MULTITROPHIC SYSTEM FOR AQUACULTURE PRODUCTION IN FLOATING AND SUBMERSIBLE CAGES

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Abstract: *The multitrophic system for aquaculture production in floating and submersible cages is a highly efficient, innovative biotechnology for the cultivation of different hydrobionts. The integrated production operates in a closed cycle with the aim to increase the economic efficiency of the aquafarm. The effective use of waste organic and dissolved inorganic substances from the feeding of fish, cultivated in rigid wall and net cages - floating and submerged, is accomplished. Cultivated mussels near the cages use waste organic matters. The algae cultivation system is installed after the shellfish cultivation system and they use the dissolved inorganic substances. This cultivation technology ensures sustainable and environmentally friendly aquaculture, while preserving the equilibrium in the aquatic ecosystem.*

Key words: *fish, shellfish, algae, integrated aquaculture, sustainable and environmentally friendly aquaculture*

Introduction

Aquaculture is among the most extensively developing agricultural sectors worldwide (Zaikov, 2008). During the next years, the produced fish would increase to attain 80 million t by 2050 (FAO, 2012). This growth in the sector will be mainly a result from intensive production systems development – fish culturing in net cages and recirculation systems that gain an increasing importance for fish farming (Barcellos et al., 2004; Tal et al., 2009; Martins, 2010).

The culturing of fish in net cages is of major significance for teleost farming and one of most economically efficient technologies. The earliest data about fish farming in cages date back to 1800 from Southeastern Asia, more precisely freshwater river and lake systems of Kampuchea (Coche, 1976; Pantulu, 1979; Beveridge, 1987). Marine net cages aquaculture emerged in the beginning of the 1950s in Japan, when researchers from the fisheries laboratory to the Kinki University farmed the species *Seriola quinqueradiata* R. in net cages (Chua and Tech, 2002). The start of carp farming in net cages dates back to the same period (Kuronuma, 1968).

In Europe, net cage farming of rainbow trout in fresh water began by the end of the 1950s. Norway started production of salmon in the 1960s, while in the early 1970s the researchers from the Institute of Freshwater Fish Farming – Plovdiv laid the foundations of aquaculture in net cages in Bulgaria. Subsequently, large farms were built in the waters of many dams – Ovcharitsa, Kardzhali, Zhrebchevo, Vacha etc. The main farmed species were common carp and rainbow trout (Zaikov and Staykov, 2013, 2014). One of the main disadvantages of hydrobiont production in net cages is the negative impact on the environment manifested by contamination with nutrient wastes, alteration of natural habitats and harm on populations freely living in the water basin (Gross, 1998).

On the present stage of development of Bulgarian aquaculture, mariculture in net cages is not practiced despite the Black Sea coastline. Among the primary causes is the exposed shore with few bays protected from winds as well as the relatively small resistance of currently used floating net cages to rough waters. The cultivation of aquatic plants is also unknown in our country. Mariculture in Bulgaria is based only on cultivation of black mussels (*Mytilus galloprovincialis*).

The purpose of the study was to design a system for complete utilisation of wastes from fish extruded feeds, inorganic and organic substances with full utilisation of solids and solutes through culturing of additional hydrobiont species (invertebrates and plants) which are able to use these substances from their natural environment ensuring a sustainable and environmentally friendly aquaculture with preserved equilibrium in the aquatic ecosystem.

Materials and Methods

The following existing models are analysed:

1. Installation for fish farming built from one or several connected floating or submersible net cages, anchored with at least one anchor through provided tackle. Patent № WO 2014/060107;
2. Aquaculture system for hydrobionts – fish or shellfish. The construction comprises connected pipes and pipe rings, the floating or submersible cage installation is tied with an anchor connected to the installation through an anchoring rope. The system includes randomly situated cages in which different species of fish and invertebrates are farmed. The hydrobionts are fed directly by dispersion of nutrients (feed) with different nutritional and physical properties in the water. Part of them fall on the bottom of the water basin as sediment, while another part, dissolved in the water, are not fully utilised. Patent № WO 2013/095021.

The flaws of existing constructions of floating submersible cages are identified and possibilities for their improvement were analysed.

Design of newly constructed multitrophic aquaculture system

The new multitrophic aquaculture system is designed by improvement of existing installations with floating submersible net cages Patent № WO 2014/060107 and Patent № WO 2013/095021. The diagram of designed multitrophic aquaculture system is drawn in CorelDRAW®. A description of the possible realisation of designed installation is provided.

