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Editorial

Aquaponics Software in Greece

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Introduction

A valuable and sustainable approach for food security could be the further expansion of aquaponics production. Aquaponics is the combination of fish farming in recirculating aquaculture systems (RAS) and cultivation of plants in water (hydroponic). Research on the sustainability of aquaponics is focused on system water quality parameters and availability of nutrients for the three components: the plants, the fish, and the bacteria (Tyson et al., 2011; König, et al., 2016). The technology works as a closed loop system that reduces the consumption of fresh water compared to conventional monocultures and uses the nutrients excreted by the fish as fertilizer for the plants. Nitrogen uptake depends on the plants species that play an important role in avoiding the accumulation of NO_3-in aquaponics**.** In addition, carbohydrate addition to aquaculture systems stimulates heterotrophic bacteria growth that results in the removal of inorganic nitrogen through assimilation. Thus, all fish waste and feed nutrients can be utilized and recycled (Graber and Junge-Berberovic, 2009). The need for technological advancements is also addressed (König et al., 2016).

Aquaponic technology can help meet the goals of establishing large-scale, eco-efficient and economically viable aquaponic farming projects, especially by using existing technological advantages to monitor the aquaponics system through mobile devices with minimum involvement in recording management tasks. Such a system to the knowledge of the authors is not currently available in the market and can highly contribute to the future development of sustainable aquaponics production in the Mediterranean region. The technological change in aquaponics ensures that it is maximizing the quality of the farmed products, while improving resource efficiency and minimizing impacts. In addition, young farmers can nowadays use the available technology to supervise their farms online. The purpose of this editorial paper is to highlight current market needs for an affordable technological solution used in such a multidisciplinary system, both on a small scale and a more complex commercial scale.

Aquaponics in the Mediterranean Region: The Case of Greece

Aquaponics in the Mediterranean region is still in an embryonic stage. Until now, more than 150 species of vegetables, herbs, flowers, and small trees have been successfully used in aquaponics systems and are used or could be used in the Mediterranean aquaponics. In particular, leafy plants such as salads are grown extremely well in the Mediterranean aquaponics, as are tomatoes, cucumbers, and peppers. However, plant production is species-specific for each cultivar and the same aquaponic nutrient pool may not be totally applicable to other plant varieties for optimal growth due to different nutritional needs. In addition, the need for beneficial bacteria increases the complexity associated with

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creating a sustainable balance (Tyson et al., 2011). Root crops and more sensitive plants do not grow efficiently in aquaponics due to their specific needs associated with nutrition and growth mediums (Gianquinto et al., 2013). Overall, there are two nutrient demand levels for cultivating plants in aquaponics; the low and the high category. In the low demand category, major plants include lettuce, chards, herbs like basil, mint, parsley and coriander, mustard, watercress, peas, and finally beans. In the high demand category, the fruiting vegetables like tomatoes, eggplants, cucumbers, zucchini, strawberries, and peppers, and including most of the root plants like onions, carrots, and beets, are used. The growth of microgreens can be highly promoted as a future plant in Mediterranean and in Greek aquaponics. They do not demand high nutrient levels, they grow in a short period of time and usually the have a very high selling price. A huge variety of species is available, including mustards, basil, cress, radish, chard. Mixture of crops or intercropping is a possible future use of aquaponics to provide a mechanical, repellent and/or inhibitive effect against pests. In general, companion plants can help produce healthier crops either by better pest management or nutrient additions. As an example, beans and peas can be used with almost all of vegetables and herbs to provide nutrients and pest management (Pappa et al., 2013). However, a very critical factor that should be considered is the water salinity. In some areas, water salinity is much higher than the threshold levels of the maximum production. Several studies have shown that the plants can build a salt-tolerance mechanism and the knowledge of the cultivars resistance plays a critical role (Shaheen et al., 2013).

Aquaponics farmers in Greece can find a lot of information about tipapia, carp, trout and catfish in order to start a small-scale home system (FAO, 2014). However, in the Mediterranean region, consumers' preferences for seafood are mainly for marine aquaculture fish species. Thus, fish produced from aquaponics will not be desired for human consumption but will serve mostly to provide the nutrients to cultivate the plants or to be introduced as "new species" for human consumption with a lower price. The introduction of new fish species that can be used in aquaponics in Greece, such as the grey mullet (*Mugil cephalus*) and the European eel (*Anguila anguila*), are very important seafood species in the region. In Greece, hobbyists, educators and Universities construct most of the aquaponics systems. There is only one experimental facility based in Western Greece (Amaliada) where different crops (leafy plants, tomatoes, cucumbers, peppers, eggplants, lettuce, peas etc.) and fish cultures (carp, tilapia, cephalus, eel) are being tested in parallel with the development of a unique software and hardware platform.

New Technologies in Aquaponics domain: The Case of Greece

Love et al. (2015) showed that seventy-one percent of the commercial producers designed their aquaponics system themselves, and the remaining 29% either hire a consultant and/or purchased a kit. In the future, as aquaponics systems will become larger, systems will be designed to adapt to the variety of the methods used for the aquaponics production and special software will be designed for best practice management techniques. Available software focusing only on fish farming (AKVA, http://www.akvagroup.com/products/land-based-aquaculture/software and AquaManager, http://www.aqua-manager.com/) or plant cultivation (Hoogendoorn, http://www.hoogendoorn.nl/en/product/isii-process-computer/) can be found in the market.

