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Considerations upon energetic efficiency of a recirculating aquatic system (RAS) for super intensive fish culture

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Abstract. The efficiency of the aquaculture using recirculating systems depends on many factors among which the most important it is the energy consumption of the system. To assure a high level energy conservation in an aquatic recirculating system, the intensity of water recirculation must be maximized, but this leads to a increasing of the consumed energy for water circulation. That is why is required a rigorous analysis for the energetic consumption for a system of this type and establishment of optimum solutions to minimize the consumption. This paperwork presents a detailed analysis of the energy consumption for a recirculating aquatic system for fish breeding, as well as considerations and solutions for optimization of the energy consumption.

key words: fish breeding, super intensive, system, aquatic, energetic consumption.

Rezumat. Eficienţa acvaculturii practicată in sistemele cu recirculare depinde de mai mulţi factori, printre care cel mai important este energia consumată de sistem. Pentru a asigura un grad de conservare al energiei ridicat, intr-un sistem acvacol recirculant, trebuie maximizat gradul de recirculare al apei. Dar acest lucru conduce la creşterea energiei consumate pentru vehicularea apei. Din acest motiv se impune o analiză riguroasă a consumului energetic al unui astfel de sistem şi stabilirea soluţiilor optime pentru diminuarea acestuia. Lucrarea prezintă o analiză detaliată a consumului de energie al unui sistem acvacol recirculant de creştere superintensivă a peştilor, precum şi consideraţii şi soluţii în direcţia reducerii acestuia.

Cuvinte cheie: creşterea peştilor, superintensiv, sistem, acvacol, recirculant, consum energetic.

Résumé. L'efficacité de l'aquaculture pratiquée dans les systèmes avec recirculation dépend de plusieurs facteurs, parmi lesquels le plus important est l'énergie consommée par le système. Afin d'assurer un haut degré de conservation de l'énergie dans un système acvacol recirculant, il faut maximiser le degré de recirculation de l'eau. Mais cela conduit à une augmentation d'énergie pour véhiculer l'eau. Pour cette raison, il exige une analyse rigoureuse de la consommation d'énergie d'un tel système et établir les meilleures solutions pour la réduire. Le papier présente une analyse détaillée de la consommation d'énergie d'un système acvacol recirculant pour la croissance super intensive des poissons, ainsi que des considérations et des solutions pour la réduire.

Mots-clés: croissance du poisson, super intensive, système, acvacol, recirculant, consommation d'énergie.

Introduction. Traditional aquaculture production in ponds requires large quantities of water and as well as vast land surfaces. For flooding a pond with a surface of 1 ha are required approximately 9500 mc of water, and to compensate for evaporation and seepage a same amount of water is needed. In this conditions to produce 5000 kg fish/ha the water consume will be very high, about 0.9 mc water/kg of fish. That's why in many of Romania areas pond aquaculture is not possible due to the limited water reserves or the lack of fields suitable for pond construction.

Recirculating aquaculture production systems may offer an alternative to pond aquaculture technology. Through water treatment and reuse, recirculating systems use a fraction of the water required by ponds to produce similar yields. Because recirculating systems usually use different types of tanks dense populated, to obtain the culture product, the requirement concerning the area of land needed is also much smaller than in the traditional aquaculture.

Aquatic crop production in tanks where the environment is controlled through water treatment and recirculation is an issue studied since the 70's, when the first types of these systems had developed. Although these technologies have been costly, claims of impressive yields with year-round production in locations close to major markets are important arguments to approach aquaculture in recirculating systems.

An aquatic recirculating system for fish breeding it's a partially closed system, which trough water treatment and recirculation allows the breeding of the aquaculture product in controlled environment conditions. Water treatment from the systems consists in solid waste removal, oxidation of ammonia and nitrite-nitrogen, carbon dioxide removal and water disinfection. In Figure 1 the technological scheme of a recirculating system for super intensive fish breeding is presented.

Main technological equipments used for water treatment are: mechanical filters, biological filters, aeration/oxygenation devices and UV filters. To create proper environment conditions for fish breeding it is necessary to assure a adequate quality of the recirculation water (Bura 2008).