Results and Discussion

Technical summary of designed multitrophic aquaculture system

The installation for utilisation of inorganic and organic wastes from feeding extruded feeds to fish comprises: three types of cages – with rigid walls, net floating submersible cages and crustacean farming cages, as well as at least two types of plantations for other hydrobiont species, namely bivalves – mussels or oysters, an algal plantation; all of them together and simultaneously submerged in a natural or artificial water basin but situated in a specific order downstream. The arrangement of aquaculture installation elements is as follows: at least one cage with rigid walls, at least two parallel floating submersible cages, placed parallelly or after the rigid walls cage; beneath each of floating submersible cages is attached a rigid-wall net cage for shellfish farming. The two floating submersible net cages could be at water level or submerged in the water. After the three types of cages, along the flow of the basin, plantations for other hydrobionts are arranged. These could comprise at least one system for bivalves (mussels and/or oysters) followed by at least one algal plantation.

The cage with rigid walls is located in the beginning of the system and is supplied with two pipe systems – pumping and supplying, equipped with pumps located one against the other. The beginning of the supplying pipe system is submerged at a depth equal to „a“ (up to 130 cm) under the water level.

Parallelly to or after the cage with rigid walls, in the direction of the water flow, there are two parallel floating submersible net cages made from pipes. Each floating submersible cage is equipped with pneumoelements connected to an air or volatile gas compressor, which fill the pipes with air or water upon a command from the operator. This provides floating of cages or regulates the submergence. Each floating submersible net cage is fixed by at least one anchoring rope to a metal chain, which is on its turn connected to at least one anchor attached to the chain. Beneath each of floating submersible net cages, at least one cage with rigid walls for farming crustaceans is attached.

An exemplary multitrophic aquaculture system

The installation for processing inorganic and organic waste substances from extruded feeds for fish includes: three types of net cages – with rigid walls 1, floating submersible net cages 2 and 3; submersible net cages for crustaceans 4, mussels plantation 5 and algal plantation 6, all submerged in a natural or artificial water basin and situated downstream. The different elements of the system are arranged as follows: the cage with rigid walls 1 is parallel or after the two floating submersible cages 2 and 3, which are adjacent one to the other. Beneath each of floating submersible cages 2 and 3, a rigid-wall net cage for farming crustaceans 4 is attached. After the three types of cages are arranged the mussel plantation 5 and algal plantation 6 (Fig. 1 and Fig. 2).

