



Analysis of the policies and constraints limiting the aquaponics industry in Portugal

Fernando Mata^{a,*}, Maria dos-Santos^{b,c}

^a CISAS - Centre for Research and Development in Agrifood Systems and Sustainability, Instituto Politécnico de Viana do Castelo, Rua da Escola Industrial e Comercial Nun'Alvares 34, Viana do Castelo 4900-347, Portugal

^b DINÂMIA-CET, ISCTE – Instituto Universitário de Lisboa, Av. das Forças Armadas, Lisboa 1649-026, Portugal

^c ESCS – Escola Superior de Comunicação Social, Instituto Politécnico de Lisboa, Campus de Benfica do IPL, Lisbon 1549-014, Portugal

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ABSTRACT

Aquaponics is an innovative and potentially sustainable method of producing vegetables and fish, enabling local, inland fish production, and vegetable production without the need for artificial fertilization. With the aim to analyze the potential development of commercial aquaponics in Portugal, a group of Portuguese stakeholders and experts were interviewed to capture their understanding of the challenges faced by the emerging Portuguese aquaponics sector. The paper evaluates and discusses the main issues experienced by stakeholders, proposing solutions to overcome barriers and restrictions. Legal and administrative barriers were identified, and it is recognized that aquaponics requires its own legal and administrative framework. Bureaucracy is duplicated in licensing processes, authorizations for sale, and permits. Exotic fish species, such as tilapia (*Tilapia spp.*) face legal barriers to their use in aquaculture. The freshwater aquaculture species to consider for integration into aquaponics systems are largemouth bass (*Micropterus salmoides*), pikeperch (*Sander lucioperca*), and eel (*Anguilla anguilla*). To address barriers to the organic certification of aquaponics products, producers need to collaborate and establish their own certification schemes.

1. Introduction

1.1. The challenge

Humanity will need to produce as much food during the 21st century as it did throughout its entire history up to the 20th century. This is easily calculated by observing the population growth curve. We can observe that by breaking the curve in its median we obtain two halves that give similar integral figures or areas. Farmland remains a finite resource, along with other crucial natural resources such as water, soil, and fertilizers. While food production is of fundamental importance, ensuring that future generations can also access these natural resources is paramount.

The Global Footprint Network has identified the first of August as Earth Overshoot Day for 2024 (Global Footprint Network, 2024). This marks the day from which we begin consuming natural resources beyond the Earth's regeneration capacity for that year. Essentially, we are living on credit until the end of the year.

In addition to addressing food production challenges, humanity must

focus on preserving natural resources, conserving species and habitats, mitigating unfavorable side effects of intensive production systems promoting soil and water conservation, and building resilience to climate change. It is equally crucial to produce nutritious food free from toxic compounds, socially responsible, ethically respectful, and affordable. Consequently, urban farming movements are gaining momentum (Krishnamoorthi et al., 2024), and aquaponics may play an important role in this movement (Dos-Santos, 2016; Gustavsen et al., 2022; Kyaw and Ng, 2017; Wirza and Nazir, 2021). Embedding food production in urban landscapes fosters sustainable food distribution, reducing carbon footprint and waste. Proximity to consumers cuts transport emissions. Urban farms can integrate space, water, energy, and waste recycling within city resources, enhancing sustainability (Goldstein et al., 2016).

1.2. The Portuguese diet

The term "Mediterranean diet" was noticed by the notably lower frequency of cardiovascular diseases in relation to other diets. The Mediterranean diet revolves around fruits, vegetables, cereals, and nuts,

* Corresponding author.

E-mail address: fernandomata@ipvc.pt (F. Mata).

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featuring moderately high intakes of fish and relatively low quantities of meat (Trichopoulou et al., 2003). Olive oil, rich in polyunsaturated fatty acids with known health benefits, is also a crucial component of the Mediterranean diet (Serra-Majem et al., 2004).

The Portuguese diet exhibits Mediterranean characteristics, with a distinct emphasis on the remarkably high consumption of fish. In terms of fish consumption per capita, Portugal ranks first in the EU and second globally, following Iceland (FAO, 2023). Despite the country's extensive coastline, it faces a negative trade balance (a covering rate of 50.7 %), importing almost double the quantity of fish it exports (INE, 2022). Therefore, there is potential for increasing aquaculture production, as sustainability concerns in sea fisheries impose restrictions.

