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Technical and Business Evaluation of Professional Aquaponics in Europe

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Abstract: The European aquaponic sector started to develop and professionalize in the early 2010′s. This development and the subsequent challenges faced by early practitioners were investigated in various publications between 2015 and 2020. Although most of these studies were focused on educational and research institutions, only a few included commercial entities. The present survey is aimed at defining and assessing the recent evolution of the European aquaponic activities in professional structures. One hundred and forty professional aquaponic entities (non-profit organization, educational, and commercial) having an aquaponic system with more than 1 m^3 of water in their recirculating aquaculture systems were identified in Europe. Among them, 46 responded to a survey about the technical and business aspects of their structures. In comparison to previous surveys, a much higher number of entities had larger systems (up to 14,000 m^2), with higher yields (up to 20 t of fish or vegetables per year), whereas 59% of them declared making profits. This revealed a clear expansion and professionalization of the sector, which was found to be highly diversified, with systems varying greatly in size, design, and technology. Business models and activities were generally diverse, and included a combination of production, education, and/or services. Most entities also combined different customer segments. At the time of the survey, the aquaponic sector was still struggling to find its economic viability, as the business model of most entities did not only rely on fish and vegetable sales, but also largely relied on free labor through volunteers or internships. Acquiring knowledge as well as optimizing production and business models were perceived as the main challenges for the steady growth of the sector. Consequently, there is a clear need to increase training, to continue the research and development work, and create public support systems for aquaponics farms to further improve and expand the commercialization of aquaponics in Europe.

Keywords: aquaponics; sustainable agriculture; innovation adoption; commercial producers; international survey

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1. Introduction

Aquaponics—the integration of recirculating aquaculture and soilless horticulture—has been cited by supranational entities (the FAO, the European Commission) as one of the most promising food production technologies in terms of sustainability and efficiency [1]. Despite early research dating back to the late 1970s [2], it has taken over 35 years for the first commercial aquaponic companies to be set up in Europe [3], while some of the earliest European research was conducted in 2009 [4]. Interest in aquaponics has greatly increased in recent years, especially in the research and education sectors. Several books on small-scale and commercial aquaponics [5–8] as well as more than 595 articles have been written on the subject [9].

Although interest has clearly increased within the academic field (e.g., COST action FA1305: COST EU Aquaponics hub, Blue Grass, or Aqu@teach), there is a common concern regarding the economic viability and sustainability of commercial production [10–13]. More recently, commercial aquaponics has been said to be an innovation environment where hype prevails over demonstrated outcome [14]. The statement is relevant considering the high risk of failure and rare accounts of successful farms, especially in Europe. However, these concerns cannot be critically assessed to predict economic challenges as literature on the economics of aquaponics is very sparse, and much of the early literature was primarily based on theoretical and pilot models [15]. Most studies are limited to small-scale systems and are simplistic due to their lack of details on expenditures [16–18]. A review scanning all scientific papers published between 1978 and 2018 highlighted the fact that over one third of the papers were published on trends and challenges associated with aquaponic systems [19]. Turnšek et al. [20] recently reviewed economic analyses in the existing literature and concluded that hardly any reliable data was available for a comprehensive economic evaluation of aquaponics. This is partly due to the broad spectrum of system designs operating in a wide range of conditions within varying markets [21]. In addition, corporate companies are not likely to disclose business and financial details. The lack of modular economic models and the myriad of factors affecting economic assessments make it very difficult to compare and evaluate the economic viability of commercial aquaponic practices at this point.

From a corporate standpoint, early market forecasts estimated the potential worldwide aquaponic market size to be around \$180 million in 2013, expected to reach \$1 billion in sales by 2020 [22]. A later forecast from the same service company projected the aquaponic market to increase from \$409 million in 2015 to 906.9 million in 2021. IndustryArc now claims that the global aquaponics market is estimated to hit \$1.19 billion by 2023. Another market intelligence and consulting firm valued the global aquaponics market at more than \$580 million in 2015 expected to reach \$1.7 billion by 2026, with a compound annual growth rate of 13.5% throughout the forecast period [22]. As the large majority of non-professional and commercial aquaponic practitioners are located in North America [23–25], it is hard to know the share of these estimations, if at all reliable, attributable to the European market. However, commercial aquaponic activities including pilot-scale projects and industrial farms of thousands of m^2 are emerging in Europe. Thorarinsdottir in 2015 [3] identified 10 pilot aquaponic farms, half of which were still under construction and too small to be considered commercial and two of which have now declared bankruptcy (Nerbreen et Ponika). In 2016, a specific European survey conducted based on a previous study surveying mainly North America and Australia reported approximately 20 European commercial aquaponic companies [26]. One year later, a map was created identifying 45 commercial companies [26]. Nevertheless, the reliability of the map is questioned as it contains non-European companies, companies that have ceased to trade, and only about one third are focused on food production [20]. Despite the slow development of commercial aquaponics in Europe reported in current academic literature [11,21], aquaponic activities appear to be on the rise, hence, a clear need for an appropriate and updated listing of current commercial aquaponic practices in Europe.

The slower development of this innovative technology at the European level is partly due to the current European institutional framework, including gaps in legislation and the lack of common and uniform legislation among EU member states [27]. According to the European Commission, neither RASs nor hydroponic cultivation can be certified organic. This restricts the potential market for aquaponic products. Heavy administrative and organizational constraints are imposed by general or specific codes in the European standard classification of production activities, but aquaponics is not considered as an activity per se. Therefore, aquaponic activities cannot benefit from Common Agricultural Programs, which play a pivotal role in the competitiveness of other EU agricultural activities [28]. Moreover, environmental and technical constraints such as considering solid fish excrement as waste or inexplicit norms for the commercialization and food safety of aquaponic products further hinder the development of aquaponics at the European level [29,30]. In general, there is no aquaponics-specific legislation, so that aquaponic farmers have to refer to the legislation of both aquaculture hydroponic vegetable production.

Early observations of consumer acceptance showed that aquaponic products were generally very well received. Studies in Romania [31], Canada [32], and Malaysia [33] showed that end consumers generally had a positive attitude towards aquaponic products. However, in Germany only 27% of surveyed people showed a willingness to pay for aquaponic products, whereas 28% did not approve of aquaponic production in urban areas [34]. Results from a European survey on consumer knowledge and acceptance of aquaponic products showed that half of the respondents did not know what aquaponics was [30]. The importance of consumer perceptions and acceptance of aquaponic products for the success of commercial aquaponics was emphasized by Turnšek et al. [21]. To date, no survey has been specifically conducted on professionals in the field. Furthermore, all previous surveys focused on fresh aquaponic products (fish or plants), but did not mention acceptance of other types of products or services surrounding commercial aquaponics.

Previous studies demonstrated that aquaponic activities in Europe were mainly focused on education, research, or the associative/non-profit sector and that only few commercial initiatives had emerged. A rough review of these papers would suggest a great potential for the further development of aquaponics in Europe, but would highlight raising concerns about its commercial feasibility. This study aims to better define and assess the evolution of European aquaponic activities in professional structures—commercial entities, non-profit organizations (NPOs), and research and education institutions—in terms of technical developments and their economic viability.

2. Materials and Methods

In order to provide a better understanding of the activities surrounding aquaponics in Europe, commercial enterprises promoting their activities on the internet are listed. The list included commercial producers, universities, social or non-profit organizations, schools, consultants, and suppliers of aquaponic products. To avoid collecting data on hobbyist and aquaponic enthusiasts, the list compiled entities that currently had RASs with a minimum volume of 1 m^3 and an integrated hydroponic sector. This way, we focused on the more professional side of aquaponics, even if the system itself was not directly the source of income (e.g., in education and research). The list includes data such as the company name, address, and website.

A quantitative questionnaire was developed based on surveys used in pre-existing scientific articles [23,26]. The most recent survey intended for European companies [26] had 25 questions distributed in five categories, half as many as the previous international survey [23], as the authors assumed that commercial production was still low in Europe. The survey developed for this study had 67 questions distributed among 10 categories to highlight the assumed increase in commercial production and to collect more appropriate data. In brief, the sections included Consent (n = 2), General Information (n = 7), Organization (n = 4), Products and Services (n = 2), Production Methods (n = 7), RAS (n = 9), Hydroponics (n = 4), Waste Treatment (n = 4), Monitoring and Control (n = 2), and Business (n = 23). The complete survey is presented in the Supplementary Material File S1. As a large proportion of the identified aquaponic activities in Europe are operating in France. The survey was written both in French and English to maximize participation. Compared to previous studies, more detailed questions were asked about the characteristics of the systems and the financial and business aspects of the commercial operation in order to reach a more precise understanding of the levels of technological implementation and economic viability. The survey was sent out to the contact person of each entity of the previously compiled list and distributed on various social media to broaden the scope of our list. Partial completion of the nine first sections of the survey (all except business section) by the respondents were removed from the raw data. It was open between December 2019 and January 2020.

The responses to open-ended questions were analyzed according to established procedures for interpretive research. The data was specifically analyzed through a process of response coding and triangulation between the authors. Codification consists in transforming raw data (i.e., the texts of open answers) into a first significant formulation (code), whose meaning remains close to the testimony embedded in the raw data. We considered a code to be "most often a short word or phrase that symbolically assigns a salient, summative, essence-capturing, and/or evocative attribute to some part of language" [35]. Based on these codes, categories were defined and subsequently associated with the responses. Codes and categories were assigned and refined inductively based on concepts and meanings that emerged throughout the analysis process [36].