However, software considering both aquaculture and hydroponics to create a balanced management system is very limited in the Mediterranean region and in Greece. Aquaponics requires knowledge in aquaculture and hydroponics; farmers need to handle both fish and plants efficiently. Software exist like, Ponnod Smart (http://smart.ponnod.com/), UF (https://urbanfarmers.com/technology/uf-controller) and ATC (http://www.atcsystems.eu/) have been developed for aquaponics management that join aquaculture and hydroponics. All the above developed software and hardware synchronize fish growth performance and at the same time the nutrient requirements for cultivating a healthy plant. "Ponnod Smart" was built on years of experience with aquaponics, both in household and commercial systems. It calculates the optimum balance where both fish and plants have their nutritional requirements met. The system monitors and controls the plants based on rules specifically designed for aquaponics, but also provides the user with alerts, tips and advice on how to be smart in aquaponics and more profitable than ever before.

The "UF software" monitors, records, controls and automates UF Systems using a UF controller which is a LabView software protocol based on a hardware which connects all major farm sub-systems such as filters, pumps, timers, actors and sensors. Thus, the production environment can be fully controlled, enabling real-time performance monitoring, system automation as well as data analysis and storage capabilities for the user. The "ATC platform" for an aquaponics facility is divided in two modules, the Aquaculture and the Greenhouse module, incorporating major inputs such as water, energy, and fish feed. A very sophisticated control system was created in Greece and was based on the developed hardware that collects operational data from electromechanical equipment (such as oxygen, oxygen pressure, feeders, pH, EC and salinity sensors) and stores them in the database (cloud) to simulate the production and fish growth rate in various temperatures based on the collected data. The Aquaculture module is also able to perform fish batches and fish feed traceability since it calculates the feed conversion ratio (FCR) and the required fish feed for each fish tank depending on the temperature and oxygen levels, the fish growth rate, and the stocking density. The Greenhouse module supports soil, hydroponic, aeroponic, and aquaponic growing methods (**Table 1).** presents a comparison between the three European software used in aquaponics.

New technologies and further development of software systems to increase productivity and manage aquaponics installations in a sustainable way are urgently needed.

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Table 1: A comparison of European software management practices in aquaponics; UF, Ponnod and ATC Systems. (Key: √ = existing; - = not existing; ? = unknown).

	Key Functions	UF*	Ponnod**	ATC
	Maintain full connectivity with any major Aquaculture and Hydroponic original equipment manufacturer (OEM) and specification	√	√	√
	Number of supported fish tanks, cage, aquariums and egg tumblers	?	?	900
	Number of supported greenhouses	?	?	900
	Support of renewable energy equipment (photovoltaics and wind turbines)	-	-	√
	Support of heating systems	?	-	√
Automated key Production	Fish Feeding	√	√	√
	Nutrient dosing	√	√	√
	Recirculation pump control	√	√	√
	Drum filter monitoring	-	-	√
	UV filter monitoring	-	-	√
	Well pumps control	√	√	√
	Artificial light control	-	-	√
	Fish cage culture support	-	-	√
	Fish pond culture support	-	-	√
	Egg tumbler culture support	-	-	√
	Pipe line water pressure pump drive	-	-	√
	Air blower / Aerators control & monitoring	-	-	√
	Greenhouse Irrigation manifolds control with programs	-	-	√
	Greenhouse Irrigation filters monitoring and control	-	-	√
	Greenhouse environmental control	√	√	√
	Control the equipment without internet access	√	-	√
Log Farm Activities	Seeding	√	√	√
	Harvesting	√	√	√
	Fish Feeding	√	√	√
	Fertilizer Input	√	√	√
	Log health & safety activities	√	√	√
	Monitor 24/7 all critical performance aspects of the production	√	√	√
	Set-up and set all crop varieties in harvest configuration tab	√	√	√
	Keep automated visual diary	√	√	√
	Aquaculture water quality parameters monitoring	?	√	√
	Greenhouse water quality parameters monitoring	?	√	√
	Fish feeding traceability	?	?	√
	Plants harvest traceability	?	?	√
Storing and Alerts	Provide standard operating procedures (SOP) for the farm crew	√	√	√
	Provide maintenance to the farm crew	-	-	√
	Report farm performance real-time, accurately and consistently	√	√	√
	Access farm remotely through the Internet	√	√	√
	Store and back-up all operational data on data cloud	√	√	√
	Download your data into excel	√	√	√
	Set important alarm functions and emergency escalation procedures	√	√	√
	Keep farm data private locally	√	-	√

*UF: https://urbanfarmers.com/technology/uf-controller/.
**Ponnod: http://smart.ponnod.com/
*** Applied Telemetry and Controls (ATC) Systems [ATC Systems website: http://www.atcsystems.eu/]

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