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URBAN GREEN AREAS USING SUSTAINABLE AQUAPONICS

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Abstract

Aquaponic technologies and systems are considered growing industries in many countries, with great environmental and socio-economic benefits. Aquaponics uses a system that combines two technologies such as aquaculture specialized in fish farming, and hydroponics, which studies the cultivation of plants. Climate change and the impact of global warming on the ecosystem, declining aquatic animal stocks and the response to growing demand are turning points in our century and in the era of sustainability. Through a phytotron type system, different solutions can be implemented to collect performance indices, impose plant watering criteria (follow the parameters of the aquaponic system such as temperature, water level, humidity and others) using cloud data storage support other facilities offered by the Internet of Things (IoT) concept. Therefore, this study focuses on the sustainable use of aquaponics as a platform for all-in-one solutions covering technical, managerial, socio-economic, institutional and environmental measures in the implementation requirements taking into account the possibility of aquaponics systems to have on the side of electricity a certain energy autonomy if these aspects are considered from the implementation of the aquaponic system.

Key words: *aquaponics, durability, energy storage, sustainability, urban agriculture.*

INTRODUCTION

The main advantage of aquaponic systems is the possibility of installation in various environments, requiring a relatively small investment to create such a system. It offers remarkable landscapes and brings a beneficial change to the environment and contributes massively in reducing the CO_2 footprint. Also, the materials used in the development of these aquaponic systems do not involve an expensive recycling technology, noting that in a sustainable way they are considered to have met most of the criteria (Simke, 2020). Figure 1 ilustrates an aquaponics system where the plants are placed in floating plates without soil in the fish ponds.

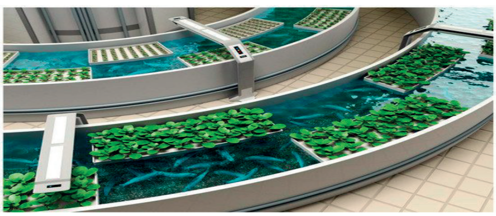

Figure 1. Aquaponics systems with water from fish tanks: the plants are placed in floating plates without soil (Simke, 2020)

Several sustainable development goals (SDGs) were highlighted for the study of aquaponics, mentioning 5 principles from the sustainable development goals set by the United Nations in 2015:

- SDG2: Zero hunger;
- SDG7: Clean energy for everyone;
- SDG8: Both job satisfaction and economic growth;
- SDG12: Responsibility to create, responsibility to use;
- SDG14: Protect the richness of the sea, life underwater.

Aquaponic systems have a smaller effect on the ecosystem because it has the capacity for self-regulation, also there is no need to use pesticides, herbicides, or fertilizers. According to Simke (2020), 70% of water consumed on a global scale in feed production could be saved by up to 30-70% if efficient irrigation systems were used and up to 90% if systems used aquaponics. The above shows the potential of the respective aquaponic systems and their high adaptability to the environment. According to Naylor et al. (2020), the aquatic field, respectively freshwater fish have contributed a lot to food security compared to any other aquaponic production in the last 200 years.

MATERIALS AND METHODS

We studied studies published in the 2010-2021 period, to extract the main ideas on sustainability, design, energy production using compressed air and works about aquaponic systems. Following the consultation of the specialized published studies on the fields of interest, we could ascertain a special compatibility between the electricity production systems with the help of compressed air and the aquaponic systems. In order to outline an overall idea and to create a connection between several fields that apparently have no connection, solutions were sought for the energy independence of aquaponic systems, the sustainability part was consulted, respectively the optimization of energy consumption. Looking for different solutions, different concepts were encountered, approaching the concept of storing renewable energy in potential energy in the form of compressed air which subsequently maintained the movement of a device for producing electricity adding extra strength due to the floating/ buoyancy principle explained in the following sections.

RESULTS AND DISCUSSIONS

Research on aquaponic systems has begun to increase from 2010 to the present, so the more researched, the newer connections can be created in various fields of scientific research. In the following were taken into account factors related to the life cycle, important parameters in a system as well as the possibility of capitalizing on losses in a system for producing electricity using compressed air.

Aquaponics/Aquaculture Life Cycle Sustainability

In order to implement an aquaponic system from the point of view of the life cycle, it must follow the paths of a project, namely the process of conceptualization, initiation, planning, implementation, monitoring and closing the steps or closing the project where we put the conclusions and determine if the project closed as expected or not. Thus, all the steps mentioned above lay the foundations of the life cycle of the project.