The data were compiled and analyzed in an Excel file. The statistical analysis (ANOVA and correlation) was performed in R, using the packages Agricolae and Openxlsx [37,38].

3. Results

3.1. Demographics, Background and Experience

One hundred and forty professional aquaponic structures with an aquaponic system of at least one cubic meter were identified (see Supplementary Materials Table S1). It is important to note that most of these structures were identified on the internet, limiting the scope of our study. The list probably better represented larger rather than smaller aquaponic structures as it is assumed that larger structures would have more internet visibility. Forty-six entities completed the first part of the survey, and 39 (84.8%) answered business related questions.

Among the respondents, 65.2% (n = 30) of them were the founder, the CEO, or the director of the structure, and the large majority of the remaining 34.2% held key positions in their respective structures. The typical respondent was a young educated man; 60.9% (n = 28) of the respondents were between 25 and 39 years old, 71.7% (n = 33) held at least a master's degree, whereas 78.3% (n = 36) were men (Figure 1).

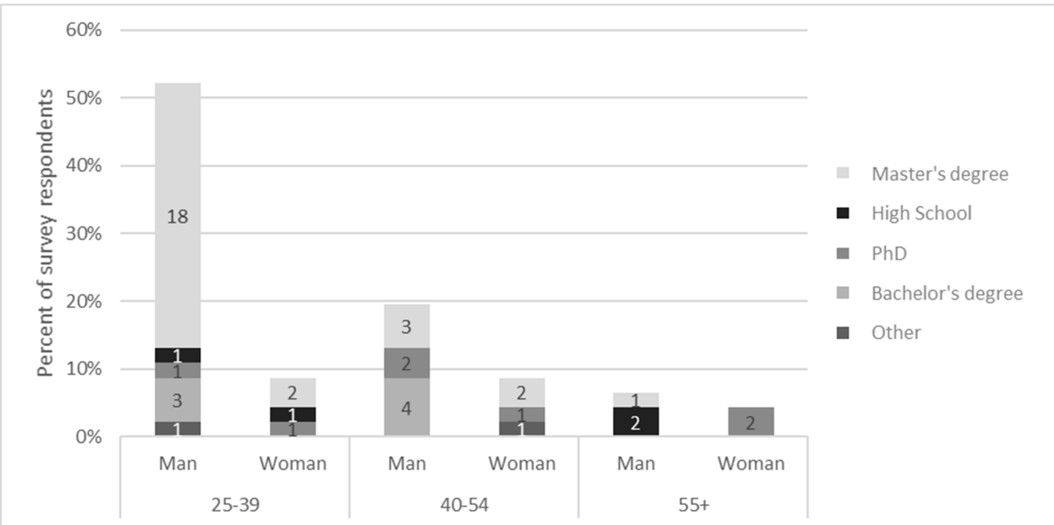

Figure 1. Age range, sex, and education level of the respondents.

3.2. Location, Size, Age, and Objectives of the Facility

Among the 140 identified structures, most aquaponic activities took place in France (37.1%, n = 52), followed by Belgium (10.7%, n = 15), Germany, and the UK (7.8%, n = 11 each) for a total of 25 countries.

Our panel of respondents was representative of the geographic distribution of the total number of structures, with 41.3% (n = 19) of respondents in France, followed by Belgium (19.6%, n = 9). Germany, Sweden, The Netherlands, and the United Kingdom had 4.3% (n = 2) respondents each. Austria, Czechia, Greece, Italy, Lithuania, Portugal, Slovakia, Slovenia, Spain, and Swiitzerland had one respondent each. The fact that this study was mainly conducted in English and French and was partially delivered through local networks could explain the high participation of French and Belgian entities. However, the distribution of the aquaponic systems identified here reflects the findings of previous studies [26].

Despite the promotion of the benefits of aquaponic systems in urban environments [39], it was surprising to notice that aquaponic systems were very evenly distributed among urban (30.4%, n = 14), peri-urban (34.8%, n = 16), and rural (34.8%, n = 16) areas. Different markets apply to these different zones, suggesting a high degree of variability in the design and management of aquaponic systems.

Among the 46 entities, 13.0% (n = 6) were non-profit. The education sector, including primary and secondary schools, training centers, universities, and research centers represented 26.1% (n = 12) of the entities. The remaining 60.9% (n = 28) combined production, retail, and consulting activities and will be regarded as "professionals" henceforth. Professional activities clearly increased compared to previous studies. In a study conducted in 2016, only 19.1% of the respondents identified themselves as commercial structures, 51.4% were educational structures, and 14.7% were NPOs [26].

The oldest aquaponics system of our panel was created in 2009 (Figure 2). Half of our panel created its aquaponics system between 2011 and 2017. Interestingly, 15 systems were created in 2018. The first two professional systems were created in 2012 in the United Kingdom and Spain. The third and fourth professional systems were created in 2015, one in France and one in Belgium. Professional aquaponic systems started appearing in higher numbers after 2015. This may reveal that many new professional aquaponics entities were created after 2015 or were an artefact in the representativeness of our panel, as new entities may be more motivated than older ones to contribute to such studies.

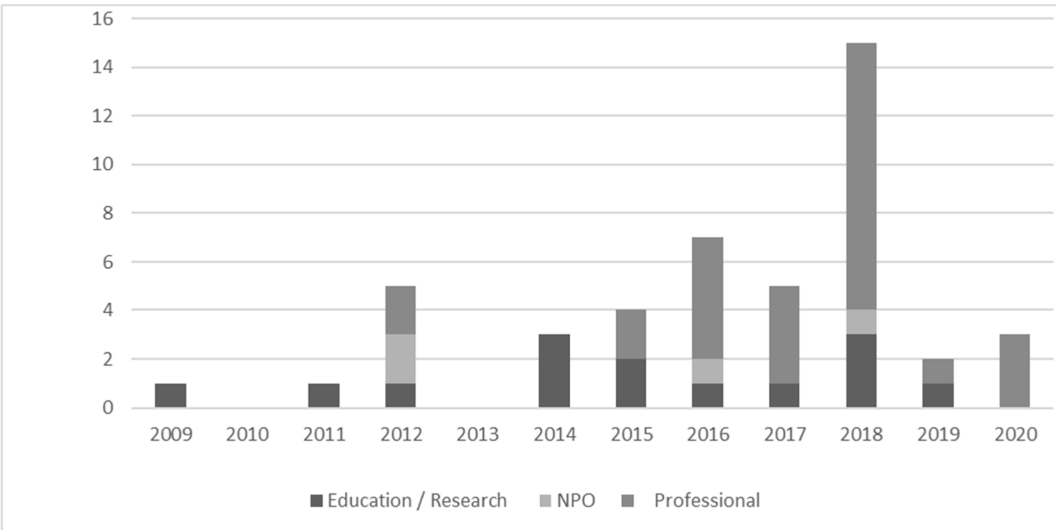

Figure 2. Year of creation of aquaponics system.

The survey investigated the main purposes of the entities (Figure 3). The commercial aspect and financial gain were very important in all projects. This is particularly interesting, because it contrasts with the result of the survey by Turnšek et al. [21], where only 36% of the respondents claimed choosing aquaponics for "having a higher economic potential". The main differences between the panels were that (i) our panel only includes infrastructure with actual aquaponic systems, (ii) the panel of Turnšek et al. [21] included early enthusiasts who invested time and money in aquaponic activities, and (iii) the study by Turnšek et al. [21] was conducted in 2017, whereas the present study was conducted in 2019–2020. This reveals that the respondent's conviction for financially viable aquaponic activities was lower in previous studies. "Innovative food production systems" and "Environmental durability" were important or very important for, respectively, 93.5% (n = 43) and 95.7% (n = 44) of the respondents. Then came, by decreasing order of importance, "Research and development", "Improve food nutritional quality and taste", "Local consumption", "Subsistence (food security)", "Recreation", "Consultancy", and "Social integration". This is in accordance with the observations of Turnšek et al. [21]. "Customary land use" was not a main concern for the majority of the respondents: 63.0% (n = 29). This is a surprising result as it was previously understood that aquaponics was particularly adapted to areas not suitable for other food production techniques, for example, polluted areas, cities, and rooftops [11,40].

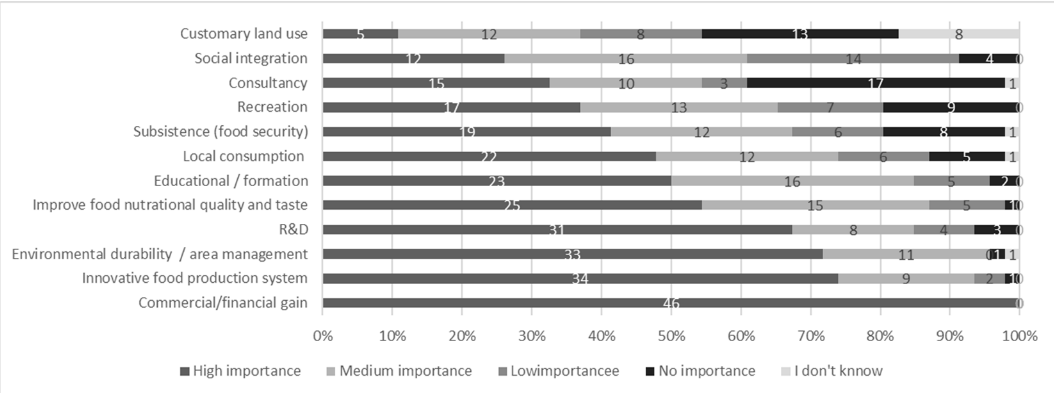

Figure 3. Main purposes of the different entities.

