Attitudes, perceptions, and trends of honey consumption in Portugal

Abstract

This study explores the potential for the development of aquaponics systems in Portugal. A group of persons of interest were interviewed to collect information about constraints faced by the embryonic Portuguese aquaponics sector. The paper evaluates and discusses the problems felt by stakeholder and proposes solutions to overcome barriers. [aquaculture, aquaponics, Mediterranean diet, hydroponics, Portugal, sustainability]

Context

The challenge

At the present mankind faces enormous challenges. If it took all the history up to 1804 to reach the first billion of habitants on earth, it took only 123 years to reach the 2nd billion, 34 to reach the 3rd , … , and now every 12 years or so we have one more billion habitants in the world. We are on the brink of counting 8 billion people and in 2050 we will count 9.7; for 2100 it is predicted 10.4 billion people leaving on planet earth (UNDESA 2022). Mankind will need to produce during the 21st century as much food as it was produced during all its history up to the 20th century[1]. While population growth, farmland remains a finite resource, as do all the natural resources used in food production such as water and fertilisers. While the production of food has fundamental importance, it is of utmost importance to make sure that the coming generations can also access natural resources. However the Global Footprint Network has calculated the 28th of July as the earth overshoot day for 2022, or the day from which we are consuming natural resources above

earth regeneration capacity for that year. We are therefore, living from credit up to the end of the year.

On the top of food production we need to preserve natural resources, conserve nature, mitigate unfavourable side effects and be resilient to changes. We also need to produce nutritious food, free from toxic compounds, socially responsible, ethically respectful, and affordable. As such Urban Farming movements are gaining momentum (Davenport and Mishtal 2019; dos Santos 2016; Migliore et al. 2019)

The Portuguese diet

The wording "Mediterranean diet" was coined by Ancel Keys in 1951 after realising the differences in cardiovascular disease frequency, very high in the USA and almost absent in Naples, Italy (Moro 2016). The Mediterranean diet is a heritage from ancient Greeks, Phoenicians, Arabs, and Romans, based in fruits and vegetables, cereals and nuts moderately high intakes of fish and relatively low quantities of meat (Trichopoulou et al. 2003). Olive oil is rich in polyunsaturated fatty acids with benefits for the human health and is also part of the Mediterranean diet (Serra-Majem et al. 2004).

The Portuguese diet has the Mediterranean characteristics, with the particularity of very high consumption of fish. Consumption of fish per capita rates the country as 1st in the EU and 3rd worldwide, after Iceland and Japan (Madsen and Chkoniya 2019). With this elevated consumption and despites the Portuguese sea extension, the country has a negative balance of trade with other countries, and imports almost double the exports (Alves 2015). Exists, therefore, room for increasing catches, particularly from aquaculture, as the sustainability of sea fisheries imposes restrictions. In the interior of Portugal, away from sea, there is a traditional appetency for the consumption of freshwater fish. The country is full of freshwater fish gastronomic festivals[2] with restaurants and fairs filling up on those days.

Aquaponics

Aquaponics is a cleaver, innovative and sustainable production system, recognized as such by FAO (Somerville et al. 2014). This production system has enormous potential in the regulation and recycling of valuable nutrients, otherwise lost to the environment with pollution potential.

Aquaponics integrates freshwater aquaculture and hydroponics in a mini ecosystem. It uses the water of a Recirculating Aquaculture System (RAS) in soilless plant farming. A RAS is a closed- or semi-closed-loop aquaculture system where the water circulates to get oxygenated and to be filtered and purified before returning to the system. The process includes a biofilter where nitrifying bacteria oxidise ammonia, resulting from fish excreta or uneaten feed, into nitrates. While fish are highly sensitive to ammonia, they are more tolerant to nitrates. Nevertheless, nitrates need also to be removed from the fish environment before accumulation to toxic levels. This can be done by denitrification processes, that transform nitrate in nitrogen gas expelled to the air, or by dumping off some of the recirculation water and bringing in clean water. Denitrification processes are expensive, difficult to manage, have complexities and are not fully efficient (Pungrasmi, Phinitthanaphak, and Powtongsook 2016). Therefore dumping off some water is recurrent in RAS, which creates a negative environmental image of intensive aquaculture (Apostle 2017).

