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AQUAPONIC SYSTEMS: A TOOL TO PROMOTE LOCAL CONSUMPTION AND TO CREATE A SUSTAINABLE IMPACT IN FAMILY GARDEN PRODUCTION

SISTEMAS ACUAPÓNICOS: UNA HERRAMIENTA PARA PROMOVER EL CONSUMO LOCAL Y GENERAR UN IMPACTO SOSTENIBLE EN LA PRODUCCIÓN DE HUERTOS FAMILIARES

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Resumen

La producción de alimentos de traspatio es una opción viable para obtener alimentos frescos y ecológicos, que pueden contribuir a la salud humana. Esta práctica es crucial para la población y repercute en la situación socioeconómica de las familias rurales y urbanas. La agricultura de traspatio es determinante para la disponibilidad mundial de alimentos, la preservación de la producción alimentaria tradicional, la conservación del medio ambiente y la innovación tecnológica. Sin embargo, una de las principales preocupaciones en la producción de alimentos es la falta de tecnologías sostenibles, consistentes y respetuosas con el medio ambiente. Por ello, este artículo presenta una alternativa para la producción de alimentos mediante la implantación de sistemas acuapónicos en la agricultura de traspatio. Estos sistemas optimizan el uso del agua combinando los métodos de crianza de animales acuáticos y cultivo de las plantas. Los sistemas acuapónicos también son convenientes en territorios rurales estériles o como conceptos de jardinería en zonas urbanas. En conclusión, la acuaponía puede ser un método sostenible, pero se necesitan más estudios sobre su impacto socioeconómico en las zonas rurales.

Palabras clave: acuaponía, comunidades vulnerables, consumo local, producción familiar, sostenible

Abstract

Backyard food production is a viable option to obtain fresh, organic food, which can contribute to human health. This practice is crucial for the population and has an impact on the socioeconomic status of rural and urban families. Backyard farming is determinant to global food availability, traditional food production preservation, environmental conservation and technological innovation. However, a major concern in food production is the lack of sustainable, consistent and environmentally friendly technologies. Therefore, this article presents an alternative for food production through the implementation of aquaponic systems in backyard farming. Such systems optimize the usage of water by combining the methods of aquatic animals and plants. Aquaponic systems are also convenient in barren rural territories or as gardening concepts in

urban areas. In conclusion, aquaponics can be a sustainable method, but more studies about the socioeconomic impact it in rural areas are needed.

Keywords: aquaponics, family farming, local consumption, sustainability, vulnerable communities.

Introduction

As the world population has increased, so has the need for food production systems effectiveness [1]. A milestone in this process was the selection and domestication of valuable grains, which enhanced field exploitation rates [2] and originated the development of new, higher yield varieties. Nobel Peace Prize Laureate Norman Borlaug acknowledges this progression as the start of the Green Revolution. Furthermore, the new varieties were photoperiod insensitive semidwarf plants, more resistant to oxides and responded positively to nitrogen fertilization [3].

The Green Revolution, on one hand, saved millions of lives by bringing food security to a lot of countries, especially to underdeveloped ones [4]. On the other hand, it implemented soil exhausting methods and promoted plague resistance under the usage of agrochemical products [5]. The environmental impact of these products harmed the biodiversity and had a high social cost [6]. Now scientists call for a new Green Revolution: proposals for production systems and methods [6], [7], [8].

Aquaponics, which consists in the incorporation of plant and fish production as a single system, is one of such proposals. The concentration of nutrients in the fish production wastewater promotes the growth of the incorporated plants [9]. These arrangements are commonly based on recirculating aquaculture systems (RAS), which connect aquaculture tanks with water based plant production [10]. Also, aquaponic vegetables are more resistant to plagues and pests, avoiding the massive application of pesticides [17]. There are four different Hydroponic system concepts; and their adequacy depends on the crop specific production requirements:

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— Floating rafts: Styrofoam board floats covering the aquaculture tanks to facilitate the plant root contact with the concentrated fish tank water, but it has the need of oxygenation [12].

— Substrate beds (or gravel beds): boxes or pipes filled with different types of organic or inorganic substrates [13], through which the residual wastewater recirculates supporting the plant growth [11].

— Nutrient film technique (NFT) [11]: a PVC pipe channel system that supports the plants growth [12] by establishing direct contact between the roots and the nutrients in the wastewater solution.

— A fourth, less common procedure consists in irrigating the crops with aquaculture wastewater without a recirculation system [14].

