Aquaponics installation using soil in waste water from fish farms

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Abstract. The paper presents the results of the study on the cultivation of lettuce (*lactuca sativa kucheryavec odesskiy*) in an aquaponics installation using soil in the conditions of closed water supply systems installations developed on the basis of the Russian-Scandinavian aquaculture center of the BiRH Institute of K. G. Razumovsky Moscow State University of Technologies and Management, Moscow. As a result of which, growth and productivity indicators of lettuce in an aquaponics installation were obtained. Hydrochemical studies made it possible to determine the efficiency of consumption of nitrates and phosphates at the maximum plant phytomass and to calculate the optimal power of the hydroponic installation for a given volume of fish tanks.

1. Introduction
The new doctrine of food safety (approved by Decree of the President of the Russian Federation of 01.21.2020 N 20) provides for increased quality control and food safety, its compliance with the mandatory requirements of technical regulations of the Eurasian Economic Union. One of the current directions of ensuring food security in Russia is the further development of aquaculture in the country with the aim of obtaining tasty, healthy, environmentally friendly products at socially affordable prices in the required volumes.

An innovative type of development can be ensured by industrial aquaculture, in which technologies are used that use high fish landing densities, which significantly increase the output per unit volume - this is fish farming in closed water supply installations (CWSI). Industrial aquaculture technologies make it possible to obtain cyclical year-round planned production, with a high degree of automation of production processes, to expand the boundaries of the geographical location of aquaculture facilities, obtaining ecologically friendly products that are not infected with parasites [1,2].

The main disadvantage of the use of CWS is the high cost of farmed fish, which is about 4-5 times higher than the self- cost of pond fish and almost 2 times higher than the self- cost of cage production [3].

Aquaponics - the integrated cultivation of fish and plant products, is one of the promising ways to increase the profitability of fish farming in CWSI.

The basis of production is the use of natural processes of vital activity of freshwater aquaculture as a growth medium for industrial plants. During the process, plants consume the necessary products of excretion of living organisms - chemicals (nitrogenous, potassium, phosphorus compounds, carbon
dioxide, etc.), dissolved in water, and - at the same time, naturally purify and enrich it with oxygen. In the production process, the need to use various chemical fertilizers is eliminated, with a complex system for their dosing and storage: the process of chemicalization, processing and purification occurs naturally and in a closed cycle. Thus, aquaponics imitates the natural swirl of nutrients in nature. They are balanced ecosystems capable of producing organics that do not contain inorganic minerals, often found in vegetable crops grown by traditional methods [4].

Most modern aquaponic systems are a type of hydroponics, where plants are grown without soil and these systems are included in a closed cycle of water circulation with fish breeding tanks. But unlike hydroponics, where the plant receives from the solution all the necessary nutrients in the right quantities and exact proportions, the main problem in aquaponics is the exact observance of the fragile balance of the artificially created ecosystem, combining the difference, but the interdependence of the characteristics of water - a vital environment in the symbiosis of animals, land plants and microorganisms. And, as a rule, water from fish tank does not contain all the necessary macronutrients and trace elements for the full growth of land agricultural plants [5, 6].

Purpose of the study: to create an aquaponics installation using soil included into the system of replaceable water from fish-breeding tanks of CWSI.

Research objectives:
1. To create a technological scheme and a prototype of an aquaponics installation using soil included in the system of replaceable water from fish-breeding tanks of ultrasonic protection.
2. To conduct a study on the cultivation of salad products on the created prototype, and obtain results on the quality and quantity of products for the applied biotechnology.
3. To conduct hydrochemical researches of the consumption of the main nutrients (nitrogen and phosphate compounds) in the aquaponics installation, in order to calculate the possible received plant products at the enterprises with CWSI.
4. Based on the studies, give practical recommendations on optimizing this biotechnology for the production of crop products under the conditions of CWSI.

