimental to fish, attacking fish larvae, but ducks consume them and this reduces feeding costs for ducks and helps health control of the fish.

Aquaculture system agriculture, (Figure 4)

Figure 4: Integrate aquaculture with agriculture crops. (Photos taken from the Internet).

This system is the simplest practice of integration, because in the possession of the land agriculture is guaranteed. Agricultural crops are supplied with water from the pond for irrigation when it is abundant and without risk of drastically reducing its volume. This water is rich in nutrients and contributes decisively to the progress of the plantations, decreasing the expenses in the purchase of fertilizers, in addition when emptying the reservoir, the skies can be used to strengthen the substrate of the crops. Fish, in turn, can benefit from the contribution of vegetable crops, fruits, grass, etc.

Fish-Agricultural and herbal farming, (Figure 5)

Figure 5: Integrate aquaculture with agriculture and herbal farming. (Photos taken from the Internet).

The integration between agriculture and fish farming is based on the reciprocity of the benefits, because both the water and the ponds skies contribute to the productivity of the harvest and in turn, rewards the fish with forage and food. In intensive and semi-intensive fish crops, high quantities of organic fertilizers and food are applied to the ponds, so large quantities of organic material (silt) will be deposited in the bottom of the ponds. This causes water quality instability and decreases the pond's productivity. At the end of the crop, the silt should be removed and used in agricultural fertilization. Agricultural productions are reversed in turn in food for fish.

Cultivation of the different herbs used in the agriculture of integrated fish farms

For the integration of a farm, consider the following aspects:

1. To make an appropriate selection of aquaculture and agricultural species (including herbs) that are feasible to grow in the area, depending on their climatic, geographic conditions etc. [13].
2. Plants used for cultivation (herbs) will be the most:

- Highly nutritious possible.
- Acceptance by fish.
- Highly productive crops (75.000 kg/ha annually).
- Easy to operate and operate, that is, it does not require sophisticated crop and crop technology.
- Highly tolerant and easily adaptable to any climatic condition, diseases and various types of soil (Figure 6).

Figure 6: (*Medicago sativa*) Alfalfa; 2: (*Lilian multiflorum*) King's Grass; 3: (*Pistia stratiotes*) Water-lette; 4: (*Euchhornia crassipes*) Water Hyacinth; 5: (*Pennisetum purpureum*) Elephant Grass; 6: (*Sorghum vulgare. Sudanese Variety*) Sudan's Grass. (Photos taken from the Internet).

Integrated aquaculture with cows and worms, (Figure 7)

Figure 7: Integrate aquaculture with agriculture and herbal farming. (Photos taken from the Internet).

Cattle manure is the best substrate for the cultivation of fungi, which are used together in worm cultivation. Worms are used in feeding ducks and fish, as well as for the production of biogas.

Figure 8 shows the relationships between the different elements that become part of the integrated cow-worm-fish system.

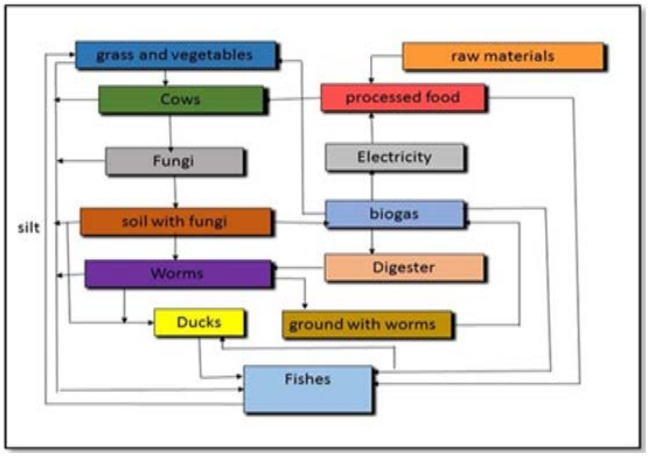

Figure 8: The integrated system fish, cows-worms establishes a closed circulation of energy, with the most rational use of resources.

When 600 to 700 kg of livestock manure is used, more than 300 to 400 kg of grass can be obtained, 1000 kg of fungal substrate (culture medium) is obtained. This substrate can produce 130 to 160 kg of fungi [6].The substrate can be used directly on fish farms, since they have 10 to 10.5% dry protein. The integrated cow-worm-fish system establishes a closed energy circulation, with the most rational use of resources. When we add 40% of the substrate, plus 60% of commercial feeds, 25 kg of fish can be produced, with a conversion factor equal to 40. This substrate can be used in the cultivation of worms and these in turn, in the fish culture [6].