This is where hydroponics may come in as a useful manner of disposing nitrogen off the RAS. Nitrogen is the main macronutrient for plant growth, therefore an indispensable element in fertilisation. Nitrogen fertilisers are expensive, consume energy to be produced, and are commonly dissolved in solutions in fertirrigation of cultured plants. This practice has, however, the inconvenience of releasing in the soil quantities of nitrogen eventually not uptake by the plants, and therefore lost by lixiviation into

watercourses, causing pollution. In hydroponics, the plant roots are immersed in a water solution, from where the necessary quantities of nutrients are uptake[3].

The advantages of combining a RAS with hydroponics becomes therefore evident as a win-win solution for the problematic nitrates of the RAS and the expensive nitrogen fertilisers of plant production. Aquaponics efficiently completes the RAS's loop allowing water to be saved, and recycling nutrients. A mini ecosystem of animals, plants, and bacteria working together in a symbiotic homeostasis. Many specialist textbooks can be consulted for a detailed explanation on these topics (e.g. (; Davison 2018; Ebeling and Timmons 2012; Goddek et al. 2019). On the top of these advantages, aquaponics also allows landless farming systems, such as urban farming, to develop in smart cities promoting short supply chains (dos-Santos 2016).

Aquaculture has been growing worldwide once natural fisheries cannot provide enough without disruption of the ecosystems. In an overfishing scenario, future catches are compromised (Zeller and Pauly 2019). According to FAO (FAO 2020), worldwide, while fisheries' catches have been upheld, aquaculture production has been on the rise. In 2018 aquaculture produced 46% of the world catches, most of it (28.7%) inland. Inland (or freshwater) aquaculture represented, therefore, 62.5% of the total worldwide aquaculture production (FAO 2020).

Generally, marine RAS is not used in aquaponics due to salt restrictions in plant viability, however, integration of seaweed production and fish production may also be possible. Even some salt tolerant plants can be used in specific marine aquaponics (Gunning 2016; Puccinelli 2022).

Aquaponics emerges in the Portuguese context as an excellent opportunity for a local and sustainable production of products with high market potential. Whether the freshwater fish, or the legumes, both locally sourced in the interior of the country, can, therefore,

contribute for the mitigation of the carbon footprint in food production. Can also contribute for the maintenance of the traditional Portuguese diet recognised as healthy.

Legal and administrative barriers to aquaponics in Portugal

Despites the positive impacts at first sight, aquaponics has so far failed to scale up to industrial levels. FAO has been promoting small scale local solutions for urban food production (Somerville et al. 2014). Small scale businesses have increasingly become popular but do not scale up (Greenfeld et al. 2019). However it was only from 2010 that research in the area has been taking off, and therefore aquaponics can be classified as an emerging scientific topic and technology (Junge 2017). Industrial scale projects are therefore giving initial steps worldwide, and particularly in Europe (Villarroel 2016). Start-ups and research are increasing in Europe (Miličić 2017).

Institutional restrictions to the development of the aquaponics sector have been identified: i) Lack of harmonisation in law across the various member states of the EU, which impacts negatively trade (Joly, Junge, and Bardocz 2015; Miličić 2017); ii) Gaps in the national legislation of the different EU countries (Joly, Junge, and Bardocz 2015; Miličić 2017); iii) The NACE Rev.2 (Statistical Classification of Economic Activities in the European Community), which is commonly adopted by all the EU countries including Portugal, does not identify a code for aquaponics, having separate codes for plant and animal production (Joly, Junge, and Bardocz 2015). Accordingly to (Miličić 2017) this fact brings commercialisation and financial restrictions; iv) Impossibility of recognition as organic production for products obtained from aquaponic in the EU (Fruscella, Kotzen, and Milliken 2021; Kledal, König, and Matulić 2019; Miličić 2017;), as opposed to the USA and Australia. This restriction disallows added value to aquaponics products. RAS products cannot be classified as organic and vegetables need to grow in soil to be able to be classified as organic under EU law (Miličić 2017); v) The Portugal law imposes a ban

to some exotic freshwater fish species, such as Tilapia (*Tilapia spp.*) (Kledal, König, and Matulić 2019). This is a fact under the Portuguese law (Portuguese Parliament 1999) due to the invasive potential of these species. Water temperatures in the winter are mild and tilapia could eventually survive and adapt in the wild, which would compromise the ecosystems and the native species; vi) There are environmental concerns regarding the discharges of nitrate rich water from RAS, which could anyway be used as fertilisers, and that exactly what aquaponics does. (Joly, Junge, and Bardocz 2015) highlight the fact of specific legislation across the European countries that could separate effluents from aquaculture and aquaponics.