2. Materials and research methods
On the basis of the Institute of BiRH of K. G. Razumovsky Moscow State University of Technologies and Management an aquaponics system was developed at CWSI which eliminates this problem. The main feature of this system is that it is not included in the closed cycle of water circulation with fish breeding tanks, but in the system of replaceable water, which is 10% daily of the total working volume of CWSI, and accordingly, water after passing through the aquaponics installation does not go to the fish breeding tanks. It is removed to the sewage system. This feature made it possible to use soil, which is a source of trace elements missing in water, for the full growth of plants.

![Figure 1. Schematic diagram of an aquaponics installation using soil.](image-url)
The experimental aquaponics installation consists of PVC pipes with a diameter of 110 mm and a total length of 6 m installed on a shelving unit, through which water from fish tanks is discharged into the sewage network. Throughout the length of the pipe, holes were drilled for containers for vegetable products, which consist of two plastic tanks of 150 ml volumes. The lower tank, to prevent erosion of the soil by water, is 1/3 filled with coconut fiber, which also performs two important functions: creating a favorable oxygen regime for the roots and at the same time is a substrate for microorganisms that provide more efficient root nutrition of cultivated plants [7]. The upper tank was completely filled with universal soil for vegetable roots. The lower part of both tanks is perforated for free penetration of the root system of the grown crops into the aquatic environment (figure 2).

![Figure 2. Experimental aquaponics installation at the Institute "Biotechnology and Fisheries of K. G. Razumovsky Moscow State University of Technologies and Management, Moscow.](image)

To illuminate the hydroponic installation, 4 LEDs luminaires ULI-P17-14W / SPLE IP20 WHITE 870 mm length, Uniel trademark, were used for plants. They provided illumination of 8000 lux. The light mode was 12 hours. In an experiment on growing vegetables in an aquaponics, leaf lettuce (lactuca sativa kucheryavec odesskiy) was used. Growing time was 30 days from the time of full germination. The water flow through the aquaponics unit was 60 l/h, the water temperature was 25 C. Water was supplied directly from the biofilter to the aquaponics installation. The total volume of fish breeding tanks was 14 m3, which contained warm-water objects of tilapia aquaculture (Oreochromis mossambicus) and African clari catfish (Clarias gariepinus). To determine the quantitative consumption by plants of nitrogen and phosphorus of their water, and to approximate the possible optimal capacity of the aquaponics installation at these fish breeding tanks, at the inlet and outlet of water from the aquaponics, hydrochemical indicators of water for the content of nitrates (the main source of nitrogen) and phosphates were studied. Hydrochemical researches were carried out on the 29th day of the experiment, when the plant phytomass was maximal, and, accordingly, the nutrient consumption from water was maximal. Standard research methods were used in the work: the concentration of nitrates in water was determined by the potentiometric method and phosphates by the spectrometric method [8], the indicator of plant illumination in lux was determined using PH 300 light meter. At the end of the experiment, morphometric parameters of plants were measured: height and crude plant phytomass.
3. Research results and discussion
At the end of the experiment, lettuce (*lactuca sativa kucheryavec odesskiy*) growth indicators had the following values (table 1). On average, during the experiment, the mass of one plant was from 105 to 130 grams, the average weight indicator was 120 grams. The minimum height of the plant is 24 cm, the maximum is 32 cm, the average value is 27 cm. The yield in the experiment was 960 g. per meter of water installation per month or 11.52 kg per year. During the experiment, the observed plants showed no visible deviations of development indicators.