These designs benefit agricultural food production in that their ecological impact results milder [15], due to the relative independence from agrochemicals and heavy machinery in comparison to intensive monoculture [16].

A major issue of traditional monoculture is the need for vast fertile territories [18]. Aquaponics, on the contrary, can be accommodated in small spaces such as backyards [19], independently of soil fertility [14]. These constructs are convenient for self-consumption in a family farming concept. The double benefit of local production and self-consumption is key for sustainable food security in rural areas [20].

The steady production of healthy food is also a social and cultural matter. New trends promote the idea of "producing, buying and eating locally" [21]. Local consumption can be more sustainable and environmentally friendly; according to independent reports, governments and civil organizations promote the acquisition of local food [22] as a way to increase alimentary security [23]. In this context, backyard family farming can have a positive impact [24]. Therefore, the present objective is to justify home farming aquaponics as a viable food source and a means to improve the socioeconomic situation in rural and urban areas.

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The socioeconomic *status quo* of rural communities

The transportation of goods and foods is one of the key generators of greenhouse gases and other environmental impacts [15]. The massive migration to urban areas also intensifies the environmental impact due to the resulting transportation needs, both for people and food [25]. Moreover, since climate change poses a new threat to agriculture, new strategies [26] must address the dependency of farmers' income on climate and weather changes. Moreover, farmers struggle to adapt to these alterations because of a lack of access to information and financial resources [27]. Another problem of mass food production in rural areas is the use of agrochemicals; exposure to these compounds is known to cause Parkinson's disease and several types of cancer [28].

The factors that define socioeconomic status are food security, housing, sanitation and medical conditions, infrastructure and purchasing power, biodiversity and ethnic disparities of a location [29]. The socioeconomic status of rural areas depends mostly on the income; this aspect is mainly generated by the food production industry, agriculture, forestry and fishing, with a minimum of 38% of employment in these economic activities [19]. In the last decades, the evolution of traditional agriculture, which has failed to generate abundant income [30], into off-farm systems exposed the unreliability of agricultural production. Furthermore, these circumstances caused a migration movement from the rural regions to urban metropolitan zones in search of higher life standards [31]. In the future, such urban growth will demand more provisions, rendering the production in rural areas a key actor in the supply chains [15]. On the other hand, it will direct attention towards the development of viable urban farming concepts and expose the rural areas even further [32]. Today, metropolitan population density is growing at such a rate that, by 2050, two thirds of the world population could be concentrated in urban areas [33].

The socioeconomics of food production is fundamental for farmer families, because it affects management of production capacity, technologies, market integration and ecology [34]. The impact of household farming in food production is evident in statistics: it represents 50% of global human food supplies. These numbers exclude game meat and fish, which constitute an additional 20% [35]. Moreover, by taking up 53% of agricultural farmland [34], family farming is a pillar of economic growth

and food security [36], providing self-sufficiency to underprivilege families [37]. In many countries, industrialization reshaped the demographic structure of rural areas and offered better work opportunities in urban areas to the rural population. Therefore, there are great differences in labor occupation between rural and urban areas, because the economic status in the former is more delicate given dependency on agricultural labor [38].

The socioeconomic status, cultural factors and daily habits of agriculture workers determine the productivity of the grain yield [39]. By passing down expertise generationally, ancient cultures have an effect on the socioeconomic importance, [40] defining the source of income and employment in rural areas [41]. Nowadays, these home garden practices are deemed effective self-provisioning [42]. In fewer words, rural areas are vital for food production [24]; therefore, they need new strategies to improve the local socioeconomic conditions [43].

The new focus on local food production and consumer behavior

The agricultural sector has evolved from intensive labor-based production systems into a modernized high knowledge-based systems, decreasing poverty and improving economic stability [43]. Prospectively, agriculture will be essential for the sustainable development goals of the United Nations [44], especially for food security [45] and preservation of rural cultural heritage [46].

Therefore, consumption of local food relates to the regional cultural heritage but also to the differences of local natural conditions and the knowledge of the local situation; such implication entails an exchange between the local communities and the geographic transportation status [47]. A community's social structure and its relation with the environment are crucial in the availability and variety of edible vegetation [48]. Consumers around the world prefer local food because it implies freshness, palatability and support for the local producers and businesses in general [49]. Besides patrons seek menus with local organic ingredients [50]. Family gardens are important for the global food system, but each location must be understood in its own agrobiodiversity context [42].