If we want to ensure the success of the project started and increase the chances of control and the central management system that is based on a technical expertise such as aquaculture and aquaponics, we must consider to define well and in a timely manner the main factors. and their proper selection. According to them, the importance of the management plan and the ranking of the implementation steps becomes obvious. Within an aquaponic system, the harmonization and distinction of the different types of life cycle must be delimited.

The life cycle of a technical project can be classified into three main categories:

1. Predictive or fully based on the plan;
2. Incremental or process-based iterative;
3. Agile or adaptive change-oriented.

Mostly, the types of life cycles are differentiated by the reference stages or the sequential implementation of the phases (for example: phases carried out by overlapping, in fraction or in parallel, etc.), the level of definition of the scope and the implementation of the scope (e.g. project level, phase level, reference level, iteration level, etc.), project types and complexity and level of stakeholder involvement. The first step is the design and sustainable modelling of an aquaponics project and is done with the realization of an adequate analysis of the life cycle. To explore this proposal, project life cycle types are taken from the PMBOK Project Management Institute, detailed in Table 1.

Table 1. Summary of distinctive factors for project life cycle types (Rowley, 2013; PMI, 2017)

	Predictive	Iterative	Adaptive
Conceptual Chaude	Plan-Driven	Process-Driven	Change-Driven
Phases implementation	Sequential, overlapping	Sequential overlapping	Sequential overlapping, parallel
Scope definition	At the beginning of project	At the beginning of each phase	At the beginning of phase or iteration
Scope description	Covers all project phases	Only for each phase	Only for each phase or iteration
Detailed Planning	At the beginning of project OR rolling wave	Only for each phase	Only for each phase or iteration
Application purpose	Well-defined projects or products	Large and complex projects	Product is not well understood, rapidly changing environments
Stakeholders' involvement	Beginning, when scope changes, and project end	Periodic	Continuous

According to the Project Management Institute report, adaptive or agile life cycles are mainly applied in most information technology IT projects.

Pillars of durability and efficiency of aquaponics

According to FAO (2020) the consumption demand for food products resulting from aquaculture results in an average annual consumption of 20.5 kg per capita with a slight wet growth fish products being estimated at $ 401 billion.

China remained the main producer in 2018, with a total production of 35% as can be seen in Figure 2.

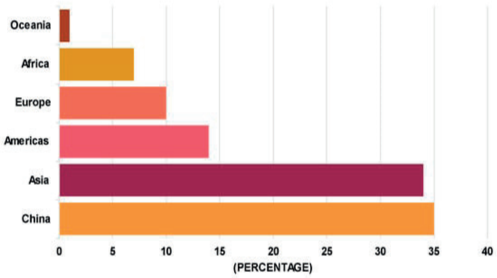

Figure 2. World aquaculture production (Simke, 2020)

Aquaponics require:
- Small investment at startup;
- Low operating cost, including minimal supervision;
- Low maintenance and management costs.

Overall, due to the high demand for trained human resources in various fields, capital investments and treatment systems are considered expensive.

The comparative analysis of the filter performance was done with an average time with certain types of fish by measuring the effluent criteria based on water quality in litres per hour.

For this process, these parameters can be assessed using an environmental quality objective (EQO) approach, technology-based approach or a combination of these approaches for different types of filters, comparing performance according to the required parameters (Table 2) (Ragas et al., 2005; Jegatheesan et al., 2007; Masabni & Sink, 2021).

Table 2. Parameters of aquaponics to produce aquatic products

Parameter	Unit
Dissolved oxygen (DO)	
Ammonia (NH_3)	
Nitrite (NO_2^-)	
Nitrate (NO_3^-)	mg/L
Phosphate ($P0_4^{3-}$)	
Ferric chloride ($FeCl_3$) (for flocculation)	
Water Hardness	
Turbidity (NTU)	
Conductivity	(µS/cm)
pH	
Water temperature	°C/F