3.3. Design, Production, and Techniques

The aquaponic facilities of this study ranged from 8 m^2 to 14,000 m^2. To more appropriately reflect the data, the systems were classified in the following size categories: 0–99 m^2, 100–499 m^2, 500–1999 m^2, 2000–4999 m^2, and 5000–15,000 m^2 (Figure 4). The most represented classes were 100–499 m^2, 500–1999 m^2, and 0–100 m^2. They represented 32.6% (n = 15), 26.1% (n = 12), and 21.7% (n = 10) of the systems, respectively. Systems with a total surface greater than 2000 m^2 represented only 17.4% of the panel (n = 8). One entity did not provide its total surface. The average size of the facilities was much bigger than in previous studies where aquaponics facilities ranged between 1 and 1600 m^2, and the majority were smaller than 100 m^2 [26]. This indicates a significant increase in the sizes of aquaponic facilities between 2014 and 2020.

The area dedicated to plant production ranged from 4 to 12,000m^2, and the volume of water in the RAS ranged from 1 to 5000 m^3. The correlation between the area dedicated to plant production and the volume of water in the RAS was not significant. This reflects the variability of the plant-production-area-to-RAS-water-volume ratio (0.02–50) and further demonstrates the heterogeneous nature of professional aquaponic systems. Surprisingly, no significant statistical correlation was found between total area, plant production area, or RAS water volume and the activity of the structure (Professional vs. NPO vs. Education/research), suggesting that the size of the aquaponic system is not defined by the main activity of the structure. Among the 46 entities, 47.8% (n = 22) also produced vegetables in soil, 13.0% (n = 6) produced insects, and 13.0% (n = 6) produced mushrooms. This shows that entities using aquaponics tend to diversify their production. A very wide range of systems was observed. Most companies designed and built their own systems (67.4%, n = 31), some had systems designed by consultants (28.3%, n = 13), and only two systems were bought in a kit (4.3%). These results are in line with previous findings on European systems [26].

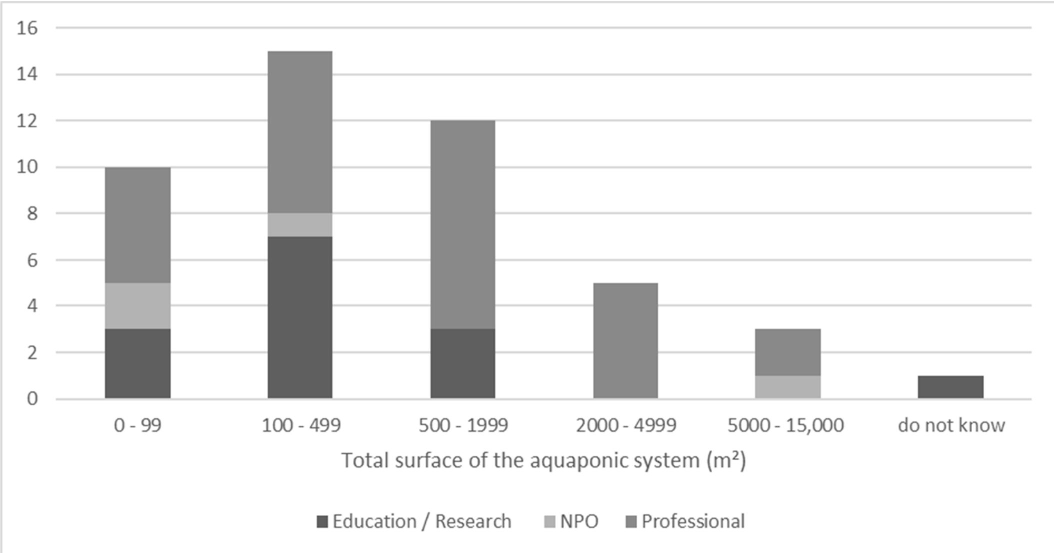

Figure 4. Total surface classes of aquaponic systems and institution types.

About one third of the systems (30.4%, *n* = 14) were coupled, about one third (37%, *n* = 17) were decoupled, and about one third (32.6%, *n* = 15) were hybrid systems, including both coupled and decoupled loops. There was no significant correlation between the coupling type and the system size or the date of creation of the system. Similarly, the coupling type seemed evenly distributed between the size and the activity of the structure (Professional vs. NPO vs. Education/research). The increase of decoupled systems compared to previous studies is easily explained by its advantage in terms of risk management and increased yields [10]. Nevertheless, among the 11 most recent systems (operating after 2018), only three of them were coupled, hinting to a global trend towards more decoupled systems but still with an interest in coupled systems in 2018.

RASs were located in cold greenhouses (37.0%, *n* = 17), inside buildings (34.8%, *n* = 16), heated greenhouses (17.4%, *n* = 8), and outdoors (8.7%, *n* = 4). One answer of RAS location was "other". A few RASs were located on rooftops: two in a cold rooftop greenhouse, one in a heated rooftop greenhouse, and two outside on a terrace. Most of the aquaponics producers used greenhouses for plant production, including cold greenhouses (47.8%, *n* = 22) or heated greenhouses (34.8%, *n* = 16); the others grew plants in buildings (17.4%, *n* = 8) or simply outdoors (10.9%, *n* = 5). Five entities (10.8%) were growing plants in different locations.

Most respondents (71.7%, *n* = 33) used city water, 43.5% (*n* = 20) used rain water, and 26.1% (*n* = 12) used well water. Among them, 47.8% (*n* = 22) combined different sources of water. No significant correlation between the water source and the size of the system was identified.

The most popular fish produced in the systems was trout, followed by carp and tilapia, present in 47.8% (*n* = 22), 30.4% (*n* = 14,) and 21.7% (*n* = 10) of the systems, respectively (Figure 5). An important proportion of systems (45.7%, *n* = 21) reared more than one fish species. This result is very different from Villarroel et al. [26] where the prevalent species were tilapia (27%), catfish (10%), ornamental fish (8%), and trout (7%). The decrease in occurrence of tilapia and catfish may be associated with a lack of consumer interest in these species on the European market and due to invasive species as well as breeding regulations in certain European countries. The range of annual fish production was wide, with 26% (*n* = 12) of the respondents producing 1–49 kg of fish per year, and only one farm had an annual production of 20,000 kg of fish (Figure 6).

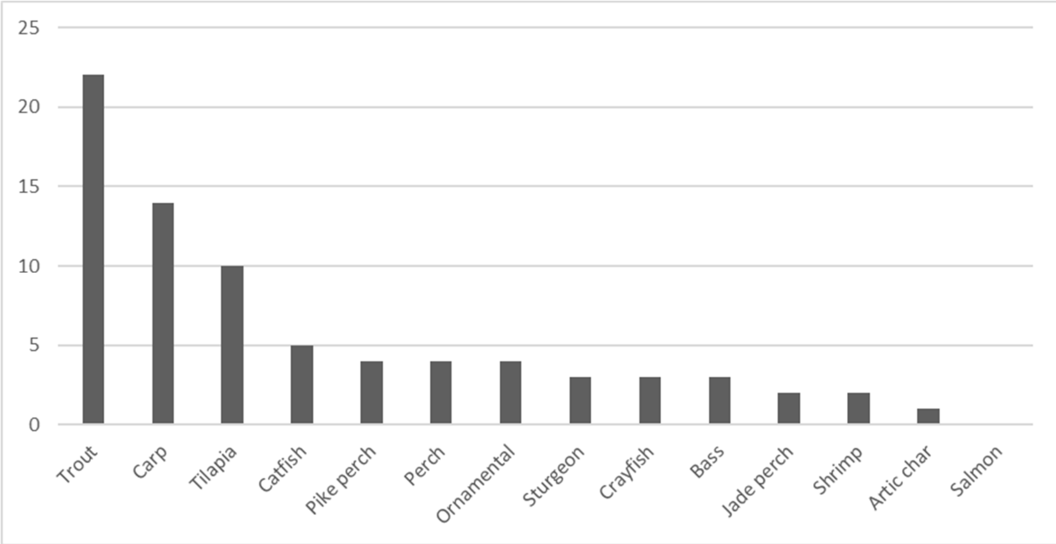

Figure 5. Number of institutions rearing the different fish species.

