

MOBILE, MODULAR TYPE RECIRCULATION INSTALLATION, FOR INTEGRATED AND SUSTAINABLE CULTIVATION OF HYDROBIONTS AND PLANTS

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Abstract: *Biotechnology is a mobile, modular, recirculating system for integrated cultivation of hydrobionts and plants under conditions of periodic change of location of the facilities and its product-volume modeling, by addition and / or removal of operating modules, depending on the specific demand on the market.*

The production system is in the field of sustainable cultivation of hydrobionts and low-stemmed plants - flowers, herbs and vegetables, in places with limited water flow, providing mobility and small-scale farming as an additional business. This facility is for economically efficient and sustainable growing of hydrobionts, with the optimal using of waste water in the process of cultivation of plant species. The mobile installation provides local needs for fresh products for tourist complexes, mountain resorts and other similar places.

Key words: *mobile recirculating installation, recirculation system, aquaculture, hydrobionts, vegetables*

Introduction

Recirculation systems for hydrobiont farming are very popular and basic for sustainable aquaculture. The farming of different species in closed recirculation systems eliminates the negative impact of fish farming on the environment and guarantees ecologically friendly production (Spotte, 1979). The farming of fish in such systems is continuously increasing (Piedrahita and Conklin, 2004; Barcellos et al., 2004, 2006; Schneider, 2009; Summerfelt et al., 2009; Tal et al., 2009; Martins, 2010). According to cited researchers, this is due to the considerable reduction of land areas in closed aquaculture systems for fish (Duning et al., 1998; Masser et al., 1999). Another advantage is the possibility to build the farm in a place with limited water resources or close to retail markets to save time and transportation costs (Hutchinson et al., 2004). The organisation of production, farm management and security is more efficient (Todorov, 1989; Swar and Pradhan, 1992; Losordo, 1999; Staykov, 2001; Kidd, 2001; Hutchinson et al., 2004; Summerfelt et al., 2004; Timmons et al., 2004).

With respect to the constant monitoring and control of water pollution, recirculation systems ensure a better environmental sustainability than traditional aquaculture systems. Possibilities for integrated aquafarming and utilisation of waste waters for hydroponic farming of various crops are given (Summerfelt et al., 2004). Another important advantage is the offered by the possibility for farming various hydrobiont species (fish, crabs, shrimps, mussels etc.) in line with market demands (Timmons et al., 2002).

Combined farming of fish and plant species is possible in recirculation systems, known as aquaponics (Timmons et. al. 2002; Diver 2006).

Valuable nutrients left from fish feed are generated through microbiological degradation of organic wastes and absorbed directly by plants cultivated without soil (Rakocy et al. 2012). In aquaponic systems, plants are cultured with their roots submerged partially or entirely into water rich in nutrients coming from fish farming in the system (Dalrymple 1973). Lennard and Leonard (2006) found out that after passing through the plant section, water is cleaned from toxins and contains more oxygen, and suitable to be returned back to the fish farming section. Aquaponic systems are a modern biotechnology with huge potential allowing for production of ecologically pure cultures. This method of food production is the only one eliminating the use of chemicals (Salm et.al 2013) The lack of access of weeds and fungi to the system should be also noted, hence no herbicides and fungicides are necessary. Various fish species are farmed in aquaponic systems - tilapia, barramundi, silver perch, some catfish species, jade perch, Murray cod, crabs, shrimps, as well as cultivated plants as green leafy vegetables (lettuce, Chinese cabbage etc), beans, green peas, curly kale, radishes, strawberries, melons, onions, turnip, herbs.

Materials and Methods

Analysis of an existing model of the aquaponic recirculation system

The prototype is a stationary aquaponic system (BG utility model № 2690U1). The flaws of the existing model are analysed and possibilities for its improvement are discussed.

Design of a modular type mobile recirculation system

The new mobile modular type recirculation system is designed from the existing stationary aquaponic system (BG utility model № 2690U1). Diagrams are drawn in CorelDRAW®. Description of the possibilities of the model is provided.

Results and discussion

Technical summary of designed multitrophic aquaculture system

The system comprises at least three modules placed in one mobile container K. The number of the first module of the system is from 1 to „n“, and that of the second module: from 1 to „m“. The number of containers K and configuration of modules inside is variable and is determined by the equation $K = (n-1)+(m-1)+1$, depending on specific conditions and operator's desire.

Any module M_{1n} is situated inside container K, made of thermoinsulating panels and contains at least one tank for hydrobiont farming, connected with technological appliances of the inlet and outlet pipe systems of the installation and is equipped with ventilation, lighting and air conditioning units.

Any module M_{2m} is situated inside container K, made of thermoinsulating panels and contains at least one aquaponic tank for cultivation of plants, connected with technological appliances of the inlet and outlet pipe systems of the installation and is equipped with ventilation, lighting and air conditioning units as well as system for water dispersion - fogger.