In Portugal's inland regions, there is a traditional preference for consuming freshwater fish. The country hosts numerous gastronomic festivals celebrating freshwater fish, where restaurants and fairs thrive on those particular days.

1.3. Aquaponics

Aquaculture has grown worldwide as natural fisheries cannot provide enough without disrupting ecosystems. In an overfishing scenario, future catches are compromised (Zeller and Pauly, 2019). According to FAO (FAO, 2020), while fisheries' catches have been maintained worldwide, aquaculture production has been on the rise. In 2018, aquaculture produced 46 % of the world's catches, with the majority (28.7 %) from inland sources. Inland (or freshwater) aquaculture represented 62.5 % of the total worldwide aquaculture production (FAO, 2020).

Generally, marine RAS is not used in aquaponics due to salt restrictions on plant viability. However, integrating seaweed production and fish production may be possible. Some salt-tolerant plants can also be used in specific marine aquaponics (Gunning et al., 2016; Puccinelli et al., 2022).

Hydroponics can play a vital role in disposing of nitrogen from the RAS (Maucieri et al., 2019). Nitrogen, a primary macronutrient for plant growth and an essential element in fertilization is costly to produce as nitrogen fertilizers (Eck et al., 2019). These fertilizers also consume energy and are commonly dissolved in solutions during plant fertirrigation, allowing fertilization through irrigation. However, this practice releases excess nitrogen into the soil, leading to leaching and water-course pollution. In hydroponics, plant roots are immersed in a water solution where they uptake the necessary nutrients (Joyce et al., 2019).

Combining RAS with hydroponics presents a win-win solution for addressing RAS nitrates and reducing the expense of nitrogen fertilizers in plant production (Davison, 2018; Ebeling and Timmons, 2012; Goddek et al., 2019). Aquaponics efficiently closes the loop of RAS, saving water and recycling nutrients within a mini ecosystem of animals, plants, and bacteria working together in symbiotic homeostasis (Lennard and Goddek, 2019). In addition to these advantages, aquaponics allows for landless farming systems, such as urban farming, to develop in smart cities, promoting short supply chains (Dos-Santos, 2016; Dos-Santos, 2019; Greenfield et al., 2020).

Aquaponics is a clever, innovative, and potentially sustainable production system, acknowledged as such by the Food and Agriculture Organization (FAO) (Somerville et al., 2014). This system holds tremendous potential in regulating and recycling valuable nutrients that would otherwise be lost to the environment, posing pollution risks.

Aquaponics integrates freshwater aquaculture and hydroponics into a mini ecosystem. It utilizes the water from a Recirculating Aquaculture System (RAS) in soilless plant farming. A RAS is a closed- or semi-closed-loop aquaculture system where water circulates, gets oxygenated and filtered before returning to the system. This process includes a biofilter where nitrifying bacteria oxidize ammonia, derived from fish excreta or uneaten feed, into nitrates (Meisch and Stark, 2019). While fish are highly sensitive to ammonia, they are more tolerant to nitrates (Ciji and Akhtar, 2020), however these need also removal before accumulation to

toxic levels. This can be done through denitrification processes, transforming nitrate into nitrogen gas expelled into the air, or by replacing some recirculation water with clean water (Ciji and Akhtar, 2020). Denitrification processes are expensive, complex, and not fully efficient (Tom et al., 2021). Therefore, water dumping is common in RAS, contributing to a negative environmental perception of intensive aquaculture.

In the Portuguese context, aquaponics presents an excellent opportunity for local and sustainable production with high market potential. Whether freshwater fish or legumes, locally sourced in the country's interior, can contribute to mitigating the carbon footprint in food production and maintaining the traditional Portuguese diet, recognized as healthy. 1.4 Objectives

Legal and administrative barriers to aquaponics in Portugal have been identified, despite its positive impacts. The FAO has been promoting small-scale local solutions for urban food production (Somerville et al., 2014). Small-scale businesses have gained popularity but have yet to scale up (Greenfield et al., 2019). However, it was only since 2010 that research in the area has been taking off, classifying aquaponics as an emerging scientific topic and technology (Junge et al., 2017). Industrial-scale projects are taking initial steps worldwide, particularly in Europe (Villaruel et al., 2016). Start-ups and research are increasing in Europe (Miličić et al., 2017).