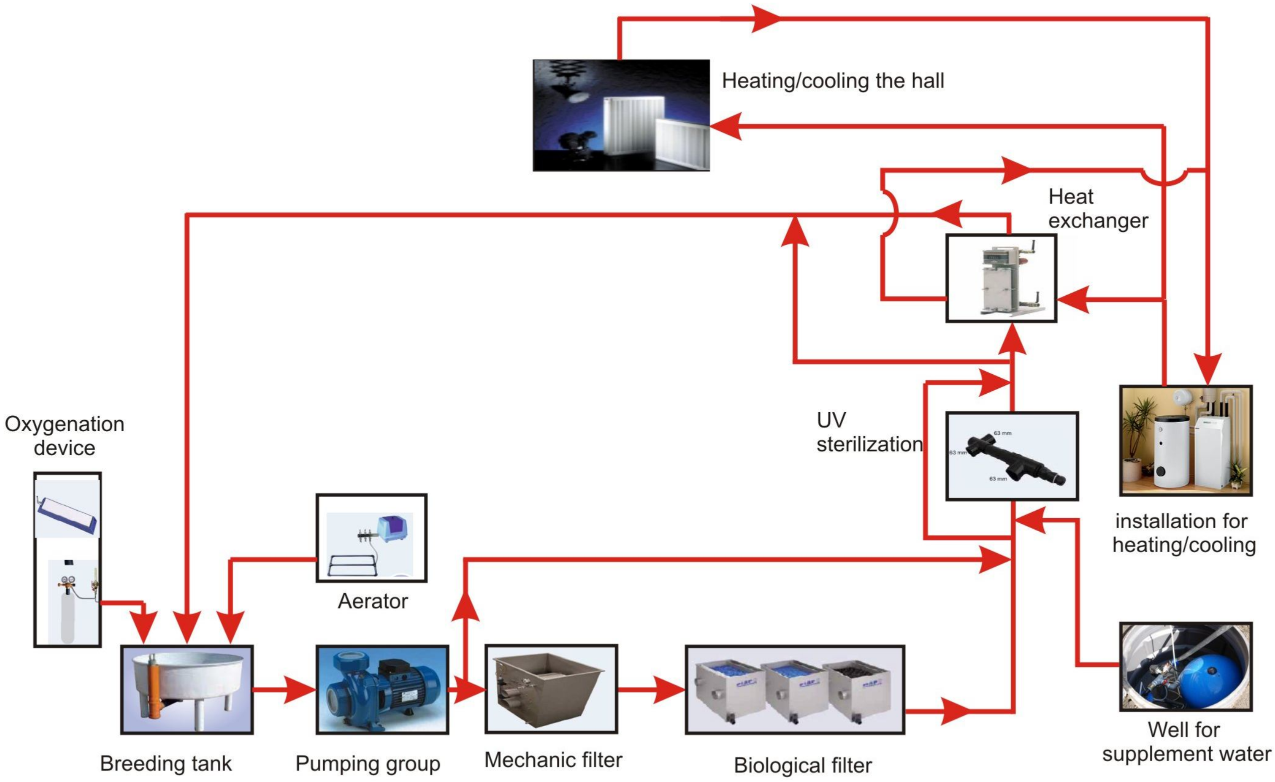

Figure 1. Technological scheme of a recirculating aquatic system for super intensive fish culture

In the same time a constant and adequate temperature must be assured for every fish species. For example for the sturgeons, the adult fish need a water temperature of 20 ^{0}C. Also the air from the breeding hall must have an adequate temperature (Lazu & Patriche 2008).

Unitary energetic consumptions of a RAS. Energy required for functioning of a RAS is split in two categories (Cristea et al 2002):

1 – Electric energy needed to power different technological equipments

2 – Calorific energy needed to heat/cool the water from the system and the breeding hall

Electric energy needed to power different technological equipments. The equipments powered with electric energy are:

- recirculation pumps
- mechanical filters (some types)
- aeration pumps
- sterilization UV installation

The unit energy consumption (for 1 mc of water) of this equipments varies between large limits varying with the equipment type, the using method, the feed quantity and quality as well as the level of food consumption, the populating density and other factors.

Pumping group has the role to assure the circulation of water in the system. The energy consumption depends on the pump type, efficiency, pumping height and the hydraulic resistance of the system. To circulate 1 mc of water about 4.6 – 6 Wh/mc of electric energy is used.

Radial, rotating and "drum" types of mechanic filters are mostly used for the recirculating systems, use energy to realize rotation moves of the brake drum and to power the washing pump of the filtering material. The unit energy consumption depends on the dimension of the orifice of the filtering material and the washing intensity of it, ranging between 3.4 – 4.5 Wh/mc.

Aeration pumps have the role to introduce air in the water from the system to increase the quantity of dissolved oxygen in the water. The needed oxygen quantity for fish varies with the fish species, age and population density, but also with other factors such as: water temperature and pH, ammonia, nitrite-nitrogen concentration etc.