Fish farms of maximum complexity. Fish, Industries-Commerce, (Figure 9)

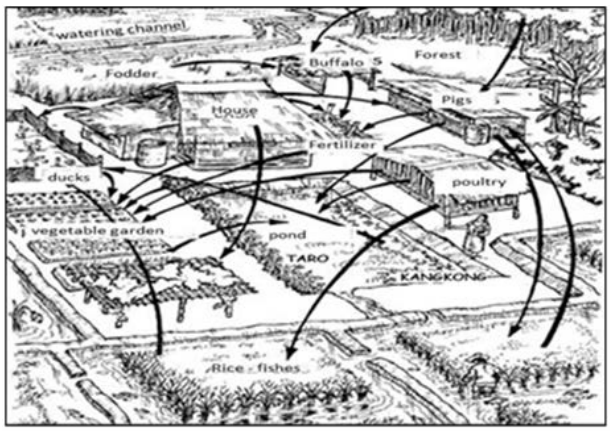

Figure 9: Complex integrated farm. Residues and food flows. (Taken from Integrated Aquaculture Agro. FAO [14].

The basic principle of the integrated farms is the incorporation in the area to be used, of the highest percentage of plant and animal species, which in a harmonious and controlled way, contributes to the maximum formation of human food biomass and to the support of the ecology that generates it. The use and reuse of energy is the main aspect of management. Fish polyculture has its origins in the combination of up to eight species of different ages and sizes in a single lagoon, where frogs, freshwater shrimps and oysters can coexist to produce pearls. It is necessary, for the perfect balance of coexistence of these species, a theoretical and practical knowledge adequate to establish the best controls to achieve the objectives. Integration constitutes a complex system of production, due to the numerous demands imposed by the work with different species simultaneously. (Figure 9) This aquaculture modality of Chinese aquaculture provides the right method for mastering the technique and obtaining productive and economic results by controlling not only an economic benefit of the farm, but also the food contribution of the population.

In order to increase revenue, the system has been integrated with industry and trade, thus allowing the development of fish farms. The economic, commercial and industrial aspects are at the top of the vertical integration of the farms. At the exit of the productive process the chickens and ducks are processed, which will be sold to the restaurants. The skin of the duck and the liver are exported, increasing the variety of agricultural products and thus the optimal efficiency. The domestic waste of the restaurants returns to the farm as a raw material to feed the species included in the integrated system.

Figure 10 shows the connections between the different operations performed on the highest-efficiency integrated farm. The aspects of the recycling of waste by virtue of the feeding of the species that are part of the system, allow a rational use of the energy and its conversion to the biomass used in the human food.

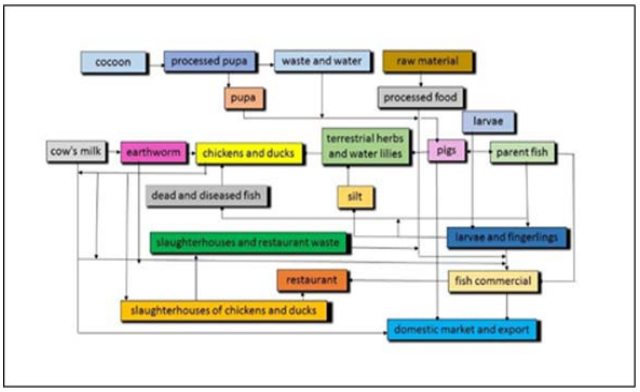

Figure 10: Organization of an Integrated farm for maximum use.

Conclusion

It is shown in this article, that integrated aquaculture is much more than subsystems in reciprocal trophic interaction. According to Yan and Hu [12] Chinese integrated fish farming is so broad in scope and has so many models that there is no comparative farming system in the world. The Chinese system had developed its own characteristics and has attracted world attention. The reason for this is the full system's development and utilization of local natural resources and subsequent production of food and attainment of economic self-sufficiency.

Multitrophic aquaculture integrated in its current interpretation and practical support, is based more on the relationship of a mutualist symbiotic character of a few species, (fish, algae and mollusks), which away from a more complex integration with which is achieved greater efficiency in the use of the wasted energy. The most complete and efficient integration is when the products obtained in their varied qualities are processed in the farm, including the handicraft techniques of smoked, salted fish and meat, preserves of fruits and vegetables, biogas, handicrafts, restaurants, educational visits, etc.

It is not intended to reverse a definition that has been rooted in the

contemporary scientific context. In recent years, many research work has shed light on this ancestral method of aquaculture production from an academic optics, but the idea that integrated aquaculture was conceived many years ago cannot be discarded to achieve harmonic, rational and efficient exploitation in food production. This type of aquaculture calls, not only science, but global food security.

It is to that end where the intentions and attentions of those who see in aquaculture must be addressed, an indisputable resource for achieving greater and better productions on a planetary scale. In a historical context where we intend to produce more with less environmental involvement, integrated aquaculture is shown as a paradigm to use, mainly in countries with little or no technology.

It may be agreed or not with the above, but: Will the definition of integrated aquaculture and integrated multitrophic aquaculture be seen as asemantic phenomenon of appointment, or how two viewing angles other than the same aquaculture phenomenon? Integrated aquaculture puts more attention to the widespread food deficit in the world than to an academic or commercial interest. You can't miss this prospect. Integrated Aquaculture is an in evitable paradigm in a global context where multiple productive processes threaten society and the environment.

It was made possible more than a thousand years ago in China and is currently part of its productive strategy, which has become a support for global aquaculture production. Now, with a long time of delay and as has happened with other Chinese contributions to the knowledge of humanity, take it by the hand and place it in the place where it is most useful.

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