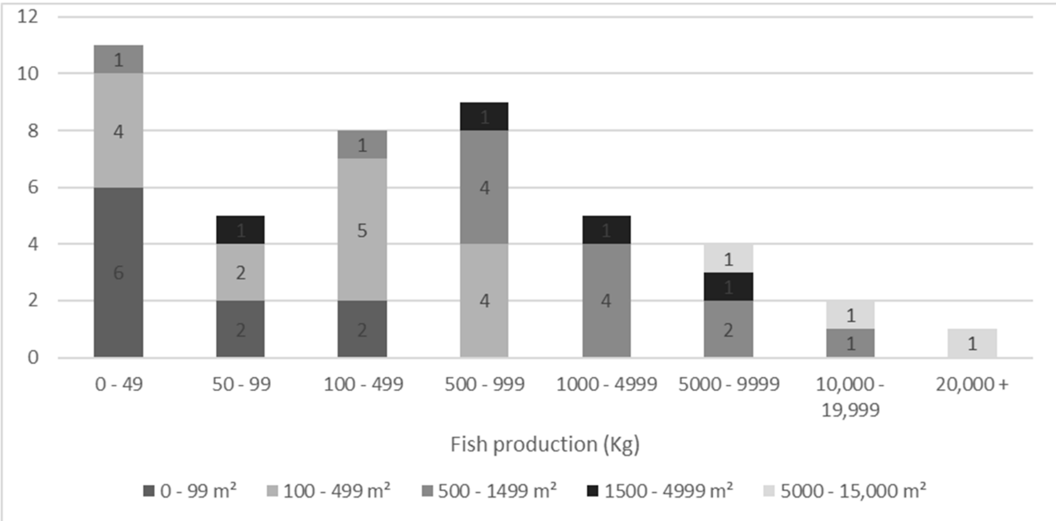

Figure 6. Fish yield and total surface of the aquaponic systems.

Several interesting trends were noticed in the technical aspects of fish production. The two most represented mechanical filters were sedimentation filters and drum filters, found in 50.0% (n = 23) and 39.1% (n = 18) of the systems, respectively. Media beds were present in 8.7% (n = 4) of the systems, and 6.5% (n = 3) of the respondents claimed to use no filter. Some systems (15.2%, n = 7) were equipped with a combination of different filters. As for biofiltration, most of the respondents used moving beds or media beds (63.0%, n = 29 and 37.0%, n = 17, respectively). Others used bead filters (4.3%, n = 2) or other types of biofilters (8.7%, n = 4). A combination of biofilters was present in 17.4% (n = 8) of the systems. Pure-oxygen and UV filters were present in respectively 82.6% (n = 38) and 56.5% (n = 26) of the systems, suggesting increasing implementation of technology and a trend towards intensified production. Few systems (8.7%, n = 4) had a biofloc unit. Concerning the feed, the respondents were using pellet feeds based on animal proteins (80,4%, n = 37), pellets including insect proteins (17.4%, n = 8), 100% vegetal feed pellets (23.9%, n = 11), and live feed (8.7%, n = 4). A combination of feed types was used in 28.3% (n = 13) of the systems.

The management of fish sludge was also investigated in the study. Most respondents (78.3%, n = 36) claimed that they used fish sludge for soil amendment in agriculture (45.7%, *n* = 21) and/or in their hydroponic system (45.7%, *n* = 21). Among them, 32.6% (*n* = 15) used sludge for both soil and hydroponic production. Some respondents (13.0%, *n* = 6) did not reuse the sludge, and 8.7% (*n* = 4) did not know how the sludge could be used. The most popular sludge treatment was aerobic mineralization (37.0%, *n* = 17), followed by anaerobic mineralization and vermicomposting (10.9%, *n* = 5 each). Two respondents used sludge for biogas production, one respondent used sludge as soil compost, and 10.9% (*n* = 5) did not know how it was treated.

Thirty-one varieties of plants were identified in the present survey (Figure 7). Contrary to fish, where three species were prevalent, numerous vegetable species were well represented. Six species were present in more than 25% of the entities and 20 were present in more than 10% of the entities. Aromatic herbs, tomatoes, and lettuce were the most represented plants and were present in 45.7% (*n* = 21), 37.0% (*n* = 17), and 32.6% (*n* = 15) of the entities, respectively. The number of species per system ranged from 1 to 33, and 32.6% (*n* = 15) of the structures produced fewer than three vegetable species, 39.1% (*n* = 18) produced three to nine vegetable species, and 28.3% (*n* = 13) produced 10–33 vegetable species. Again, no significant correlation emerged between the number of species and the type of organization. Large aquaponic systems with low or very large numbers of species were found, and small systems with low or very large numbers of species were also observed. The high variability of these parameters in the data further demonstrates the complexity and diversity of current aquaponic farms. The range of annual plant production followed that of fish production: 15.2% of the systems (*n* = 7) produced 1–49 kg of vegetables per year, whereas 8.7% (*n* = 4) produced more than 20,000 kg of vegetables per year (Figure 8).

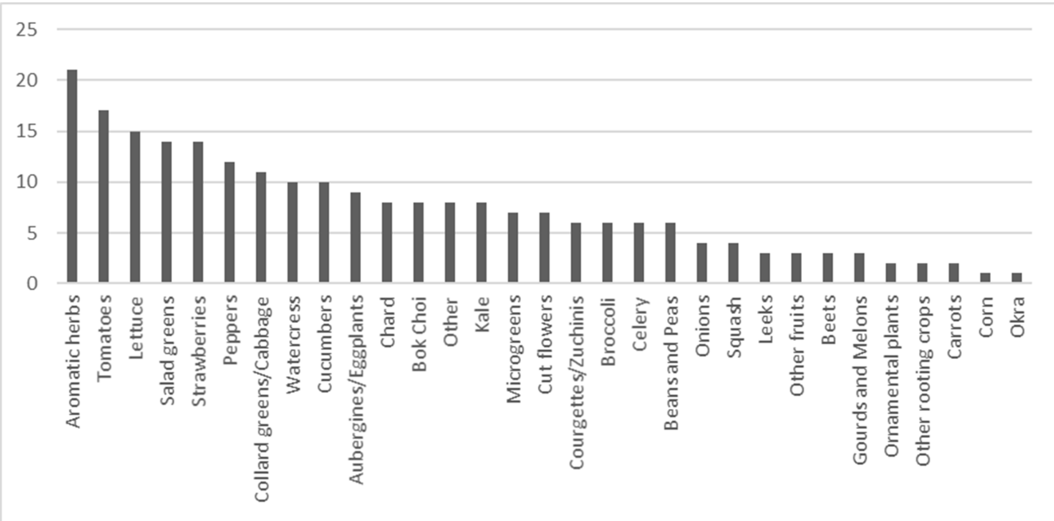

Figure 7. Number of entities growing different plant species.

The most common hydroponic production systems were rafts, media beds, NFT, drip systems, and were present in 69.6% (*n* = 32), 43.4% (*n* = 20), 15.2% (*n* = 17), and 30.4% (*n* = 14) of the entities, respectively. Vertical towers, ebb-and-flow, and wicking beds were less represented (15.2% (*n* = 7), 4.3% (*n* = 2), and 2.2% (*n* = 1), respectively). Most entities (63.0%, *n* = 29) were combining different production systems. The structures equipped with rafts had a significantly higher number of species than those with no raft ($p = 0.007$). The systems where high numbers of species (>13 species) were grown all had rafts. This reflects the adequacy of rafts to a wide range of plant species. Heated greenhouses harbored a significantly lower number of species ($p = 0.02$) than cold greenhouses did, maybe because heated greenhouses are generally used to grow fruit vegetables (tomatoes, eggplants, peppers), hence, a more restricted number of species. Moreover, heated greenhouses require more energy and a higher investment, so that entities would tend to intensify production of a few species to reach a certain economy of scale. No significant association between the type of production system and the size of the aquaponics facilities was identified. Artificial light was present in 32.6% (*n* = 15) of the structures. Most structures (65.2%, *n* = 30) had an automated monitoring system. Moreover, half of the entities (50.0%, *n* = 23) utilized monitoring systems within both fish and plant production, again highlighting the implementation of high-tech equipment.

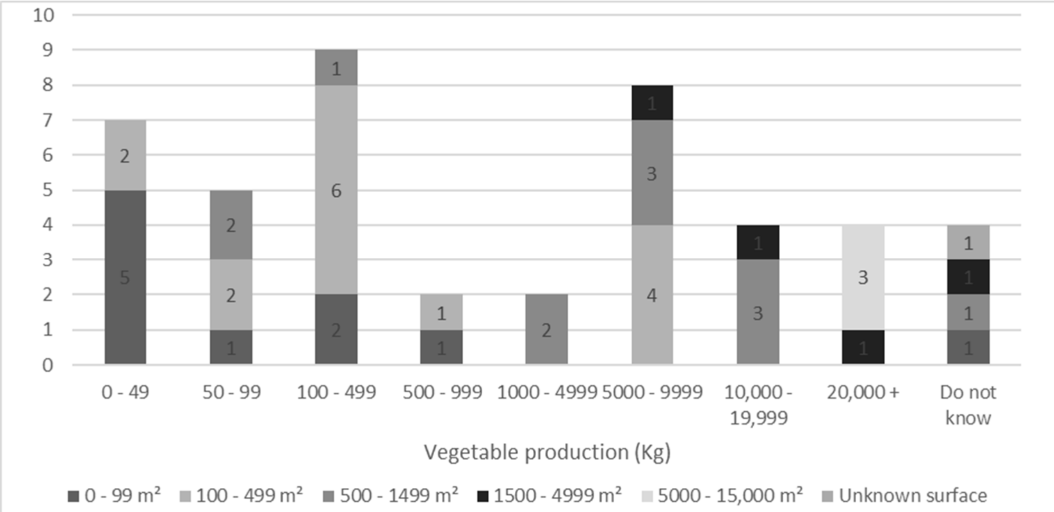

Figure 8. Plant yield and total surface of the aquaponic systems of the respondents.