Institutional restrictions to the development of the aquaponics sector have been identified:

- i) Lack of harmonization in laws across various EU member states negatively impacts trade (Joly et al., 2015; Miličić et al., 2017).
- ii) Gaps in the national legislation of different EU countries also hinder development (Joly et al., 2015; Miličić et al., 2017).
- iii) The NACE Rev.2 (Statistical Classification of Economic Activities in the European Community), adopted by all EU countries, does not identify a code for aquaponics, creating commercialization and financial restrictions (Joly et al., 2015).
- iv) Recognition as organic production for aquaponics products is impossible in the EU, unlike the USA and Australia, limiting added value to aquaponics products. RAS products cannot be classified as organic, and vegetables must grow in soil to be classified as organic under EU law (Miličić et al., 2017).
- v) Portuguese law imposes a ban on some exotic freshwater fish species, such as *Tilapia* spp.) (Kledal et al., 2019) due to their invasive potential and potential impact on ecosystems.
- vi) Environmental concerns regarding the discharges of nitrate-rich water from RAS, which could be used as fertilizers, remain unresolved. Joly et al. (2015) highlight the absence of specific legislation across European countries that could separate effluents from aquaculture and aquaponics.

Given the potential to increase sustainable food production, understanding how these and other restrictions may impact the sector's evolution becomes crucial. This study is an attempt to explore the aquaponic business viabilities in the Portuguese context. The first objective of this research is to explore the main constraints and restrictions impacting the evolution of the aquaponics sector in Portugal. The second objective is to explore solutions to the problems identified.

2. Materials and methods

To promote this potentially sustainable food production system in Portugal, the authors select ten stakeholders to be interviewed. These are linked to the Portuguese aquaponics sector and include entrepreneurs, policymakers, academics, and a hobbyist. This panel expressed their perception of how the industry is evolving in Portugal, identifying the main constraints, and discussing progress-making. It complements an initial exploratory study and collects information to allow an understanding of how research and policy making be directed to boost aquaponics in Portugal.

The interviews were conducted directly with the interviewees,

scheduled days in advance to allow for thoughtful preparation on the conversation topics. The interviews took place in informal settings, such as at café tables, to encourage relaxed and fluid responses. The interviewees provided informed consent for the information to be used solely for this research. They were also assured that their data would be treated anonymously.

The interviews were based on open-ended questions to collect qualitative information and included the following seven questions:

- 1) What is your perception of the opinion about aquaculture of entrepreneurs, managers, policymakers, and consumers?
- 2) What limitation do you think companies may have should they want to invest in aquaponics?
- 3) How do you think the Portuguese companies may perceive the above limitations?
- 4) How do you think these limitations may prevent these companies from investing in aquaponics?
- 5) What actions do you think policymakers should take to promote the development of aquaponics?
- 6) What do you think would be a good marketing strategy to promote products from aquaculture?
- 7) Are you aware of any legislative limitation preventing further development of aquaponics?

The panel of ten interviewees comprised: two academics with expertise in the sector; two policymakers; four entrepreneurs directing aquaponic start-ups (only one already producing); one entrepreneur from the hydroponics sector with interests in aquaponic; one entrepreneur from the algae aquaculture production sector with knowledge of aquaponics, and one hobbyist with koi fish recycling part of the water with small vegetable garden. The interviewees were recruited using a snowball approach by inquiring with the interviewees about other individuals with an interest in aquaponics. The number of interviewees with that condition is limited and academics and other entrepreneurs with knowledge about aquaponics were recruited to increase the sample size. Despite the limited number of interviewees, the sample is deemed to be representative of the sector in Portugal.