Given the potential to increase the sustainable production of food, becomes evident the need to understand how these and other restrictions may impact the evolution of the sector.

Aim and methods of the study

With the aim of understanding how the industry is evolving in Portugal, identifying constraints and discuss progress making, we have identified and interviewed ten entrepreneurs, policymakers, and academics across the country. This study is, therefore, an attempt to explore aquaponic business viabilities for the Portuguese context. It complements an initial exploratory study and collects information to allow understanding how should research and policy making be directly to boost aquaponics in Portugal. We have based our interview in open ended questions to collect qualitative information. The following six questions were posed to the interviewees:

1) What is your perception of the opinion about aquaculture of entrepreneurs, managers and policymakers?

2) What limitation do you kind companies may have should they want to invest in aquaponics?

3) How do you think the Portuguese companies may perceive the above limitations? How do you think these limitations may prevent these companies from investing in aquaponics?

4) What actions do you think policy makers should take to promote aquaponics?

5) What do you think it would be a good marketing strategy to promote products from aquaculture?

6) Are you aware of any legislative limitation preventing further development of aquaponics?

The panel of ten interviewees comprise: two academics with expertise in the sector; two policy makers; tree entrepreneurs directing aquaponic start-ups (only one already producing); one entrepreneur from the hydroponics sector with interests in aquaponic; and one entrepreneur from the algae aquaculture production sector with knowledge of aquaponics.

The questions were analysed by an inductive qualitative method as prescribed by (Drisko and Maschi 2016). An initial thematic content analysis was performed to retrieve a comprehensive view of the common ideas. This was followed by a narrative analysis where specific and individual aspects of the interviewees answers were also given consideration. Followed a discussion where the main issues identified are desiccated.

Analysis

There is a perception that most of the consumers don't know what aquaponics is, which may be a constraint for marketing. It is recognised by some interviewees that the sustainability concept of aquaponics could be an important marketing asset. The interviewees also have the perception that a minority of consumers knows the activity; despites lacking detailed knowledge about the technicities, this minority is aware of the sustainability benefits. Some consumers confuse it with hydroponics or aquaculture but

are unable to link both, and the majority don't have a clue about aquaponics. There is also a perception that policy makers are not sensitive to the activity and are uninformed. One interviewee refers that most of the policy makers are not informed even about aquaculture, therefore they completely ignore what aquaponics is. The absence of specific investment programs is pointed out as evidence.

In relation to entrepreneurs and managers, those with an activity in hydroponics or aquaculture know about aquaponics, however, most also lack detailed technical knowledge. It is recognised that some may be familiar with the technicalities, however it is referred that a RAS requires important backup systems (electricity, oxygen) and detailed supervision of water parameters and oxygen. A RAS it is portrayed as a complex system that brings production risks with it. One interviewee refers that freshwater fish don't have an attractive market in Portugal with a low market demand.

At the moment there is only one commercial aquaponic systems producing at low scale in Portugal, still in implementation and test stage. It is a business-to-business concept and the entrepreneur guaranties sales with a deal made with a local supermarket chain. There is a start-up with a project facing difficulties to be implemented, namely regarding the use of Tilapia in a RAS. However, after some efforts to try reverting the law to allow this species in Portugal, that was not possible and therefore the project was frozen. Another start-up has tried to implement an aquaponics project. The idea was to develop a RAS for the production of Largemouth Bass (*Micropterus salmoides*). The difficulties felt here where lack of funding from developing programmes and licencing complexities and delays.