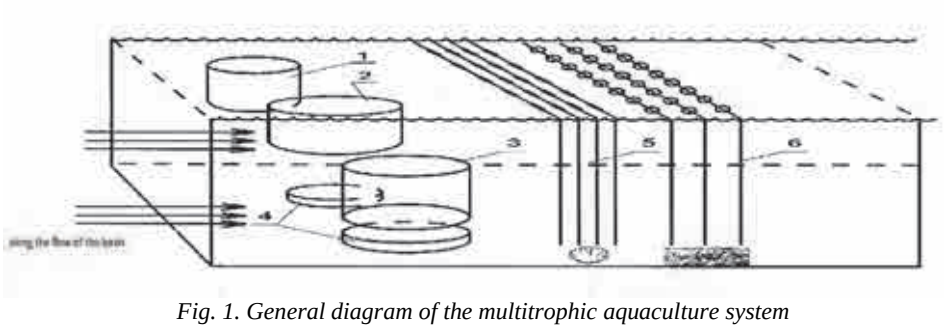

Fig. 1. General diagram of the multitrophic aquaculture system

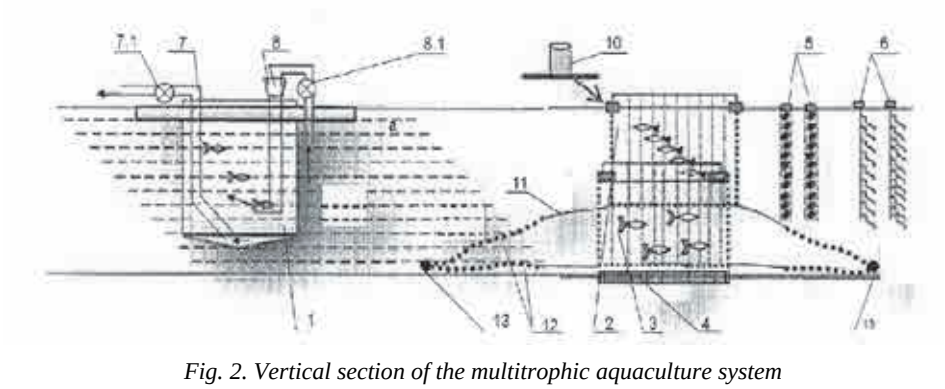

Fig. 2. Vertical section of the multitrophic aquaculture system

The cage with rigid walls 1 has a diameter of 6 m and depth of up to 4 m. It is made from rubber foil 3-4 mm thick. The cage is supplied with two pipe systems: pumping 7 and supplying 8, located one against the other. The beginning of the pumping system 7 is at cage bottom, and its end – outside the cage, in the beginning of the installation and at the same time, in the upper part of the natural flow of the water basin, along which the system is arranged. The pumping system 7 is elaborated from a HDPE pipe with diameter 100 mm. At the pumping system 7 exit, there is a pump 7.1 for waste water, containing dissolved inorganic and organic substances. The beginning of the supplying pipe system 8 at the opposite part of the cage with rigid walls is submerged at 30 cm beneath the water level and above it, there is a pump, supplying water 8.1. The exit of the supplying system 8 is in the middle of the rigid-wall cage 1.

Parallelly or consecutively to rigid-wall cage 1, two floating submersible net cages 2 and 3 made from pipes, are situated downstream, one close to the other (Fig. 3).

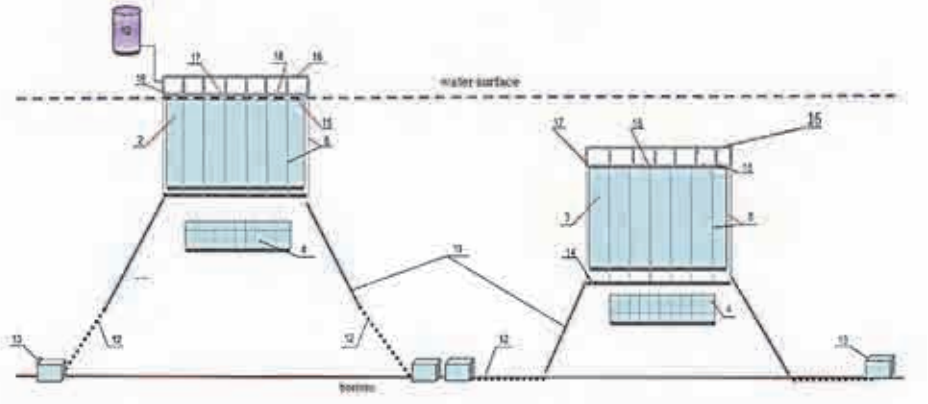

Fig. 3. Diagram of a floating submersible net cage

Each of floating submersible net cages 2 or 3 is constructed from two rings of HDPE pipes situated one over the other - 15 and 16, and a metal ring 14 located under the cages, at the base. Ring 16 is also a kind of rail. The weight of the metal ring 14 is calculated in a way that it would be lower than the buoyancy of the pipe of ring 15. Water valves 17 and air valves 18 are mounted on ring 15 (that forms the so-called path), in order to be filled with water, gas or air through compressor 10 and this, to make floating submersible net cages 2 or 3 either to flow or to become submerged. Between the contour of metal ring 14 of the net cage and the ring that is on the water surface 15, ropes connecting both rings are stretched. To each of floating submersible net cages, are mounted and anchoring rope 11 connected to a metal chain 12 and at least one anchor 13 attached to the chain. Anchoring ropes 11 are constructed in order to maintain the floating submersible net cages either floating or submerged 3 (Fig. 2). The dimensions of the floating submersible net cage are: diameter 12 m and depth 6 m, while mesh holes are greater than 20/20 mm, the height of the dry part of the mesh is 0.80 m. Each floating submersible net cage 2 or 3 is equipped with a movable cap with a zipper for easy placement and removal, that is able to withstand up to 4000 kg per linear meter. To reduce the risk from destruction from meteorological changes, each net cage could be submerged after receiving a signal for wind waves from sensor 19. Anchoring is similar to that of traditional floating cages by ropes 11, connected to a metal chain 12 and attached to the bottom of the basin with concrete anchor 13. Beneath the floating submersible net cages is attached at least one cage for farming

crustaceans 4. After the net cages, at least one mussel plantation is situated, followed by at least one algal plantation 6. The construction of the mussel plantation 5 is standard and anchored to the bottom of the water basin with concrete anchors. The number of length of the production system would depend on the production capacity of the aquafarm. The construction of the algal plantation 6 is standard, with cultivation ropes attached to concrete blocks on the bottom and anchored with a concrete anchor. Floats are attached to cultivation ropes.