3.4. Business Model

The business questions were answered by 84.8% (*n* = 39) of the 46 respondents. Among them, 58.7% of the entities (*n* = 27) declared that they had had clients in the last 12 months, versus 26.1% (*n* = 12) who declared that they had had no clients. The following sections of this article focus on the 27 entities that had had clients and in thus a commercial activity. Among them, 22 described themselves as aquaculturists/horticulturists/aquaponists, three were NPOs and two were schools. The commercial activities taking place in schools may reveal the importance of commercialization of aquaponic training programs.

In order to get a better understanding of the business strategies of the respondents, the type of offe and the targeted customer segments were investigated for the 27 commercial entities. Only 18.5% (*n* = 5) had one type of offer (product), whereas the others offered a combination of products, services, or R&D (Table 1). Most of the entities (96.3%, *n* = 26) offered products, 74.1% (*n* = 20) offered services, and 37.0% (*n* = 10) performed research and development. Services included—but were not limited to—training, visits and consultancy. As for the targeted customer segment, few entities (25.9%, *n* = 7) had only one type of segment, and the others combined different segments. In fine, 92.6% (*n* = 25) of the companies had B2B activities, 81.5% (*n* = 22) had B2C activities, and 11.1% (*n* = 3) had R&D activities. Commercial European aquaponic structures appear to be mainly opting for the production of products and services and directly targeting end customers as well as companies. One explanation of this diversity would be that most of the entities are quite recent (2018), and are attempting to reach different markets. The coming years will give insight on whether commercial strategies will remain broad or will be focused on certain key segments.

The data gathered in this study show no clear trends in the companies' business models and reflect the diverse nature of the production systems themselves. There is a high degree of variability within markets depending on the nature, size, and location of commercial aquaponic farms. Furthermore, as most farms were established in the last 5 years, commercial strategies are yet to be standardized.

Table 1. Offers according to the customer segments of the different entities.

Offer vs. Customer Segment	Product	Product and R&D	Product and Service	Product and Service and R&D	Service and R&D
B2B			2	2	1
B2B and B2C	4	1	9	3	
B2B and B2C and R&D	1		1	1	
B2C		1		1	

Specific attention was paid to the motivations of the respondents to initiate or participate in their organization. The three most representative answers were (i) "to develop full-time professional activity" (ii) "to produce food" (iii) "by passion", closely followed by "reducing CO_2 emissions". These four statements were of certain importance for more than 66.7% (n = 18) of the respondents. This underlines the respondents' belief that commercial aquaponics can be profitable and sustainable.

The survey investigated the clients' expectations by asking the producers what the expectation of their clients were (Figure 9). Since the respondents were the producers themselves—not the clients—the data and conclusion presented in this paragraph need to be taken with caution. The two greatest expectations were "having local food" and "knowing the origin of the product". These two points were regarded of high importance for 81.5% (n = 22) of the respondents. The third most important point was "having fresh and seasonal products" and was of high importance for 66.7% (n = 18) of the respondents. These results are in accordance with the observation and conclusions made by Turnšek et al. [21], who reported that aquaponics consumers were willing to pay a premium price for aquaponics products free of antibiotics, pesticides, and herbicides, connected with local producers, but not because of aquaponics as a production system in itself. Consequently, this reveals that the customer base of the respondents is mainly interested in sustainable and local farming.

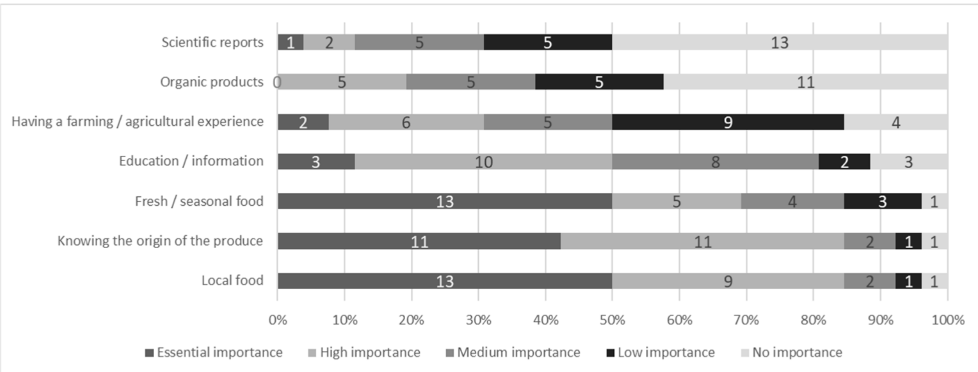

Figure 9. Levels of importance of different client expectations.

The two most popular communication channels were direct communication ("Face to face") and/or by word of mouth, which was of high importance for 77.8% (n = 21) and 63.0% (n = 17) of the respondents, respectively (Figure 10). Emails, newsletters, and websites were of high importance for 55.6% of the respondents (n = 15). Traditional communication channels such as the press/journals/TV were also well represented with at least a high importance for 48.1% of the respondents (n = 13). Among the social networks, Facebook had a certain prevalence, but others such as LinkedIn, Twitter, and Instagram were poorly represented. Consequentially, it makes sense that direct communication and word of mouth are important communication media in a sector where food locality and knowing the origin of the produce are major customer expectations. Communication channels could change if the size and production of aquaponics farms continue to increase. Bigger aquaponic farms may indeed have to find other, larger customer segments.

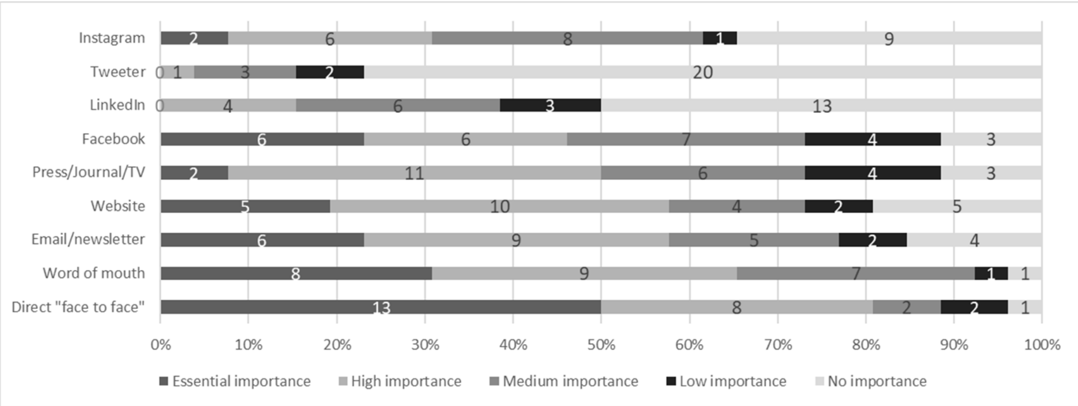

Figure 10. Levels of importance of different communication channels.

The survey also investigated stakeholder engagement and competition (Figures 11 and 12). According to the respondents, the three most engaged stakeholders were supermarkets, markets, and neighbors with at least a high engagement representing 66.7% (n = 18), 55.6% (n = 15), and 51.9% (n = 14) of the entities, respectively. Having clients as main stakeholders reveals that commercial relationships are an essential support for the aquaponic sector and suggests that aquaponics producers may be important economic actors. Most of the respondents did not feel a sense of competition: only a few answered this question (51.9%, n = 14), and among them, the proportion of respondents who declared being under high or very high competition was low. The biggest competitors, for whom competition was of high importance or more were small growers (28.5%, n = 4), supermarkets (21.4%, n = 3), and markets (14.3%, n = 2).

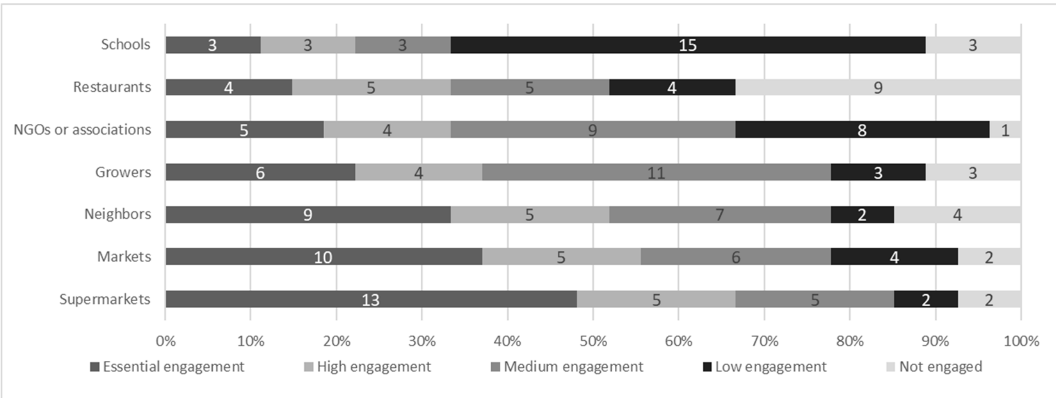

Figure 11. Levels of engagement of different potential stakeholders.