Module M_3 is placed inside container K made of thermoinsulating panels and is equipped with ventilation, lighting and air conditioning units. The three modules are arranged consecutively, are technologically connected in a way such as module M_3 is between M_1 and M_2 , and connected with them via pipes, electric circuit and air conditioning unit. Module M_3 contains a mechanical filter with a sludge discharge tap; the mechanical filter inlet is connected to the outlet pipe of module M_1 . After the mechanical filter, a biological filter with aerating unit is connected by a pipe system, and after the biofilter – a

collecting tank. The latter contains a heater, system for pH correction and unit for trace elements supplementation. The system for pH correction comprises pH electrode, controller, tanks with alkaline or acid solutions and peristalsis pump. The unit for trace elements supplementation has a mixer. At the outlet, along the pipe system, a pump is situated on the collecting tank. Through the pipe system, the pump is connected to UV filter and after it, a 3-way valve is mounted. The first port of the 3-way valve is connected to the tank for hydrobiont farming through a pipe system, and the second port – to the aquaponic tank also through a pipe system. Supply of fresh water is ensured in the collecting tank. The ventilation, lighting and air conditioning units of each of containers K inside which any of modules M_1 , M_2 or M_3 are arranged, are connected in a common system or function independently for individual containers depending on the specific design and operator's will. At the roof of at least one of modules, photovoltaic elements are mounted and connected to the electric circuit of the installation. In line with economic justification, the system could be expanded with additional modules M_{1n} and M_{2m} . A specific variant providing the mobility of the system is its arrangement either movable or stationary on a platform of a suitable transport vehicle.

Containers K could be made from transparent or opaque polycarbonate polymer.

An advantage of the system is the possibility for its transportation and correction of its capacity according to the needs by adding or removing modules. The performance of the system is increased by virtue of pH control, which has a significant effect on the utilisation of nutrients by plants as well as for the growth and development of hydrobionts. Conditions for self-sufficiency of the system are created by profiting on the solar energy, making it independent of the power grid and more environmentally sustainable. The presence of air conditioning unit permits to control the air temperature and humidity allowing for year-round production.

The advantage of the system is the efficient processing of waste waters in two directions – purification of waters contaminated by hydrobiont farming with preservation or enrichment with substances beneficial for aquaponic farming of plants, and vice versa: purification of water from aquaponic farming with preservation or enrichment with substances beneficial for hydrobiont farming.

An exemplary multitrophic aquaculture system

An exemplary design of the system comprises three modules M_1 , M_2 and M_3 each supplied with ventilation 2, lighting 4 and air conditioning 5, connected in a common control circuit. The system includes interconnected tank for hydrobiont farming 1, inside module M_1 , a purification block inside module M_3 , and three consecutively connected aquaponic tanks 6 for cultivation of plants inside module M_2 (Fig. 1; Fig. 2).

The tank for hydrobiont farming 1, aquaponic tanks for plants 6 and collecting tank 10, which is situated in module M_3 , are consecutively connected through a pipe system 3. The dimensions of modules M_1 , M_2 and M_3 are suitable for transportation. Module M_1 is placed inside a container made from thermoinsulating panels, one hydroponic tank 1 for hydrobiont farming is connected with the technological appliances of pipe system 3, namely the inlet pipe system 3.1 and the outlet one 3.2.

Module M_2 is inside a transparent polycarbonate plastic container and comprises three aquaponic tanks 6 for cultivation of plants arranged consecutively by technological appliances of the inlet and outlet pipe systems 3.3 and 3.4. Module M_2 is also supplied with a fogger (water dispersion system) 7.

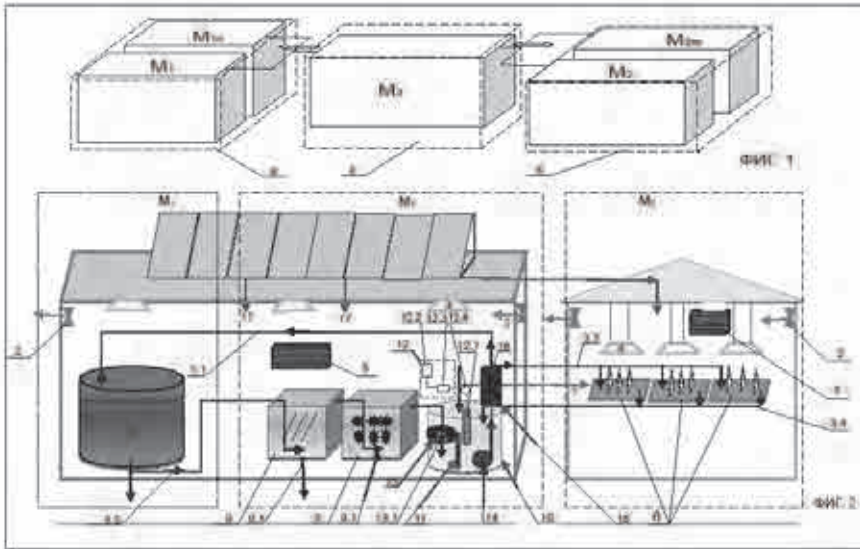


Fig.1. General scheme of the installation

Fig. 2. Components of the modules in the exemplary embodiment and the technological links between the elements