Table 1. Growth and productivity indicators of leaf lettuce (*lactuca sativa kucheryavec odesskiy*) in an aquaponics installation using soil.

| Indicators                           | Value       |
|-------------------------------------|-------------|
| Seedling density cm                 | 12          |
| Duration of the growing season, 30 days |            |
| Mass of a mature plant, gr          |             |
| Min.                                | 105 gr      |
| Med.                                | 120 gr      |
| Max.                                | 130 gr      |
| Plant height                        |             |
| Min.                                | 24          |
| Med.                                | 27          |
| Max.                                | 32          |
| Mass of the root system, gr         |             |
| min.                                | 24          |
| med.                                | 30          |
| max.                                | 34          |
| Productivity gr. per month total    | 5760        |
| Productivity g / m per month        | 960         |
| Productivity kg / m per year        | 11.52       |

To determine the optimum volume of plant products produced in an aquaponics installation in CWSI, the most reliable method, in our opinion, is to calculate the quantitative consumption by plants of the main biogenic compounds contained in the waste water of the CWSI to the volume of water passing through it. The results of hydrochemical studies of water at the inlet and outlet of the aquaponics installation showed that, with a maximum plant phytomass, the consumption from water was: 10% of phosphates (2.1 mg / l and 1.9 mg / l, respectively) and 7% of nitrates (11.54 mg / l and 10.8 mg / l), 31% nitrites (0.163 mg / l and 0.113 mg / l), 8% ammonium (0.24 mg / l and 0.22 mg / l) (table 2). Accordingly, the results received allow us to calculate the optimal capacity of the aquaponics installation for these fish breeding tanks using the main power sources i.e. on phosphates and nitrates. Based on the fact that the experiment used an aquaponics unit of six meters of working length, for full phosphorization of plants with phosphate it is necessary to have a working length of 60 m, and for the complete consumption of nitrates 75 m of working area is required. Accordingly, for these fish breeding tanks with a volume of 14 m3, the optimal working length of the aquaponics installation will be 60 m, which will make it possible to produce about 700 kg / year of leaf lettuce (*lactuca sativa kucheryavec odesskiy*). It is also important to note that the use of this aquaponics installation will completely remove phosphates and nitrites in waste with CWSI as well as reduce the concentration of ammonia by 80% and nitrates by 70%.
Table 2. Hydrochemical parameters of water in an aquaponics installation using soil grunts.

| indicators                  | at the inlet into the aquaponics installation | at the outlet from aquaponic installation |
|-----------------------------|-----------------------------------------------|------------------------------------------|
| temperature t°C             | 27                                            | 27                                       |
| pH                          | 7.1                                           | 6.9                                      |
| Ammonium (NH4 +), mg / l    | 0.24                                          | 0.22                                     |
| Nitrites (NO2-), mg / l     | 0.163                                         | 0.113                                    |
| Nitrates (NO3-), mg / l     | 11.554                                        | 10.8                                     |
| phosphates (PO43-), mg / l  | 2.1                                           | 1.9                                      |

The features of this aquaponic installation, are that it is not included into the closed cycle of water circulation with fish tanks and the use of soil allows to increase the production of vegetable products through the use of various biological fertilizers in soil, for example, such as vermicompost or worm juice [9]. It is possible to receive them directly on aquaponics waste in the form of root biomass, and on sapropel, which is removed from biofilters during planned treatment works. With the introduction of such biotechnology, in addition to receiving fertilizers and increasing plant production, it becomes possible to use valuable feed additives for aquaculture objects in the form of biomass of technological compost worms [10].

4. Conclusion
As a result of the researches under conditions of CWSI with thermophilic aquaculture objects 1 m working length, 960 gr. of finished products of lettuce (lactuca sativa kucheryavec odesskyi) were received within 30 days in the experimental aquaponic installation using soil. The results of hydrochemical researches in the aquaponics installation showed that, at the maximum plant phytomass, 10% of phosphates, 7% of nitrates, 31% of nitrites and 8% of ammonium contained in water were consumed from the water, which allowed us to calculate the optimal capacity of the aquaponics installation for this CWSI with a volume of 14 m3, which was 60 m working length and 700 kg / year of finished products of leaf lettuce, while this will completely remove phosphates and nitrites in wastewater with CWSI, as well as reduce the concentration of ammonium by 80%, nitrates by 70%.

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