Sustainable Greenhouse Cultivation in a Vertical Aquaponic System with Smart Control - Abstract

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Summary

Aquaponics is a cultivation method that combines aquaculture and hydroponics. More specifically, aquaculture waste is used to provide plants with the nutrients they need to grow hydroponically, while plants serve as a bio-filter for the aquaculture (fish). Aquaponics results in the simultaneous production of plants and fish with the smallest possible environmental and carbon footprint. Energy consumption for water recycling, oxygen supply and heating or cooling of the cultivation space, are important factors for an efficient and sustainable aquaponic system. The aim of this research was the study of energy needs and the optimization of energy consumption in the aquaponic system, focusing on sustainability with the use of smart controlling systems.

The experiment was carried out in a pilot greenhouse in Thessaloniki, Greece, where both below ground and above ground spaces of the greenhouse were utilized, for fish and plants cultivation respectively, to achieve better land and energy use efficiency. The underground system consisted of (1) two fish tanks, filled with approximately 500 fish of the species Oncorhynchus mykiss each, (2) a solid waste filter used to remove solid particles from the water which is full of fish feces and non-consumed feed, (3) a nitrifying biofilter intended to oxidize ammonia excreted by fish to nitrate and (4) two storage tanks that facilitate water recirculation. Water quality was constantly monitored with the use of pH, EC and temperature sensors, while water analysis was periodically conducted. Smart controls ensure the efficient and remote-control operation of the whole system. Water derived from the storage tanks, rich in nitrates and potassium (approximately 27 mg/l and 32 mg/l respectively), was diverted into the plants in the main greenhouse space. Greenhouse air temperature and humidity were recorded with a HOBO data logger. In our research scenario, Romaine lettuce (Lactuca sativa cv. Paris Island) seeds were sown directly into plastic rafts (33×67 cm) with planting density of 1200 plants per m2. Three hydroponic tanks in the greenhouse were supplied with different nutrient solutions each, in a floating hydroponic system scheme; 1) Tank A was filled with plain fish wastewater, 2) Tank B was filled with typical Hoagland solution (control), and 3) Tank C was filled with a mix of the above, in which fish wastewater was enriched in nutrients until it reached Hoagland's composition.

All treatments of the ongoing research are evaluated based on the growth rate and marketable fresh weight. Prior to harvest pH, EC and root zone temperature in the three treatments were 7.8, 0.55 and 26.5 °C for Tank A (fish wastewater), 7.3, 2.55 and 27.1 °C for Tank B (control, Hoogland solution) and 6.8, 2.12 and 26.7 °C for Tank C, while average air temperature and relative humidity inside the greenhouse were 26 °C and 68.6 % respectively. Quality characteristics regarding total antioxidant activity, total phenolic compounds, nitrates concentration and leaf color are also assessed. To deeply evaluate plants' performance and response to different nutrient solutions, genes involved in plant adaptation to fluctuating

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conditions will also be studied by molecular techniques. The expression of these response genes will be monitored and compared in plants grown in the three different hydroponic tanks. In Tank A and C, nitrates from fish wastewater originating from the biofilter, are expected to increase over 100 mg/l resulting in a N-fertilizer contributing to sustainable greenhouse production.

Keywords

hydroponics, aquaculture, baby leaf vegetables, intelligent monitoring