For example, while for the sturgeon species (Acipenseridae) it is required a concentration of minimum 9 mg oxygen/l water, the African catfish (*Clarias gariepinus*) resist at concentration of under 1 mg/l of water.

We can admit as a unitary energetic consumption of 2 – 6 Wh/mc.

Disinfection process with ultra-violet light it is based on the property of UV radiation of penetration and elimination of all forms of bacteria, viruses and other small organism found in liquid or gazes.

The action is instantaneous, it doesn't use chemical substances, no dangerous chemical compound, and the maintenance of the system is cheap. Unitary energetic consumption of a UV lamp depends on the turbidity of water, energy of the radiation and the wave of length used. To obtain a maximum efficiency an about 5 Wh/mc energetic consumption is considered. See the annual consumption value for the RAS equipments in Table 1.

Table 1

Annual consumption value for the RAS equipments

Equipment	*Annual consumption value kWh*	*Observations*
Recirculation pumps	145,552	For H = 7m
Mechanical filters (drum)	18,766	For holes D = 0.07mm
UV sterilization	43,482	
Total	207,800	

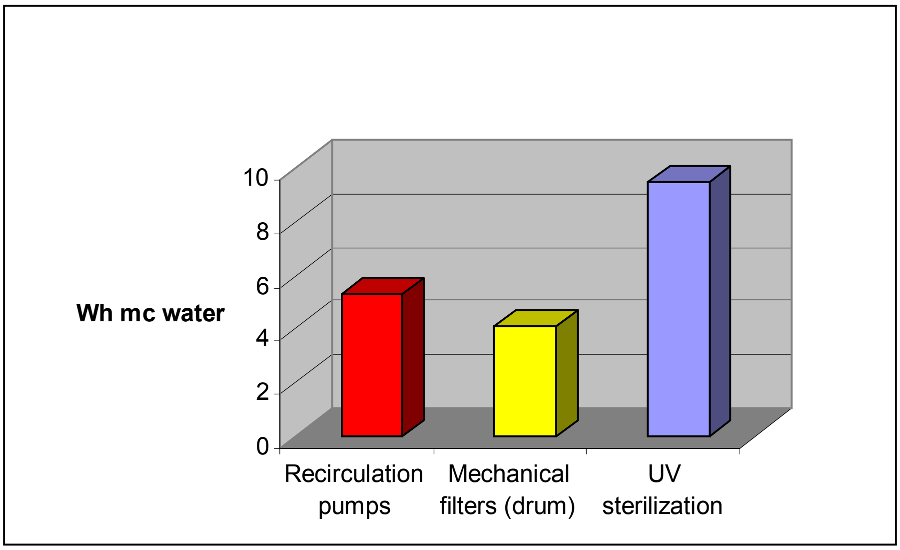

Figure 2. Electric power consumption

Case study. The super intensive breeding system for sturgeons in recirculating system from Herneacova. The recirculating aquatic system for super intensive sturgeon breeding that will be realized at Herneacova, Timis County will have a total water volume of 475 mc and the water surface of 555 square meters. The medium hydraulic resistance time is of 60 minutes (one recirculation/hour). It's stipulated to achieve a density of the biological material of about 80 – 100 kg/mc of water.

Total amount of water recirculation in the system is:

$$Q_t = 2 \text{ x } V_t + Q_A$$

where: V_t total water volume from the system

Q_A supplement water volume which represent approximately 10% from V_t

$$Q_t = 475+10/100 \text{ x}475 = 522.5 \text{ mc/h}$$

Level difference between pump aspiration and the filling hole of the buffer tank is 6 m. Pumping height, taking in calculation the network hydraulic resistance is about 7 m.

Annual energetic consumption of different equipments from the systems is:

Energy used by recirculation pumps, with a unitary water consumption of 5.3 Wh/mc E_P

$$E_P = 5.3 \text{ x } 522.5 \text{ x } 6 \text{ x } 24 \text{ x } 365 = 145{,}552 \text{ kWh}$$

Energy used by mechanical filter, with a unitary water consumption of 4.1 Wh/mc E_{FM}

$$E_{FM} = 4.1 \text{ x } 522.5 \text{ x } 24 \text{ x } 365 = 18{,}766 \text{ kWh}$$

Energy consumed for disinfection with UV, with a unitary water consumption of 9.5 Wh/mc E_{UV}

$$E_{UV} = 9.5 \text{ x } 522.5 \text{ x } 24 \text{ x } 365 = 43{,}482 \text{ kWh}$$