IoT and AI technologies present in Aquaponic systems

In general, Internet of Things (IoT) technologies and artificial intelligence have come in the context of facilitating human interaction, providing useful information and mechanisms to increase the comfort of the human factor, especially in urban areas, contributing to the idea of smart cities. But this aspect has expanded in other areas as well, becoming a tendency to look for the respective comfort to be able to easily follow the parameters of the processes. Among the proposed solutions for managing water consumption in agriculture is aquaponics. Aquaponic brings together plant growth and cultivation technologies as well as fish farming technologies by creating a closed-loop ecological system that relies largely on aerobic bacteria that facilitate the transformation of ammonia, taken from food scraps and fish droppings, into substances plant nutrients such as nitrates that are taken up by plants leaving filtered water that returns back into the fish pond. Thus we can speak of a mixed environmental monitoring solution consisting of two processes such as aquaponics for fish farming and hydroponics for plant cultivation. According to FAO 2014, aquaponic systems can produce over 560 fish species, resulting in the ability to adaptation and a diversified variety for both fish and vegetable crops (Carlos et al., 2018). In addition to the aspects mentioned above, we can also list the suitability of these systems for the reconversion of buildings in urban areas due to the high degree of flexibility and the possibility of growing plants without soil bringing very inseminated water savings (according to sources they can reduce water consumption by 80%, respectively 99% compared to conventional methods), compared to conventional systems here watering is carried out underground so it greatly reduces the occurrence of plant diseases, resulting in a healthy diet without chemical treatments or fertilizers. It is possible to better control the growth of plants, due to the control of temperature, water pH and nutrients. Compared to conventional cultivation where if you do not use herbicides you need to intervene to weed, this system is much easier because the plant growth area is pure with no germination seeds or if they appear they are insignificant, they can be removed without too much intervention time, somewhere an average time of 5-10 minutes a day and this to feed fish and check the proper operation of equipment. In addition, aquaponics has applicability in the education system for either pupils or students in university centre who can use different parameters of IoT systems to study different regulation techniques for different species of fish and plants in aquaculture, so as to integrate the student in a deep environment and to offer him a pleasant, concrete experience and applied notions in the field of technologies. Maintaining proper operation, water level, nutrient level measurement, system pH control, is easy to manage in small installations, but for a large structure it is necessary to incorporate an IoT-based system. There are various researches in the field of IoT-based aquaponics such as Yanes et al. (2020) which propose the use of aquaponics as an alternative based on the two technologies mentioned above, namely aquaculture and hydroponics, thus using this combination increases the efficiency of water use, conditioning the user to use pesticides or of chemical fertilizers due to the presence of fish, making this concept healthy, green, and sustainable. For Lee et al. (2020), an IoT-based cloud monitoring system is proposed for an aquaponic system used to measure various parameters such as: water level, water temperature, dissolved oxygen and pH value. Three infrared distance sensors at different heights located in the aquarium are used to monitor the activity of the group of fish, the data is uploaded on ThingSpeak™, a cloud platform that allows the data interpretation, uploaded via wi-fi. For Mahkeswaran & Keong Ng (2020), an aquaponic system is proposed for the home environment, thus suggesting that if each family could produce its own fish and plants, the need for food in cities and in all countries will be reduced, especially in Singapore. The classic method requires large areas of land and numerous human resources, and food security would be at a standstill, so the proposed aquaponic systems are smart and sustainable, include a wide range of sensors, actuators, as well as a microcontroller with internet connection for monitoring and control of all parameters. Uses sensors for measuring water level and temperature, sensor for determining pH, electrical conductivity, air temperature, and humidity, dissolved oxygen, light sensor adapted for the Arduino Mega 2560 microcontroller. For the mobile application it was created with Blynk, being an IoT platform for hardware control and data analysis. According to Ibtissame et al. (2020), aquaponic systems have many benefits in academic research, for example; students having the opportunity to learn tools such as mathematics, chemistry, biology and engineering, in addition, studying the interactivity between fish, plants and bacteria in a living ecosystem reporting water quality tests (measuring and tracking) fish growth rates and plants, as well as the aquaponic system are used to demonstrate various principles.

Urban Agriculture (UA)

Due to the cities development and the global population growth, the agricultural policy to cope with this trend is thus adapting to the consumer, causing major changes to food production systems due to research and innovation in the field, to meet growing demands. Over the past three decades, agricultural growth and innovation combined with the advancement of information technology have brought to the fore modern and promising cultivation techniques that are valuable in terms of the sustainability and economic viability of controlled agriculture (C.E.A.). According to Ellis (2012) agriculture in the past has been associated with urban centers to a greater extent than today.