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In the search for food security, local consumption focuses on enhancing home garden production in order to achieve self-provisioning in poor rural societies [51]. As a result, high ecological, social, economic, political and medical potential is created from local food production [34], [52], [53].

Family farms gain independence from food markets [42], boost social cohesion, promote sustainable development [35] and raise awareness for the use of natural resources [34]. Home gardens are commonplace in developing countries [54], where they constitute family income and liberate funds for covering other necessities [55]. But it has also an important social aspect: the connection between families and communities in the labor of food exchange, strengthened food diversity and preparation habits [42]. Family gardening may not guarantee food security, but enhances food access via local markets and socioeconomics because of the additional income sources to agricultural production [42], [54].

Although consumers want to support local growers, globalization and widespread of food markets and supermarkets have affected family farming in developing countries [56]. Agriculture needs support in the form of innovative technology and reliable mechanisms of natural resource management for family gardening [57].

Aquatic effluent use in circular economy concepts for plant production

Local consumption could benefit from the concept of circular economy, which consists in the generation of new goods from waste and byproducts of other processes [58]. Circular economy provides food security by reusing concentrated nutrients such as nitrates and phosphates [65] in waste products and saving nonrenewable resources [59]. Furthermore, aquaponic systems can partially relieve food production from agrochemical products [64]. Regardless, current food supply chains are yet to implement such techniques [59], [60], [61]. In this sense, aquaponic systems are effective on an economic micro-level scale [62]. Aquaponics breeds fish and grows plants in a single production system [20]; and depending on the location, it can be soilless [63] or soil-based (Figure 1) [14].

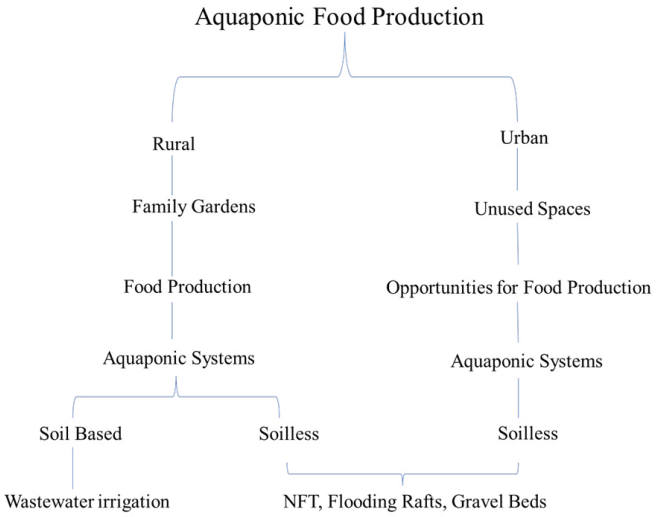

FIGURE 1.

Rural and Urban Aquaponic Food Production.

This enhancement of hydric resources creates a symbiotic growth of the fish and vegetables; while the fish effluent microbial compounds nourish the crops; the plant culture acts as biofilter for the wastewater, making it usable again [66]. Additionally, hydroponics growth season is unrestricted, which improves yield and growth rates. Most commonly cultivated edible plants under this scheme are smaller green leave species [64].

Although these arrangements are costly, the ecological impact is worthwhile [68]. A general problem of aquaponic systems is the poor plant productivity due to nutrient insufficiency in aquafeeds [69]. This lack creates a need of mineral nutrient supplements or the mix of organic fertilizers to increase plant productivity. In sum, for a hybrid fish-vegetable soilless production to optimize resources [59], aquaculture fish production needs to be nutrient dense [67].

The less known, open aquaponic system (or fish wastewater irrigation system), excels in fertile soil areas [14]. Said technique reuses aquaculture wastewater for agricultural land irrigation [70], [71], [72]. The indicators of soil quality and fertility are organic matter decomposition and nutrient cycling, which in turn is key for soil microorganisms [73].

As stated before, the design of the system depends on the specific crop and productivity goals [69], [74], [75]. On the other hand, building an aquaponic system requires a high investment [76], but can contribute sustainable off-season high-quality produce, and reduce food prices as consequence [59]. Therefore, initial investments become profitable in the long term [76].

Aquaponic systems are environmentally safer than traditional aquaculture, due to the lower hydric footprint and water contamination. It also surpasses traditional agriculture in terms of agrochemicals, hydric resources and soil pollution [66], [77], [78], [79], [80], [59].

Nevertheless, the alleged environmental advantages are still unproven and require further studies, for example, an assessment of integration into life cycles [81], [82].