An inductive qualitative method was used to explore the perceptions, attitudes, opinions, and concerns of ten interviewees, leading to the choice of content analysis for its suitability for qualitative and exploratory research (Graneheim et al., 2017; Drisko and Maschi, 2016). An initial thematic content analysis was performed to retrieve a comprehensive view of the common ideas. Content analysis enables scientific analysis and interpretation of subjective qualitative data (Moretti et al., 2011). The inductive approach identifies patterns by examining data for similarities and differences, which are categorized and themed at various levels of abstraction, transitioning from specific observations to general insights (Graneheim et al., 2017; Drisko and Maschi, 2016). A narrative thematic approach was used to produce individual case summaries and cross-case thematic analysis (Drisko and Maschi, 2016). Transcripts were read multiple times to gain new insights and develop a framework reflecting participants' general opinions. This was followed by a narrative analysis where specific and individual aspects of the interviewees' answers were also given consideration. The analysis was followed by a discussion where the fundamental issues identified were dissected.

3. Results

As a result of the survey, the main statements identifying constraints and proposing solutions to facilitate aquaponic enterprises in Portugal are summarized in Table 1.

There is a perception among the panel that most consumers are unfamiliar with aquaponics, which could pose a constraint for marketing. This is an opinion recurring across all types of interviewees.

Some interviewees, mainly entrepreneurs from the sector, recognize that the sustainability concept of aquaponics could be a significant marketing asset. However, they note that only a minority of consumers

Table 1

Frequency of statements identifying constraints and proposing solutions to AQP in Portugal.

Statements	Response frequencies	Origin of responses
Aquaculture or hydroponic managers know about AQP	11	All
Aquaculture or hydroponic entrepreneurs know about AQP	11	All
Consumers are unaware of AQP	8	4AQP, 1HYD, 1AQC, 1ACD, 1PLM
Policymakers are unaware of AQP	7	4AQP, 1HYD, 1AQC, 1HOB
Managers/entrepreneurs in AQC/HYD lack AQP technical knowledge	6	1AQP, 2ACD, 2PLM
AQP should be promoted through forums, seminars, and similar	6	2AQP, 1AQC, 2ACD, 1PLM
Support for investment specifically in AQP should be implemented	6	4AQP, 1ACD, 1HOB
Managers/entrepreneurs in AQC/HYD recognise complexity of RAS	5	1AQP, 1HYD, 2ACD, 1PLM, 1HOB
Lack of organic certification is a major constraint to AQP	5	3AQP, 1ACD, 1PLM
Organic certification in AQP should be facilitated	5	3AQP, 1ACD, 1PLM
Unawareness of AQP limits its promotion near consumers	4	4AQP, 1HOB
A minority of consumers aware of AQP understand its sustainability	4	3AQP, 1ACD
Lack of technicians in the extension services with expertise in AQP	3	3AQP
Consumers confuse AQP with aquaculture and hydroponics	2	2 ACD, 1HOB
Licensing processes in AQP are complex	2	2AQP
An AQP experimental station should be implemented for divulgation	2	1 ACD, 1PLM
Freshwater fishes have a low market value in Portugal	2	1AQP, 1HOB
Legislation limiting exotic freshwater fishes in AQP is a major constraint	1	1AQP

Note: AQP – aquaponics, HYD – hydroponics, AQC – aquaculture, RAS – recirculating aquaculture system, ACD – academic, PLM - policymaker

are aware of the activity. Interviewees agree that while lacking detailed technical knowledge, this minority is cognizant of the sustainability benefits. The academics and the hobbyist interviewed recognize that consumers confuse aquaponics with hydroponics or aquaculture but are unable to link both, and the majority have no clue about aquaponics. Most interviewees, including all those in the aquaponics sector, state that policymakers are also perceived as not being sensitive to the activity, and lacking information. One aquaponics entrepreneur mentioned that most policymakers are not even informed about aquaculture, let alone aquaponics, leading to a lack of specific investment programs and projects.

The academics and the policymakers portray entrepreneurs and managers involved in hydroponics or aquaculture operations as being aware of aquaponics, but lacking detailed technical knowledge. It is recognized that some may be familiar with the technicalities, but concerns are raised about the complexity of a Recirculating Aquaculture System (RAS) requiring significant backup systems (electricity, oxygen) and detailed supervision of water parameters and oxygen. A RAS is portrayed as a complex system that carries production risks, and two interviewees (one aquaponics entrepreneur and the hobbyist) noted that freshwater fish have a less attractive market in Portugal with low demand.