Module M_3 is located inside a container made of thermoinsulating panels. The three modules are consecutively arranged, interconnected, and module M_3 is located between M_1 and M_2 , and connected with the other two modules by a pipe system 3, comprising inlet part 3.1 and outlet part 3.2 for module M_1 and inlet and outlet parts: 3.3 and 3.4 respectively, for module M_2 . Module M_3 contains a mechanical filter with a sludge discharge tap 8.1; the mechanical filter inlet 8 is connected to the outlet pipe 3.2 of module M_1 . After the mechanical filter 8, a biological filter 9 with aerating unit 9.1 is connected by a pipe system, and consecutively to the biofilter 9 – a collecting tank 10. The collecting tank 10 contains a heater 11, system for pH correction 12 and unit for trace elements supplementation 13. The system for pH correction 12 has consecutively connected pH electrode 12.1, controller 12.2, tanks with alkaline or acid solutions 12.3 and peristalsis pump 12.4. The unit for trace elements supplementation 13 has a mixer 13.1. At the outlet, along the pipe system, a pump 14 connected to UV filter 15 after which is mounted a 3-way valve 16, is situated on the collecting tank 10. The first port of the 3-way valve 16 is connected to a tank for hydrobiont farming through a pipe 3.1, and the second port – to the aquaponic tank 6 also through pipe 3.3. Supply of fresh water is ensured in the collecting tank 10.

The ventilation 2, lighting 4 and air conditioning units 5 of any of modules M_1 , M_2 or M_3 could be connected in a common system or function independently for individual modules. At the roof of at least one of modules, photovoltaic elements 17 are mounted and connected to the electric circuit of the installation. The system is situated on a platform on a 25-tonne truck.

The system operates as follows(Fig. 3): The water from hydrobiont farming tank 1 goes through the outlet pipe 3.2 and passes consecutively through the mechanical filter 8 and biological filter 9 supplied with aerator 9.1. The mechanical filter 8 is equipped with elements decreasing water flow rate and a sludge discharge tap 8.1 so wastes are removed from the system. The biofilter 9 has elements with a large surface area permitting colonisation with appropriate bacteria. The water in the biofilter 9 is actively aerated through aerator 9.1 to ensure dissolved oxygen concentration optimal for bacterial growth and hence, biological purification. After reduction of ammonium compounds, nitrites and phosphates, water comes to the collecting tank 10. There, the water is heated by the heater 11, its pH is controlled and corrected by the system for pH correction 12, trace elements are supplied through unit 13. After preparation of the water, through pump 14 it is directed through UV filter 15 and 3-way valve 16 back to fish farming tanks 1 or plant cultivation tanks 6. In the latter case, according to specific technological requirements, the fogger 7 disperses water in module M₂ and thus, creates air humidity suitable for plants development. As modules are equipped with ventilation 2, lighting 4 and air conditioning system 5, operator could set optimum working microclimate parameters – lighting intensity, air humidity, temperature and pressure. On the roof of containers, photovoltaic panels 17 mounted on modules M₁ and M₂ cover the needs from electrical energy. Condensed used water in module M₂ returns back to collecting tank 10 through pipe 3.4 where undergoes processing and through pump 14 and UV filter 15, through 3-way valve 16 enters inlet pipe 3.1 and then, the hydrobiont farming tank 1 and thus, the cycle is closed. The installation is fitted for single-circuit work mode, but in this case, its efficacy is lower.

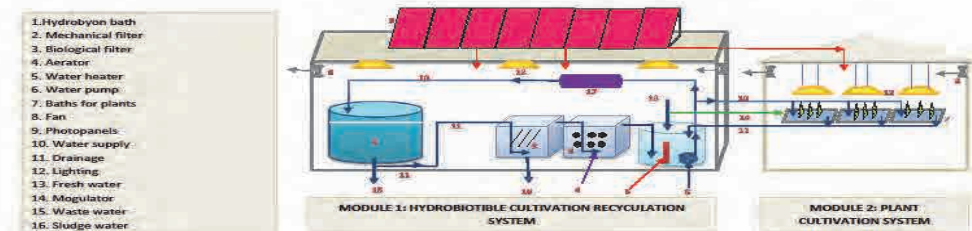


Fig. 3. Scheme of mobile modular type recirculation system for integrated and sustainable cultivation of hydrobionts and plants

Conclusion

The designed modular-type recirculation system for integrated cultivation of hydrobionts and plants is used for ecological cultivation of hydrobionts in farms together with plants (flowers, herbs, decorative bushes, vegetables) and various halophytes at farms, as well as for small-size cultivation of different algal species in different hardly accessible

places, in mobile small farms. It is an element from the optimisation of feeding schedule of different hydrobionts with efficient utilisation of inorganic and organic wastes. The mobile, module-type recirculation system is a tool for production of hydrobionts with efficient waste waters utilisation through plant cultivation for meeting local needs from similar fresh products in remote tourist complexes, huts, mountain resorts and alike.

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