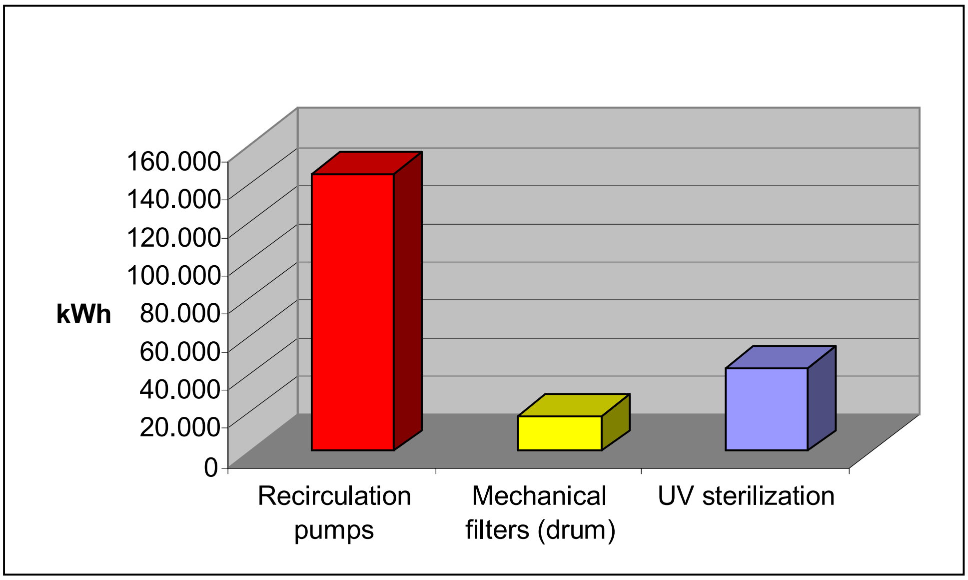

Figure 3. Annual electric power consumption

Calorific energy required for heating the water from the system and of the hall.

Calorific energy used for heating the water from the system, E_{IA}

$$E_{IA} = e \cdot (t_a - t_f) \cdot Q_A \cdot \tau_1$$

where: e = 1.16 kWh, calorific energy used for increasing with 1°C the temperate of a quantity 1 mc water.

t_a = 20°C, water temperature from breeding tanks

t_f = 12°C, temperature of water from the well

Q_A = 47.5 mc/24h, quantity of supplement water

τ_1 = cca. 180 days, number of days in a year when the water must to be heated

$$E_{IA} = 25{,}056 \text{ kW h}$$

Calorific energy used for heating the hall E_{IH}

$$E_{IH} = c \cdot S \cdot \tau_2$$

where: c = 40 kW/m^2, calorific energy necessary to heat a well sealed place, according to DIN 4701 (for a standard height of 3 m)

S = 2,175 m^2, area of the breeding hall

τ_2 = 120 days, the year period when the hall must be heated

E_{IH} = 250,560 kW h

Table 2

Value of the annual consumption

Equipment	*kWh*	*Observations*
Recirculation pumps	102,373	For H = 7m
Mechanical filters (drum)	10,775	For holes D = 0.07mm
Aeration pumps	10,512	
UV sterilization	13,140	
Total	136,800	