Currently, there is only one commercial aquaponic system in Portugal, operating at a low scale and still in the implementation and testing stage. It follows a business-to-business concept, with the entrepreneur securing sales through a deal with a local supermarket chain. Another start-up is facing difficulties in implementing a project using tilapia in a RAS due to legislative restrictions. There is also a start-up

attempting to develop a RAS for largemouth bass (*Micropterus salmoides*), but funding challenges and licensing complexities have impeded progress.

Several curious amateurs and hobbyists are experimenting with aquaponics at a small scale, learning about the practicality of the activity. However, no major offers to the market have been made from aquaponics yet.

Regarding legislative constraints, one start-up identified fish species (tilapia) as the main issue. Lack of organic certification is also recognized by five interviewees (three of them aquaculture entrepreneurs) as a significant constraint to aquaponics. Organic certification is seen by these same interviewees as crucial for differentiating aquaponics products in the market. Two aquaponics entrepreneurs, highlighted the licensing process as an important constraint, emphasizing the prolonged timeline for aquaponics projects due to additional construction and additional production layers.

Other constraints identified by three of the aquaponics entrepreneurs include lack of technical information and support offices with extension technicians to advise and facilitate overcoming technical, legal, and financial barriers.

The interviewees proposed several actions to overcome these problems, including facilitating investments in aquaculture (proposed by the four aquaculture entrepreneurs, one academic and the hobbyist), allowing organic aquaculture certification (three aquaculture entrepreneurs, one academic and one policymaker), promoting aquaponics as a sustainable activity (recognized across all types of interviewees), and creating an experimental aquaponics lab station (one academic and one policymaker). Activities like forums, seminars, exhibitions at schools and fairs, presentations, workshops, and training sessions were suggested to promote awareness and interest in aquaponics among stakeholders and the public (recognized across all types of interviewees).

In general, aquaponics entrepreneurs tend to emphasize consumer issues, legal and operational constraints, and the need for financial support.

4. Discussion

4.1. Administrative barriers to aquaponics in Portugal

There are no doubts about the benefits of aquaponics from a sustainable point of view. As introduced, aquaponics is a win-win solution in vegetal and aquaculture production (e.g. Miličić et al., 2017). However, some constraints are being identified as barriers to its development in Portugal. It is important to highlight that aquaponics has been classified as one of the ten technologies that could change people's lives (Van Woensel et al., 2015).

Regarding the lack of a specific legislative and administrative framework, there is a quotation (OJEU, 2014) that summarizes well the positions of many policymakers across Europe including Portugal: "The practice of aquaponics combines the farming of fish (aquaculture) and the cultivation of plants. Support for aquaponics is available for each of its component activities." Policymakers perceive aquaponics as an extension of both aquaculture and crop production, and both have legal and administrative frameworks, however, the integration of these two activities creates an original activity. Aquaponics needs its own legal and administrative framework to overcome some barriers. As it is, duplicates the bureaucracy associated with the licensing processes, authorizations for sale, and permits, involving different administrations. The Portuguese Ministry of Agriculture contains two different departments dealing with aquaculture and agriculture; The former is managed by Direção-Geral de Recursos Naturais, Segurança e Serviços Marítimos, while the latter is managed by Direção-Geral de Agricultura e Desenvolvimento Rural. These departments lack integration to deal with aquaponics processes.

4.2. The freshwater fishes

Another identified constraint is the list of fishes allowed in freshwater aquaculture in Portugal. While tilapia is indeed prohibited, numerous alternatives exist with growing commercial interest. Despite a suggestion from one interviewee that freshwater fish lack commercial value in Portugal, this assertion is inadequate. In various regions, particularly Ribatejo, Alentejo, and Beira-Baixa, several freshwater species, including largemouth bass, pikeperch (*Sander lucioperca*), and eel (*Anguilla anguilla*), are considered delicacies. These species command market values surpassing marine fish species and were among the highest-priced species in 2015 (Sabino, 2016). Gastronomic festivals dedicated to freshwater fish recipes are prevalent across the country, emphasizing the high market potential and competitive prices compared to marine species. Another potential species, though not widely consumed in Portugal, has a market in the Extremadura and Andalusia regions of Spain - the tench (*Tinca tinca*).