The aquaculture system operates as follows: Small fish with initial live weight minimum 1.0 g are farmed in the cage with rigid walls 1. They are reared to average individual live weight of minimum 20-30 g, and then they are transferred into floating submersible net cages 2 and 3. In them, fish is cultured for consumption. Floating submersible net cages 2 and 3 are used as floating net cages in water basins with small wave height and in basins where wind waves are not dangerous to the construction during the greater part of the vegetation period. During the periods with high waves, which are dangerous for the normal work of floating submersible net cages 2 and 3, the system for submerging is switched on to sink the cages below the water level where they are protected from destruction. The submergence at a specific depth occurs after the sensor 19 detects a wind wave stronger than a predefined value and automated switching of the system for cage submergence by opening water valves 17 and air valves 18 along the HDPE pipes of cage's ring 15. The pressure of the water pushes the air from pipes, they are gradually filled with water, which acts as ballast and brings the cage under water. After the wind waves become calmer, the sensor 19 signal triggers the opposite procedure and the net cage floats on the surface. The compressor 10 is switched, air comes through air valves 18 into pipes, which pushes water through the water valves 17 and thus, the net cage is brought to the surface. It remains floating after closure of all water and air valves 17 and 18.

The water in the cage with rigid walls 1 is contaminated as a result of farming small fish, and contains inorganic and organic waste substances. Periodically, through the pump 7.1, the water from cage 1 is pumped out of the cage and is replaced with water from the basin sucked by pump 8.1 before net cage 1. With the flow, the water exiting from pump 7.1 goes further to mussel plantation 5 together with remnants from the feed of small fish, and part of it falls on the bottom in cages with crustaceans 4. Similarly, the remnants from extruded fish feeds in floating submersible net cages 2 and 3, and other wastes from fish farming containing organic and inorganic matter, come to the bottom to crustacean cages 4, and the remaining part of wastes is brought to mussel and algal plantations and are finally utilised by them. The natural basin flow works by transporting the mass of dissolved and insoluble inorganic and organic substances and feed remnants fro fish cages to cages with crustaceans, cages with mussels and ultimately, algae. Thus, a multitrophic aquaculture system is realised, e.g. installation for cultivation of various hydrobiont species – fish, molluscs, algae. An integrated production system and close-cycle production in the aquafarm are obtained. The feeding schedule of different hydrobionts is optimised through efficient utilisation of organic and dissolves inorganic wastes from extruded feeds. Mussels from plantations 5, which are adjacent to cages and arranged downstream, e.g. from cages in the direction of mussel plantations 5, use organic wastes. The algal plantation which is situated after the mussel plantation 5, allows utilisation of dissolves inorganic matter. Thus, a sustainable and ecologically friendly aquaculture is achieved with preserved equilibrium in the water ecosystem. The algal plantation 6 should be planted with good-quality seedlings, without damage or whitening of the thalli.

The advantage of the aquaculture system consists in the efficient processing of waste waters contaminated with remnants from fish farming (feed) profiting from the natural flow

of the water basin with regard to the subsequent bioutilisation of wastes by other hydrobiont species through specific arrangement and connection of aquaculture system elements, taking consideration on the kind and speed of currents in the water basin. The combination of these two factors allows for at least two-level (three-level etc.) natural and complete cleaning of water from fish feed wastes, dissolved and insoluble substances and at the same time, maximum utilisation of fish feeds by production of other hydrobionts. A possibility for efficient bioprocessing of organic and inorganic wastes is created. The aquaculture system operation permits biological cleaning of water, utilisation of nutrients of up to 100%, maximum use of feed qualities. The economic efficiency is improved, and a sustainable ecologically friendly production of the aquafarm is ensured while preserving the equilibrium in the aquatic ecosystem.

Conclusion

The constructed multitrophic aquaculture system is used in ecologically selected fish farming and hydrobiont farming in general. It is an element from the optimisation of feeding programme of different hydrobionts with efficient utilisation of organic and dissolved inorganic wastes from feeding extruded feeds to fish of various ages in net cages, cultivation of crustaceans, mussels and algae. The production cycle of aquaculture production is closed with efficient utilisation of organic and dissolved inorganic feeding wastes.

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