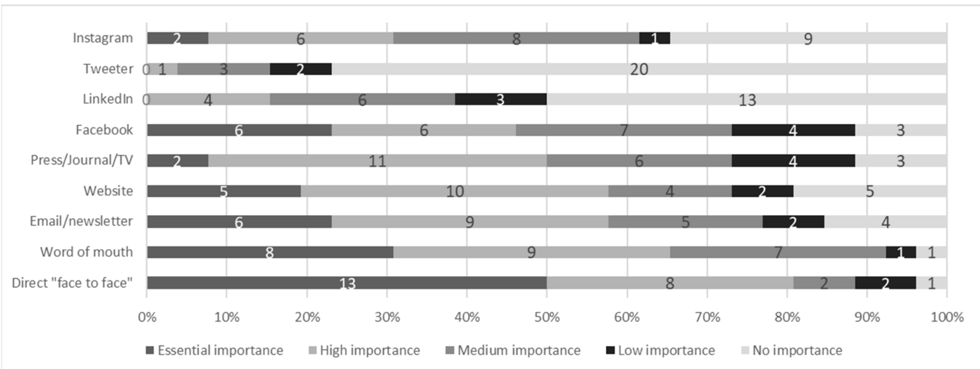
Instagram
Tweeter
LinkedIn
Facebook
Press/Journal/TV
Website
Email/newsletter
Word of mouth
Direct "face to face"
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Essential importance
High importance
Medium importance
Low importance
No importance

Figure 12. Levels of competition of different potential competitors.

To evaluate the investment cost of each system, the respondents were invited to select a range of initial investments and write the exact investment cost if the data was available (Table 2). Most of the respondents (96.3%, n = 26) provided a range of initial investment, whereas 40.7% (n = 11) provided the exact investment. Table 2 shows that the investment range was variable in each size category. Entities with investments higher than 1,000,000 € were (i) a heated rooftop greenhouse and (ii) the largest aquaponic system of this study, which also produced in a heated greenhouse. Entities with investments ranging from 500,000 to 999,999 € generally produced indoors. The systems with more technological or energy-demanding components (large RAS water volume, indoor, or heated greenhouses) required the highest investments. Yet, the system with the lowest investment was a 100 m^2 heated rooftop greenhouse. The other investment range categories included various types of aquaponic systems. Eleven respondents provided their exact investment costs. The investment cost per square meter was calculated based on their data. Four of the 11 structures had investment costs ranging from 44 €/m^2 to 93 €/m^2 and produced their vegetables in a cold greenhouse. Four of the 11 structures had investment costs ranging from 150 €/m^2 to 313 €/m^2 and had a heated greenhouse for vegetable production. Two had investment costs of 694 €/m^2 and 714 €/m^2; an indoor system, and very small system (less than 20 m^2), respectively. One system—the heated rooftop greenhouse with investment higher than 1,000,000 €—had an investment cost of 1175 €/m^2. Investments ranged from 44 to 93 €/m^2 for an aquaponic systems with a non-heated greenhouse, 150 to 313 €/m^2 for aquaponic systems with a heated greenhouse, and more than 700 €/m^2 for indoor systems. These investments per area can increase drastically in specific cases, for example, in very small systems that do not benefit from the economy of scale or in rooftop greenhouses which can lead to extra costs associated with accessibility during the construction and/or security measures due to their specific location.

Table 2. Initial investment range according to the size range of the aquaponic system.

Investment vs. Size	0–99 m^2	100–499 m^2	500–1999 m^2	2000–4999 m^2	5000–15,000 m^2
<10,000 €		1			
10,000–49,999 €	2	5			
50,000–99,999 €		1	1	2	
100,000–499,999 €	2		5	1	
500,000–999,999 €		1	2		1
>1,000,000 €				1	1
unknown	1				

When it comes to employment, the aquaponics sector appeared to rely both on paid and unpaid labor via volunteers or interns (Tables 3 and 4). The ratio between paid and unpaid labor was variable with some structures predominantly relying on paid labor, whereas the opposite was true for other structures. On average, however, there was less unpaid labor than paid labor. The high degree of unpaid labor underlines the attractability of aquaponics. Nevertheless, the important role played today by unpaid workers illustrates that the workload of these farms is higher than their ability to pay their workforce. This coincides with previous papers raising concerns about the economic viability of commercial aquaponic farms.

Table 3. Number of salaried jobs according to the size range of the aquaponic system.

Employment with Salary vs. Size	**0–99 m^2**	**100–499 m^2**	**500–1999 m^2**	**2000–4999 m^2**	**5000–15,000 m^2**
0		1			
0–0.24		2			
0.25–0.1	4	1	3	1	
2–5	1	3	5	2	
6–10		1		1	
>10					2

Table 4. Number of non-salaried jobs according to the size range of the aquaponic system.

Employment with No Salary vs. Size	**0–99 m^2**	**100–499 m^2**	**500–1999 m^2**	**2000–4999 m^2**	**5000–15,000 m^2**
0	2	2	2		1
0–0.24	2	1			
0.25–1	1	3	3	2	
2–5		1	3	1	
6–10				1	
>10		1			1

Seventeen respondents (63.0%) declared that the company made profits in the last 12 months, whereas seven others acknowledged having made no profit within the same time frame. Among them, one was an NPO, and most of them (*n* = 6) started their activity after 2018. At the time of the survey, these companies had not yet gone through a full production cycle. Among the 10 respondents who declared having made no profit, four launched their activity in 2018.

The participants were asked to identify three of the most important success factors and three of the most significant challenges faced by their companies. Twenty-five respondents provided success factors and 17 provided challenges (Figures 13 and 14). The top success factor, identified by 64.0% of the respondents (*n* = 16), was knowledge and production techniques, followed by the business model and stakeholder engagement at 44.0% (*n* = 11) and 28% (*n* = 7), respectively. The two major challenges were general production and successful business models, mentioned by 52.9% (*n* = 9) and 47.1% (*n* = 8) of the respondents, respectively. The challenges are similar to the success factors and reveal that even "success factors" are still subject to challenges and improvement. However, these results contrast with the obstacles identified by Turnšek et al. [21] which were investment costs and unexpected regulations at 33% and 21%, respectively. Other obstacles such as the lack of skilled labor (11%), and competition on market prices (10%) were identified by the respondents. This may indicate that the investment costs and unexpected regulations are not as much of a challenge anymore, as previously stated by other studies.

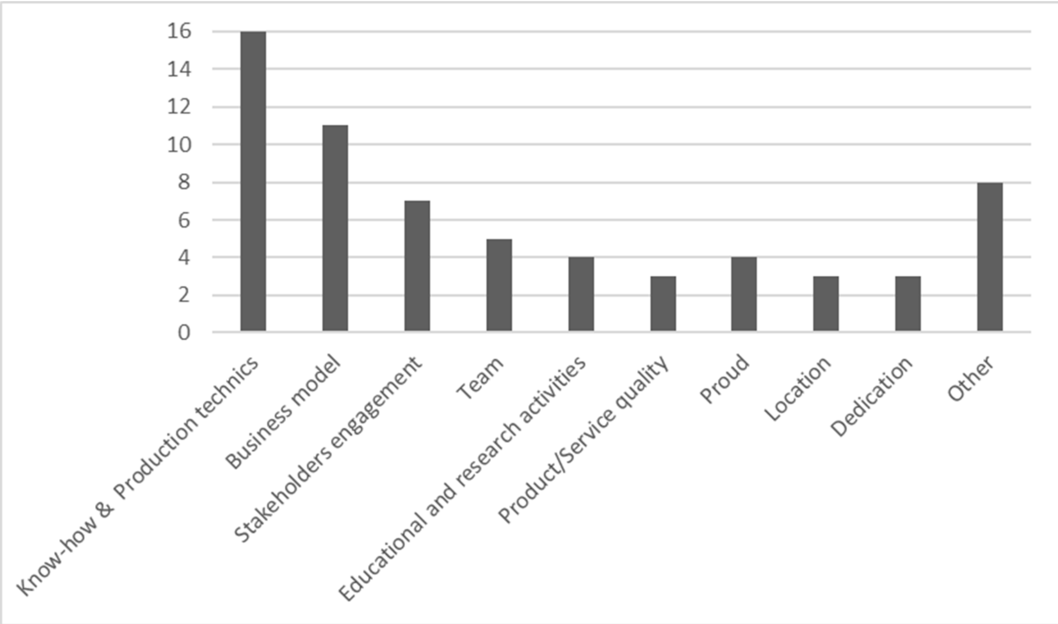

Figure 13. Number of respondents for the different success factors categories.