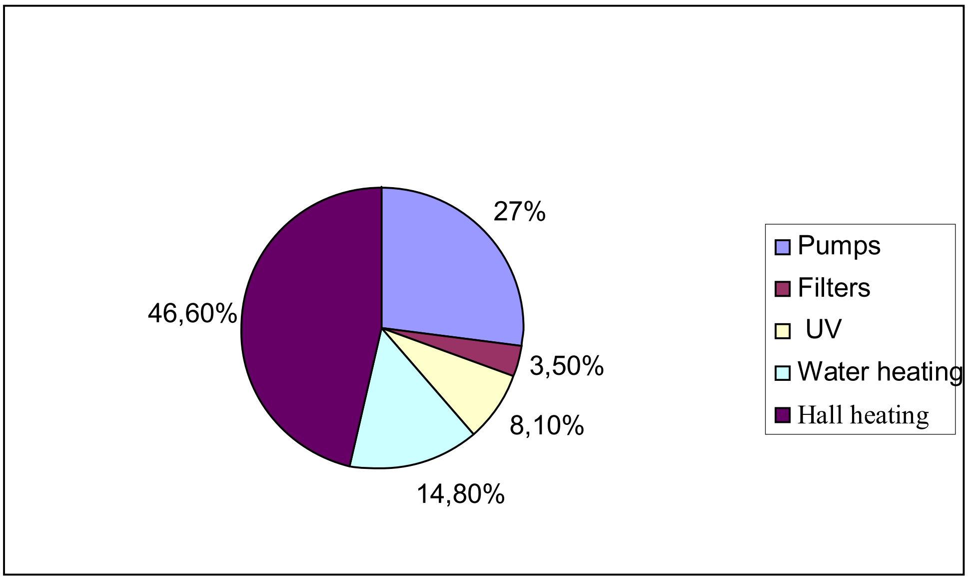

Figure 4. Annual power consumption

Discussion. In the diagram from figure 4 we can observe how the annual energy consumption of 537,704 kWh is composed from:

Energy used by recirculation pumps E_P = 27%
Energy used by mechanical filter E_{FM} = 3.5%
Energy used for UV sterilization E_{UV} = 8.1%
Energy used to heat supplement water E_{IA} = 14.8%
Energy used to heat the hall E_{IH} = 46.6%

To decrease the energetic consumptions tight to filtration, aeration, disinfection and UV sterilization (which together represents about 11.6% from the total consumption), it can be interfered only in a limited manner, by using modern equipments with high efficiency.

The main energetic consumer from a RAS (about 27%) it is represented by the energy used to circulate the water. This amount increases with the size of the system and with the intensity of recirculation, meaning the total of circulate water.

The energy consumption for water circulation can be significantly decreased by developing a type of systems which requires a minimum pumping height, avoiding the useless pumping and by good design of hydraulic networks.

In this way, for example, by eliminating the buffer tank and by reducing the pumping height with 1m, a decreasing with about 16.6% of the energetic consumption is obtained which means 4.5% from the total consume of the analyzed system and it means an economy of 24,259 kWh every year.

Costs with thermal energy (E_{IA} si E_{IH}) are also an important part of the total energetic consumption (cca. 61.4%).

Decreasing of this consumption can be made by minimizing the lost of heat through a better seal off of the constructions and the external water networks (if there are any).

Another way to decrease the consumption of thermal energy is the use of alternative energy sources, for example heat pumps (David 2004), which use the environment energy to produce calorific energy.

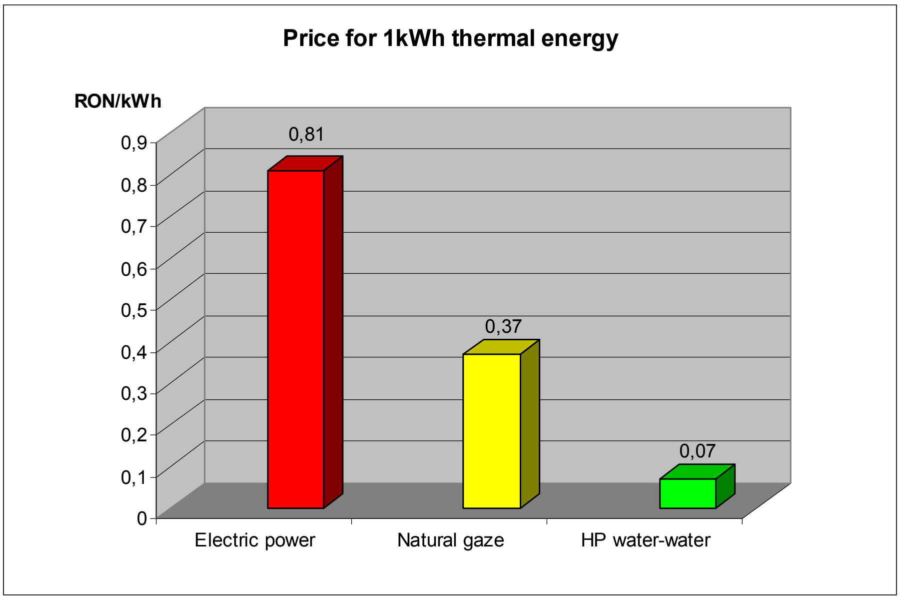

Figure 5. Costs for 1kWh thermal energy

By using a heat pump for RAS, the water-water type, with an coefficient of performance COP = 5.4, one kWh of thermal energy it is obtained 2.2 times cheaper, compared to situation when methane gaze is used, and 5.4 times cheaper compared to situation when electric energy is used (at current prices, but for methane gaze are stipulated important price raises).

Decreasing the costs with 19%, using thermal energy, a decrement of the total energetic consumption for a RAS to function with 11.6% is obtained.

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