Aquaponic systems complementing backyard production in a family farming concept

Backyard gardens develop convenient goods for household consumption [85] and are effective in the provision of healthy diets [86]; likewise, this model contributes almost 15% of the world's food supply, and the increasing numbers prove that it is crucial for national economies [42], [83], [84], [85]. Backyard production has a positive impact on productivity, but also on the access to healthy organic agrochemical free foods [87]. In the same vein, agroecological practices are essential to transition to more sustainable, biodiversity preservation oriented food production systems and shorter supply chains [60]. In other terms, home gardening benefits farmers' health due to the stress relieving nature of garden work [88]. Also, physical activity in combination with home consumption can have an educational impact.

In Latin America, the term "local production" relates to backyard gardening, family farming, or community farming and the intention of accessible food production. The process is carried out in terms of environmental, economic and nutritional sustainability [84]. Family farming in the region is a means to increase food security [89] while relieving the socioeconomic and ecological impact for families [35].

Family farming brings families numerous benefits, like self-sufficiency; however, its performance depends on technical information exchanges across a community [86]. Challenges in this matter are spatial, financial and time limitations, let alone climactic conditions and crop nutritional requirements [87], [90]. Nonetheless, backyard aquaponics is cost effective and sustainable as long as the site's characteristics, local market

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prices and operating-maintenance costs are convenient [19]. Besides, local production can improve dramatically because of home gardening in addition to aquaponics and elementary harvest methods [76].

Contrary to traditional unsustainable and environmentally aggressive food production systems, aquaponics can reduce the risk of food insecurity caused by climate change and socioeconomical turmoil [91]. In fact, aquaponics has been used as aquaculture wastewater treatment [20]; nowadays, because of the widespread of family gardens, it becomes more viable for backyard production, given its capacity to overcome space limitations [92].

Discussion

In recent years, intensive agriculture has harmed the environment, undermined small producers and failed to solve food insecurity in developing countries [93]. Consequently, it is necessary to raise awareness about these difficulties, and adopt new methods to process our sustenance. Backyard systems need to be revitalized [86] for supporting family food security. In combination with self-provision they might shorten supply chains and moderate the ecological impact caused by the transportation of food.

Nowadays, young people are interested in new sustainable technologies to improve life quality by consuming organic foods [94]. This will render local production and consumption a political topic soon, starting with the change of the food agenda; more subsidies will be granted to local producers committed to commercialize organic foods at reasonable prices. In such context, aquaponics will find its place as a sustainable and profitable system.

There is potential in aquaponic production with the development of better water usage and fish breeding technologies. For example, black soldier fly larvae can be used as aquafeed [95]; and it is believed that agriculture and aquaculture residues could feed the larvae. Were this true, a more closed food production system would be possible. Also, vertical hydroponic systems and farming concepts [96] as well as the introduction of locally produced organic fish aliment remain mostly unstudied.

Research of more compatible species is needed to optimize the systems' nutrient load and diversify family diets.

Unfortunately, due to its high initial investment and maintenance costs, food produced in these systems are expensive [97], notwithstanding increased productivity due to technological developments [94], [98]. Therefore, the population should be guided and educated on the cost-benefit of these systems and their importance for the future of food production.

For future projects, scientists must collaborate with producers in order to develop projects that really cover the needs of a community for a sustainable development [99]. It is important to research and develop new methods of animal and plant production [100]. For example, the cultivation of different types of algae for human consumption in poly-culture systems [101]; these techniques could play an essential role in food sustainability in combination with the consumption of homegrown produce.

Conclusion

Consumers have shifted towards organic and locally produced food and restaurants which offer according menus; this ideological change has boosted home and urban gardening concepts. Moreover, this movement appeals to consumers' conscience by proposing an environmentally friendly way to acquire food, albeit at a higher expense. Consequently, there is a growing interest in implementing sustainable strategies to diversify fresh, organic nourishment sources.

Aquaponic systems constitute a sustainable method of providing two fresh organic proteins, fish and plant, in a single circular system. The main benefits are the optimization of water usage and the decrease of agrochemical products. Furthermore, aquaponic systems are suitable for family and home gardens given their spatial adaptability and sole requirement of fresh water access.

Although local consumption is on the rise, more regional studies in diverse rural and urban climate zones on the impact of backyard production are needed; in specific, aquaponic systems and its positive effect

on food security, environment, society and economy. Further areas of interest are the educational impact on families and the awareness of biodiversity and nature conservation in general.

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