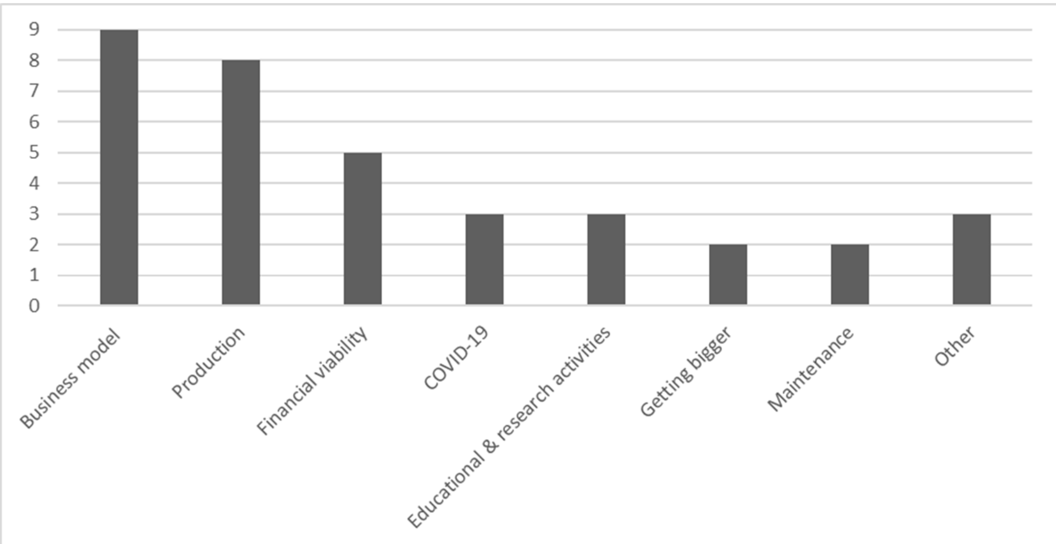

Figure 14. Number of respondents for the different challenge categories.

4. Discussion

The emergence and the following development of the European aquaponic sector has been well documented within the scientific literature. Villarroel et al. [26] and Turnšek et al. [21] investigated the sector in 2014–2015 and 2017, respectively. The current survey was carried out between December 2019 and February 2020, thus providing a new snapshot of the technical and business aspects of the aquaponics sector, and its subsequent commercialization. The main conclusions of this study are that European aquaponics (i) is becoming more professional (ii) is a very small but diversified sector, and (iii) is still investigating different strategies to find its economic viability.

The idea that the European aquaponic sector is becoming increasingly professional and increasing in size is highlighted in various ways throughout the study. This was clearly observed with the increase in size, complexity, and technological implementation of the systems, but also through open-ended questions relating to the respondents' objectives and perceived success factors. Considerable differences between the results of this study (2020) and those of previous studies (2016, 2017) clearly indicate a certain level of professionalization of the sector within a short time period. On average, a higher proportion of respondents had bigger systems with higher yields compared to the respondents of Villarroel et al. [26], on which the current survey was based. First, our study included a higher proportion and number of commercial producers (60.9% versus 19.1%). Second, both system sizes and productivity increased; most of the systems identified by Villarroel et al. [26] were smaller than 100 m^2, and 67.5% of their panel produced less than 100 kg of fish per year, whereas most of our respondents had systems larger than 100 m^2, and 63.0% of them produced more than 100 kg of fish per year. Third, many of the respondents in this study claimed to have made profits in 2019. The objectives of aquaponic activities seems to be changing; all our respondents expressed that commercial or financial gain was the purpose of the activity, whereas only 36% of the panel of Turnšek et al. [21] chose aquaponics for commercial gains. Besides these figures, in France, professional aquaponics is starting to be recognized as a professional activity. In 2019, France Compétence—a French national public organization—recognized that aquaponics technicians and workers are an emerging profession. Moreover, a company such as Agriloops even managed to gather millions of euros in public funds [41], further showing national interest. French professional aquaponic farmers organized annual meetings for professional aquaponic farmers and ecological hydroponics in 2020, 2021, and 2022 [42]. European institutions are also starting to recognize the potential of commercial aquaponics through the development of programs such as the Interreg program Smart Aquaponics or the Erasmus plus program Aqu@teach [43]. Furthermore, many commercial aquaponic training programs are currently offered by numerous aquaponic farms and institutions throughout Europe. (e.g., BiOPONi and Echologia (France), AquaAgriTech (Malta), Bio Aqua farms (UK).

The aquaponics sector is still very diversified; the plethora of system designs observed in this study clearly demonstrates the diversity of the field with a wide range of sizes, designs, and production techniques, all with different levels of technological implementation, which supports previous insights in the field. Moreover, as the respondents had distinct backgrounds and different visions for their structures, their main approach towards aquaponics also differed, creating a blend of aquaponic producers, researchers, and educators, and further diversifying the field. The various goals pursued by professional aquaponics operators, such as food production, research, and education, also contribute to the diversity of this sector. The business models are also diverse since most structures offer different types of products or services and are targeting different customers. During the writing process of this review, the authors sought to create some ideotypes of aquaponic entities, that is, groups with a significant number of farms sharing common characteristics in terms of size, design, and business models. Nevertheless, our data did not support the creation of aquaponic farm ideotypes due to the high variability of the survey results.

Besides the diversity between different entities, there was an important degree of diversity within the structures themselves. Production was very diversified. Nearly half of the respondents (47.8%) produced different fish species, and the majority (67.4%) produced more than three vegetables. Other than aquaponic products, nearly half of the respondents (47.8%) also produced vegetables in soil, 13.0% produced insects, and 13.0% produced mushrooms. Among the 27 commercial structures, most of them (77.8%) had other activities alongside fish and vegetable production, such as visits, training, consultancy, or research and development activities. This reveals the high number of different activities and skills required in each structure. The aquaponics sector tends to reduce the risks associated with a high dependence on one product or one customer base allowing the sector to be more resilient to climate change and price fluctuations. This may also be a strategy for testing, identifying, or maximizing the potential for different market opportunities.

The recent expansion of the aquaponics sector, associated with a diversity of production and business models, reveals actual economic opportunities. Nevertheless, it may also be considered as an indicator of a sector that is seeking economic viability and searching for reliable/sustainable business models. This assumption is supported by the limited number of aquaponic farms, the share of free labor in professional structures, and the observation that the success factors perceived by the sector were also their main challenges. Moreover, one of the two major challenges perceived by the respondents was associated with the optimization of their business model. Informal exchanges with aquaponic farmers between the time of the survey and publication revealed that some of the aquaponic farms of this panel were pilot farms, whereas others were considered as the final project. As seen in the survey results, many entities are involved in R&D and services such as visits, training, or consultancy, further showing the emergence of the field. These services can be profitable in a context in which expertise is under high demand and in the hands of only a few people, portraying a rapid expansion of the sector. Nevertheless, services may be less available for new aquaponic farms, so that these farms will have to rely on product sales only. The data of the present survey reveal that optimizing production seems to remain a challenge for the sector, due to the complexity related to aquaponic production.

Sustainability and ecology are very important and a source of motivation for aquaponic producers. This is marked by the fact that 95.7% (n = 44) of the respondents said that "Innovative food production systems" and "Environmental durability" were important or very important to them. In practice, this willingness is, of course, reflected by the recycling of RAS wastewater in the hydroponic compartment, but also by (i) the recycling of fish sludge by 78.3% of the respondents and (ii) the use of insect-based foods or 100% vegetable foods by 17.4% and 23.9% of the respondents, respectively. The ecological aspect is also important for consumers.

Previous research identified the first professional aquaponic activities in Europe [3,21,26]. They attested to the development of the aquaponics sector but also highlighted that it could either continue to evolve and follow a "slope of enlightenment" or remain anecdotal and disappear as a "trough of disillusionment" [21]. The current study demonstrates that the development of aquaponics at the European level is heading more towards a "slope of enlightenment" than a "trough of disillusionment". Many aquaponics producers, such as those contributing to the present study, are currently challenging and experimenting with production systems and business models to prove their viability. Furthermore, new professional aquaponic structures of varying designs and of increasing sizes may still emerge.

The key areas for promoting growth in the aquaponics industry include (i) advancing technology and techniques through R&D in both private companies and universities, with a focus on energy efficiency, sustainable fish feed, and effective waste management, (ii) providing professional training opportunities such as specific certification programs for technicians and managers, as well as integrating aquaponics in technical schools and universities, (iii) aligning aquaponics legislation and financial support with those of hydroponics and aquaculture, and (iv) creating professional networks, whether they be local, national, or international, promoting this innovative production technique and discussing the advancements and developments of the sector. Nevertheless, the expansion of commercial aquaponics within Europe is clear. Yet, further investigation on the economic aspects of the sector is necessary in order to get a better understanding of the role that aquaponics may play in a world confronted with many stressors and being forced to change its agricultural practices.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/w15061198/s1, File S1: survey; Table S1: List of the 140 aquaponic structures.