Although modern and traditional agriculture have been separated into upper layers, they remain somewhat attached to each other at the roots. By the end of the 2000s, large cities had reached the point where most people did not even need to associate food with natural resources (Abel, 2010). The concepts of urban agriculture (AU) and the associated benefits have enjoyed considerable attention and popularity lately, namely 8 years, growing to provide satisfaction to urban dwellers who focus on continuous development. A variety of systems can be included in the concept of urban agriculture (AU) in different architectures and residential areas, increasing the tourist potential of the metropolis (Figure 4), from common, personal gardens, for social and self-sufficiency purposes, to complex systems. with the potential to produce food indoors by artificial lighting or in climate-controlled areas started by small plant-producing businesses.

In most cases, urban agriculture (AU) is mostly practiced indoors, or adapted to new names, namely, vertical agriculture (VF) (Despommier, 2010), integrated agriculture inside buildings (Caplow, 2009) and agriculture (Thomaier et al., 2015). Thus, this type of food production has managed to penetrate most cities in the world, attracting special public interest.

Because the market is regulated according to demand and supply and in this field it can be seen that the need of consumers is constantly changing, so many are oriented towards the freshest and best quality food that does not compromise nature.

Several reports have indicated that several projects are involved in bringing agricultural products to cities (Mok et al., 2014; Taylor & Lovell, 2012). It is appropriate to consider the definition of the concept of urban agriculture that conforms (Benis & Ferrão, 2017; Pölling et al., 2016; Cahya, 2016, Ahlström & Zahra, 2011). Balas et al. (2020) stated taht AU is an industry that produces, processes and markets food and fuel, largely in response to the daily needs of consumers in a city or area.

Some of the proposed solutions for a closed field production system in the AU are plant factories, vertical agriculture (VA) and roof greenhouses. Figure 3 shows a conceptual demonstration of the concept of urban agriculture that can be implemented in areas with a dense population.

Conceptual demonstration of urban agriculture in high-density urban areas in transformation and conceptual design of a smart urban farm inside a center.

Figure 3. Conceptual demonstration of urban agriculture in high-density areas of changing cities (weburbanist.com)

Figure 4. Conceptual design of a smart urban farm inside a centre (weburbanist.com)

Aquaponic systems and the possibility to become autonomous

An aquaponic system consumes electricity for:

- water supply/recirculation;
- water oxygenation (bubbling air into water);
- plant lighting;
- command and control system.

In order to reduce the costs of water oxygenation and especially to find an efficient method of storing green energy, in the case of aquaponic systems the most convenient solution is to store them in potential energy using compressed air.

Thus having a potential energy in the form of compressed air, which is used to oxygenate the water in the aquaponic system, a system can be implemented to recover this potential energy with the help of an electricity generation system using the principle of buoyancy (buoyancy, buoyancy - powered generator BPG).

Hybrid CAES/GDP conceptual system

The CAES (Compressed air energy storage)/ BPG (buoyancy-powered generator) consists of two essential components cylindrical vessels that are positioned on a vertical mechanical mechanism and implement the principle of buoyancy and an installation that converts electricity produced from renewable sources into potential kinetic energy, such as a compressed air generator coupled to a source storage. Compressed air is used by the buoyancy mechanism to generate electricity and recover the energy consumed for oxygenating the water shown in Figure 5. The general concept of the generator in its simplest form in which light cylindrical vessels were used to capture air is illustrated in Figure 6.

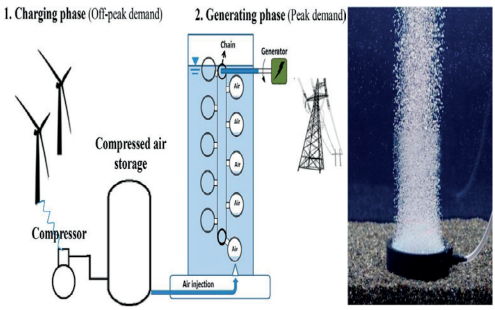

Figure 5. The basic components used are the development of the CAES/ BPG system for energy storage, applicable to water oxygenation (Hossein et al., 2019)