Different trout species, such as rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*), are also farmed in Portugal. However, most of these require cold water, with suitable conditions found only in highland areas.

Finally, sturgeons, including the beluga sturgeon (*Huso huso*) and the siberian sturgeon (*Acipenser baerii*), are raised for caviar production. Due to worldwide restrictions on wild sturgeon fishing, fish farming has emerged as a sustainable alternative. Moreover, caviar can be harvested without killing the sturgeons, making it one of the most lucrative species for freshwater aquaculture (Sicuro, 2019).

Among the identified species, those currently being produced in Recirculating Aquaculture Systems (RAS) and most suitable for RAS are pikeperch (Podduturi et al., 2020), largemouth bass (Tidwell, 2019), eel (Eding and Kamstra, 2001), sturgeons (Pelic et al., 2021), and rainbow trout (Laine et al., 2024).

Several freshwater species offer advantages over marine species in RAS. The dissolved oxygen levels required for eel (Degani et al., 1985) and largemouth bass (Tidwell, 2019) do not need to be as high. Additionally, both largemouth bass (Tidwell, 2019) and Pikeperch (Schram et al., 2014) exhibit greater resistance to toxicity from ammonium, nitrates, and nitrites.

Freshwater and brackish water fishes have proved to be a gastronomic delicacy and has been served and highly appreciated in Portuguese restaurants. In a report from 2015 (Borrvalho, 2015) these fishes have achieved market prices above those of crustaceans, varying between 9.95 and 15.42 euro/kg.

In Portugal there are gastronomic brotherhoods to promote freshwater fish, such as "Confraria dos Apreciadores de Peixe do Rio, from Proença-a-Nova"; "Confraria da Lampreia from Penacova"; and "Confraria Gastronómica from Sever do Vouga".

The gastronomic festivals dedicated to freshwater fish, normally organized by municipalities in collaboration with local restaurants are immense. Some examples: Vilar Formoso, Almeida, Ponte de Lima, Alvega, Albufeira, Grândola, Pampilhosa da Serra, Beja, Bragança, Faro do Alentejo, Alferrarede, Alcútem, Gavião, Ponte de Sor, Alandroal, Vila Viçosa, Castelo de Paiva, Santarém, Penacova, Santa Margarida do Sado, Santana, Moura, Mação, Carrazeda de Ansiães, and the list continues.

4.3. Certification

Certification is also a concern for most of the interviewees that would like to have access to organic certification. This sentiment aligns with that of other EU stakeholders. The EU position needs to be reassessed; otherwise, the EU countries risk losing competitiveness and face investment barriers, leading to disillusionment among potential investors (Turnsek et al., 2020). Unlike the USA and Australia, where organic aquaponics is regulated (Fruscella et al., 2021), barriers exist in both hydroponics and Recirculating Aquaculture System (RAS) components

within the EU. [Fruscella et al. \(2021\)](#) have extensively reviewed these aspects. According to these authors, organic aquaculture requires a fish welfare-friendly environment, a condition not achievable in a RAS. The energy-intensive nature of a RAS and the need for higher fish densities pose challenges, while the tank bottoms do not allow fish-soil interaction to raise additional concerns. On the hydroponics side, the main issue is that organic vegetables are traditionally soil-based. To address these challenges, the authors propose enriching aquaculture tanks and implementing a fertirrigation system for soil-based vegetable production. This could eventually be a solution adopted by aquaponics production in European countries aiming for organic certification.

Many scholars, some already cited in this article, advocate resolving the organic certification issue for aquaponics. The system's advantages in terms of the UN sustainability agenda outweigh any potential disadvantages. Since many certification schemes are self-imposed and regulated, a proposed solution is for those interested in aquaponics in Portugal and the EU to collaborate in creating a new certification scheme. The term "Organic" is known as "Biologic" in other countries. A potential certificate could bear the designation "Biologic Aquaponics" in former countries and "Organic Aquaponics" in the latter. In Portuguese, it could be "Produzido em modo de Aquaponia Orgânica," translated into English as "Produced in Biologic Aquaponics Mode," and similarly in other languages.