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Abbreviations

B2B	Business to Business
B2C	Business to Consumer
R&D	Research and Development
RAS	Recirculating Aquaculture System
NPO	Non-Profit Organization
NFT	Nutrient Film Technique

References

1. Van Woensel, L.; Archer, G. *Ten Technologies Which Could Change Our Lives: Potential Impacts and Policy Implications: In Depth Analysis*; EPRS (European Parliamentary Research Service): Brussels, Belgium, 2015; ISBN 978-92-823-6490-1.
2. Naegel, L.C.A. Combined production of fish and plants in recirculating water. *Aquaculture* **1977**, *10*, 17–24. [CrossRef]
3. Thorarinsdottir, R.I. *Aquaponics Guidelines*; Eco-Innovation Initiative of the European Union: Reykjavik, Iceland, 2015; ISBN 978-9935-9283-1-3.
4. Graber, A.; Junge, R. Aquaponic systems: Nutrient recycling from fish wastewater by vegetable production. *Desalination* **2009**, *246*, 147–156. [CrossRef]
5. Southern, A.; King, W. *The Aquaponic Farmer*; New Society Publishers: Gabriola Island, BC, Canada, 2017; ISBN 978-1-55092-652-1.
6. Foucard, P.; Toqueville, A. *Aquaponie-Associer Aquaculture et Production Végétale*; Quae: Versailles, France, 2019; ISBN 2759229645.
7. Somerville, C.; Cohen, M.; Pantanella, E. *Small-Scale Aquaponic Food Production. Integrated Fish and Plant Farming*; FAO Fisheries and Aquaculture Technical Paper; FAO: Rome, Italy, 2014; ISBN 92-5-108532-3.
8. Biton, G. *Guide Pratique de L'aquaponie*; Terran Editions: Escalquens, France, 2017; ISBN 978-2-35981-080-6.
9. Basumatary, B.; Verma, A.K.; Verma, M.K. Global research trends on aquaponics: A systematic review based on computational mapping. *Aquac. Int.* **2022**, 1–27. [CrossRef]
10. Goddek, S. *Opportunities and Challenges of Multi-Loop Aquaponic Systems*; Wageningen University: Wageningen, The Netherlands, 2017; ISBN 978-94-6343-172-9.
11. Goddek, S.; Delaide, B.; Mankasingh, U.; Ragnarsdottir, K.; Jijakli, H.; Thorarinsdottir, R. Challenges of sustainable and commercial aquaponics. *Sustainability* **2015**, *7*, 4199–4224. [CrossRef]
12. Konig, B.; Junge, R.; Bittsanszky, A.; Villarroel, M.; Komives, T. On the sustainability of aquaponics. *Ecocycles* **2016**, *2*, 26–32. [CrossRef]
13. Tyson, R.V.; Treadwell, D.D.; Simonne, E.H. Opportunities and challenges to sustainability in aquaponic systems. *HortTechnology* **2011**, *21*, 6–13. [CrossRef]
14. Gott, J.; Morgenstern, R.; Turnšek, M. Aquaponics for the anthropocene: Towards a 'sustainability first'agenda. In *Aquaponics Food Production Systems: Combined Aquaculture and Hydroponic Production Technologies for the Future*; Springer Nature: Cham, Switzerland, 2019; pp. 393–432, ISBN 978-3-030-15942-9.
15. Engle, C. *Economics of Aquaponics*; Oklahoma Cooperative Extension Service: Stillwater, OK, USA, 2016.
16. Tokunaga, K.; Tamaru, C.; Ako, H.; Leung, P. Economics of small-scale commercial aquaponics in Hawaii: Economics of commercial aquaponics in Hawaii. *J. World Aquac. Soc.* **2015**, *46*, 20–32. [CrossRef]
17. Bosma, R.H.; Lacambra, L.; Landstra, Y.; Perini, C.; Poulie, J.; Schwaner, M.J.; Yin, Y. The financial feasibility of producing fish and vegetables through aquaponics. *Aquac. Eng.* **2017**, *78*, 146–154. [CrossRef]
18. Bailey, D.S.; Ferrarezi, R.S. Valuation of vegetable crops produced in the UVI commercial aquaponic system. *Aquac. Rep.* **2017**, *7*, 77–82. [CrossRef]
19. Yep, B.; Zheng, Y. Aquaponic trends and challenges–A review. *J. Clean. Prod.* **2019**, *228*, 1586–1599. [CrossRef]
20. Turnšek, M.; Morgenstern, R.; Schröter, I. Commercial aquaponics: A long road ahead. In *Aquaponics Food Production Systems: Combined Aquaculture and Hydroponic Production Technologies for the Future*; Springer Nature: Cham, Switzerland, 2019; pp. 453–485, ISBN 978-3-030-15942-9.
21. Turnšek, M.; Joly, A.; Thorarinsdottir, R.; Junge, R. Challenges of commercial aquaponics in Europe: Beyond the hype. *Water* **2020**, *12*, 306. [CrossRef]

22. IndustryARC. Quaponics Market by Equipment (Grow Lights, Pumps, Valves, Greenhouse, Water Heaters, Aeration Systems); Components (Rearing Tanks, Settling Basins, Sump, Biofilter, Hydroponics); End User (Commercial, Home, Community)–Forecast (2015–2021). Available online: https://www.slideshare.net/rajesh193k/aquaponics-market-size-and-forecast-2018 (accessed on 20 December 2022).
23. Love, D.C.; Fry, J.P.; Genello, L.; Hill, E.S.; Frederick, J.A.; Li, X.; Semmens, K. An international survey of aquaponics practitioners. *PLoS ONE* **2014**, *9*, e102662. [CrossRef]
24. Love, D.C.; Fry, J.P.; Li, X.; Hill, E.S.; Genello, L.; Semmens, K.; Thompson, R.E. Commercial aquaponics production and profitability: Findings from an International survey. *Aquaculture* **2015**, *435*, 67–74. [CrossRef]
25. Pattillo, D.A.; Cline, D.; Hager, J.; Roy, L.; Hanson, T. Challenges experienced by aquaponic hobbyists, producers, and educators. *J. Ext.* **2022**, *60*, 13. [CrossRef]
26. Villarroel, M.; Junge, R.; Komives, T.; König, B.; Plaza, I.; Bittsánszky, A.; Joly, A. Survey of aquaponics in Europe. *Water* **2016**, *8*, 468. [CrossRef]
27. Reinhardt, T.; Hoevenaars, K.; Joyce, A. Regulatory frameworks for aquaponics in the European Union. In *Aquaponics Food Production Systems: Combined Aquaculture and Hydroponic Production Technologies for the Future*; Springer Nature: Cham, Switzerland, 2019; pp. 501–522, ISBN 978-3-030-15942-9.
28. Dos Santos, M.J.P.L. Segmenting farms in European Union. *Agric. Econ. (Zemědělská Ekon.)* **2013**, *59*, 49–57. [CrossRef]
29. Joly, A.; Junge, R.; Bardocz, T. Aquaponics business in Europe: Some legal obstacles and solutions. *Ecocycles* **2015**, *1*, 3–5. [CrossRef]
30. Miličić, V.; Thorarinsdottir, R.; Santos, M.; Hančič, M. Commercial aquaponics approaching the European market: To consumers' perceptions of aquaponics products in Europe. *Water* **2017**, *9*, 80. [CrossRef]
31. Zugravu, A.G.; Rahoveanu, M.M.T.; Rahoveanu, A.T.; Khalel, M.S.; Ibrahim, M.A.R. The perception of aquaponics products in Romania. In Proceedings of the International Conference "Risk in Contemporary Economy", Faculty of Economics and Business Administration, Galati, Romania, 8 December 2016; pp. 525–530.
32. Savidov, N.; Brooks, A. *Evaluation and Development of Aquaponics Production and Product Market Capabilities in Alberta*; Alberta Agriculture, Food and Rural Development: Edmonton, AB, Canada, 2004.
33. Tamin, M.; Harun, A.; Estim, A.; Saufie, S.; Obong, S. Consumer acceptance towards aquaponic products. *J. Bus. Manag.* **2015**, *17*, 49–64. [CrossRef]
34. Specht, K.; Weith, T.; Swoboda, K.; Siebert, R. Socially acceptable urban agriculture businesses. *Agron. Sustain. Dev.* **2016**, *36*, 17. [CrossRef]
35. Saldaña, J. *The Coding Manual for Qualitative Researchers*, 2nd ed.; Sage: Los Angeles, CA, USA, 2013; ISBN 978-1-4462-4736-5.
36. Charmaz, K. *Constructing Grounded Theory: A Practical Guide through Qualitative Analysis*; Sage: London, UK, 2006; ISBN 0-7619-7353-2.
37. de Mendiburu, F. *"Agricolae" R Package*, Version 1.3.2. 2020.
38. Walker, A.; Braglia, L. *"Openxlsx" R Package*, Version 4.0.17. 2017.
39. Prosch, G.; Ianchenko, A.; Kotzen, B. Aquaponics in the built environment. In *Aquaponics Food Production Systems: Combined Aquaculture and Hydroponic Production Technologies for the Future*; Springer Nature: Cham, Switzerland, 2019; pp. 523–558, ISBN 978-3-030-15942-9.
40. Hoevenaars, K.; Junge, R.; Bardocz, T.; Leskovec, M. EU policies: New opportunities for aquaponics. *Ecocycles* **2018**, *4*, 10–15. [CrossRef]
41. Jaffrès, L. Start-up. Agriloops, Prix de l'innovation William Saurin, Lève Des Fonds. *Ouest France*, 2018. Available online: https://www.ouest-france.fr/economie/entreprises/startup/start-agriloops-prix-de-l-innovation-william-saurin-leve-des-fonds-5625885 (accessed on 9 March 2023).
42. Aquaponia. Available online: https://www.aquaponia.com/aquaponie-by-echologia/index.php/le-salon-de-l-aquaponie-de-l-aquaculture-et-de-l-hydroponie-ecologiques-sur-echologia (accessed on 1 February 2023).
43. Milliken, S.; Ovca, A.; Antenen, N.; Villarroel, M.; Bulc, T.; Kotzen, B.; Junge, R. Aqu@teach—The first aquaponics curriculum to be developed specifically for university students. *Horticulturae* **2021**, *7*, 18. [CrossRef]