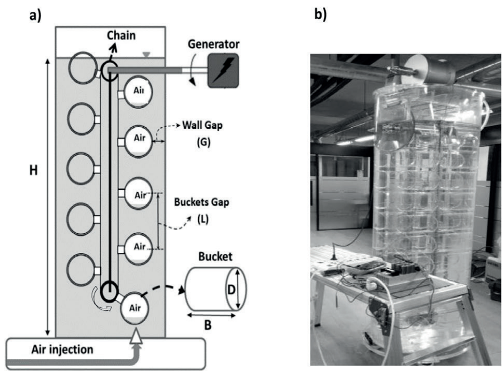

Figure 6. Systematic illustration of the power generator on the buoyancy principle and (b) a capture of the experimental installation by Infinity Sav Team (2019)

In order to be able to put into practice the system of electricity production with the help of floating, a system called BPG was created consisting of:

• A basin with 2 horizontal axes, one positioned at the bottom of the basin and the other positioned at the top of the basin;
• Four gears equal in diameter positioned on the 2 horizontal axes of the basin;
• A gear with a smaller diameter positioned on the upper horizontal axis that ensures the transmission of rotation to the generator;
• Two chains with conveyor rollers that vertically connect the gears on the 2 horizontal axes;
• Rigid cylindrical vessels of equal size, arranged at equal distances on the chain with conveyor rollers that move the axes, respectively through the axis located at the top of the basin engages through a chain the generator with permanent magnets, thus producing electricity.

Thus, when the compressed air is injected into the cylindrical vessels, air intake losses occur due to the impossibility of the cylindrical vessels being captured, respectively by their movement, but coupled to an aquaponic system these losses can be considered an advantage contributing to the oxygenation of the water to be used in the aquaponic system, this in the idea of coupling such a BPG system with an aquaponic system.

The operation of this CAES/BPG system is due to both the floating phenomenon and the respective design and construction of the device to be able to use this advantage, so the air has a density about a thousand times lower than the density of water, adding as a plus the state of air aggregation through this concept the storage of renewable energies becomes much more environmentally friendly, all components can be recycled without too high costs. As can be seen in Figure 5, the cylindrical vessels are coupled by means of the chain with conveyor rollers forming on either side of the axes two almost symmetrical parts the difference being only the orientation of the orifices of the cylindrical vessels so in one part these openings are oriented down by capturing the injected air and at the moment of rotation, passing the other side, the orifice of the vessel will remain upwards so the air will leave the cylindrical vessel allowing water to enter.

Because the movement of the bucket through the water it is gentle, the force transfer is performed by an assembly consisting of a chain gear and a gear with a well-established diameter ratio to ensure optimal kinetic energy transfer (Alexuta, 2021). The speed of the cylindrical vessels can be adjusted by the flow produced by the air source, respectively the regulation of the flow introduced by the air injection installation. Increasing the outlet torque can be increased by adding more containers on the vertical chains and increasing the depth of the pool vertically. Other methods of increasing the output force refer to increasing the volume inside each cylindrical vessel or raising the flow released by the mechanism for injecting air into the cups. There are some parametric criticisms that affect the proper functioning of the system such as chain rotation speed, container movement speed, container size and shape, container number, tensile and frictional force due to container and chain movement, exhaust air to fill the container, the space ratio and the distance ratio, noted in Figure 6 with G signifying the gap between the cylinder wall and the moving container, and L signifying the gap between the means of the moving containers. For an understanding of how the electricity generator works with buoyancy (Hossein et al., 2019).

CONCLUSIONS

Due to the possibilities offered by an aquaponic system for growing both plants and fish, considerable work has been developed stating various ideas such as food security, short chain food supply, sustainability, control of renewable resources and much more. In addition to the optimal production of aquatic products, the accommodation of aquaponics and aquaculture continues in the global food system for quantification, evaluation and market development towards sustainable development. By implementing a system of electricity production with the help of Archimedes' law, the autonomy of the system can be increased during the grey periods (night for solar energy, and when there is no wind for wind energy) of renewable sources of electricity production. The CAES (Compressed air energy storage)/BPG (buoyancy-powered generator) system applied under aquaponic systems significantly reduces the energy consumed, offering a viable option to become autonomous, depending largely on the green energy sources used, solar or wind. The potential of the idea of coupling the mechanical systems of electricity production in an aquaponic system, respectively the capitalization of losses for the benefit of the aquaponic system would increase the potential of aquaponic systems but this can be highlighted after testing.

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