Another option that producers may consider is the Aquaculture Stewardship Council (ASC) certification, which recognizes fish as "farmed responsibly" and enjoys an excellent worldwide reputation ([Roebuck and Wristen, 2018](#)). The ASC standards address the most significant environmental and social impacts of aquaculture ([ASC, 2022](#)). As the local food movement gains momentum, coupled with ethical considerations in food production, such as local production and sustainable practices, Portuguese entrepreneurs may find it advantageous to form partnerships with supermarkets willing to source products locally.

As for vegetables, pesticide-free in non-organic systems is an emergent certification ([Finger and Möhring, 2024](#)). Studies in Germany ([Nitzko et al., 2024](#)), and Japan ([Nohara, 2024](#)) have shown positive consumer willingness to pay for this type of product.

Organic fish has not been a primary focus, even for specialized organic retailers in the EU, according to a study commissioned by the European Commission ([EUMOFA, 2017](#)). The study concludes that "environmental sustainability and social responsibility can be more interesting cards to play than organic farming for large-scale retailers whose purchasing policy is permanently scrutinized by NGOs." Portuguese entrepreneurs may find an opportunity for partnership, especially with supermarkets that prioritize local sourcing, similar to the case study of the large-scale Portuguese retailer Jerónimo Martins mentioned in the report of [EUMOFA \(2017\)](#).

4.4. Other

Investing in a pilot farm could be an interesting solution to create awareness, facilitate research, knowledge building and transfer, and provide a platform for demonstration. It could also serve as a meeting point for stakeholders to encourage discussion forums and professional cooperation. Professional cooperation and lobbying efforts in Portugal and beyond in the EU are paramount to raising awareness and advancing the development of aquaponics. Consumer perception of sustainable and organic products significantly influences their purchasing decisions, driving them to prefer these items when making choices ([Roy et al., 2023](#)). This preference is rooted in a growing awareness of environmental and health benefits associated with sustainable practices. The portrayal of aquaponics as a sustainable and pesticide-free production system can effectively attract consumer interest, given the increasing demand for environmentally friendly and health-conscious food production methods.

If not properly managed, aquaponics systems can pose

environmental risks. One major concern is the energy consumption associated with RAS. These systems require continuous water circulation and aeration, which can lead to significant energy use. Additionally, improper management of nutrient flows can result in environmental pollution. Nutrients from the aquaculture component, if not adequately processed by the plant production component, can lead to soil and water pollution. This highlights the importance of integrated system management to ensure that the nutrient cycles are balanced, and that waste is minimized.

Studies highlight that the key to achieving the environmental benefits of aquaponics lies in optimizing system design and operation. Efficient energy use strategies, such as incorporating renewable energy sources, can mitigate the high energy demands of RAS. Moreover, effective nutrient management practices, including regular monitoring and adjustment of nutrient levels, are essential to prevent environmental contamination ([Goddek et al., 2019](#)).

5. Conclusion

Aquaponics is a food production system with the potential to address ethical, social, and sustainable agendas. Particularly in Portugal, there are niche markets with enormous potential to embrace these products. Some interviewees in this study have identified administrative and financial difficulties to overcome. Additionally, some interviewees have identified tilapia as an illegal freshwater fish species fundamental in aquaponics; however, as discussed, there are many freshwater fishes allowed for use in a Recirculating Aquaculture System (RAS) with good market potential. The absence of organic certification for aquaponics products was also identified as a constraint; however, as discussed, there are potential solutions. The interviewees perceive that the Portuguese consumer is not aware of what aquaponics is. There is marketing potential to be leveraged based on the ethical aspects of the system and through self-regulated certification.

While aquaponics holds significant potential as a sustainable food production system, its environmental benefits depend heavily on proper management practices. Consumer preference for sustainable and organic products can drive the adoption of aquaponics, but this must be matched with rigorous management to avoid environmental pitfalls.

CRedit authorship contribution statement

Fernando Mata: Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Maria dos-Santos:** Writing – review & editing, Writing – original draft, Resources, Methodology, Investigation, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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