There are some other curious, amateur, and hobbyists experimenting the concept at small scale. Most of these individuals are experiencing the activity and learning the practicality of it. These are all recent interests, some of the individuals have experience in extensive

aquaculture but not in a RAS. It is therefore referred that at the moment no offer is made in the market of products from aquaponics.

Relatively to legislative constraints one of the start-ups pointed out fish species (Tilapia) as the main issue. Lack of organic certification is also recognised by 5 of the interviewees as an important constraint to aquaponics. Aquaponics production need a marketing strategy to differentiate its products and the organic certification is seen as very important in this process. Two interviewees refer the process of licencing as an important constraint. One of these interviewees (a professional of aquaculture) refers that a simple aquaculture project can take up to two years to get all the legalities of licencing process overcome. He continues referring that probably an aquaponics project will take perhaps even more time once it involves additional construction and adds other production on top of aquaculture. Other constraints to invest in aquaponics identified were lack of technical information and support offices with extension technicians to advise and or facilitate overcoming technical, legal, and financial barriers.

The interviewees identified several actions that could be implemented to overcome the problems identified. To start, facilitating investments in aquaculture in general and in freshwater aquaculture in particular. Many of the interviewees have also highlighted the need to allow organic aquaculture certification, as it happens in other countries outside EU. Two interviewees have highlighted the need for a promotion of aquaponics as a sustainable activity to capture the interest of consumers, the certification of sustainable together with organic have been pointed out as necessary. One interviewee identified the required freshwater species (namely Tilapia) not being legal in the Portuguese aquaculture. One interviewee suggested that the creation of an experimental aquaponics station. The station would serve the purpose of promotion of the activity near stakeholders and the public in general. Activities such as forums of discussion and seminars involving

professionals, academics, technicians, policy makers, other type of stakeholders, and the public in general, could be developed in parallel. Other participant suggested exhibitions at schools and in fairs with presentations, workshops and training sessions to promote the activity.

Discussion

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 2017). However there are constraints that 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 lifes[4].

Relatively to the lack of a specific legislative and administrative framework, there is a citation[5] picked up by (Joly, Junge, and Bardocz 2015) that summarises 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*". In fact 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 a new activity. Aquaponics needs its own legal and administrative framework to overcome some barriers. As it is, duplicates the bureaucracy associated with the licencing processes, authorisations 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 Direcção-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.

The freshwater fishes

Another constraint identified was the list of fishes allowed in freshwater aquaculture in Portugal. While it is true that Tilapia is a species not allowed, there are many alternatives that could be used, even with increased commercial interest. It was suggested by one of the interviewees that freshwater fish lack commercial value in Portugal, however we disagree with that statement. Across the country but particularly in the regions of Ribatejo, Alentejo and Beira-Baixa, many freshwater species[6] of fish are considered delicacies, namely Largemouth Bass, Pikeperch (*Sander lucioperca*), and Eel (*Anguilla anguilla*). These species reach market values above marine fish species, and in 2015 were between the species with higher prices (Sabino 2016). There are a large number of gastronomic festivals all over the country dedicated to freshwater fish recipes. These are highly appreciated species from a gastronomic point of view, with good market potential and reaching prices competing with marine species. Another potential species not widely consumed in Portugal but with market in the region of Extremadura and Andalusia in Spain, therefore in the Portuguese border is the Tench (*Tinca tinca*).

The different trout species are also farmed in Portugal, namely the Rainbow trout (*Oncorhynchus mykissand*) and the brown trout (*Salmo trutta*), however most of these require cold water, and only in the highlands the ideal conditions are met.

Finally there are Sturgeons, the Beluga Sturgeon (*Huso huso*) and the Siberian Sturgeon (*Acipenser baerii*) for production of caviar. Fishing wild sturgeon is virtually prohibited worldwide. Fish farming is the sustainable alternative, also because caviar can be harvested without killing the sturgeons. This is probably one of the most lucrative species for freshwater aquaculture (Sicuro 2019).

From the species identified, those already being produced in RAS and also most suitable for a RAS are the Pikeperch (Podduturi et al. 2020), the Largemouth Bass (Tidwell 2019), the Eel (Eding and Kamstra 2012) and the Sturgeons (Pelic et al. 2021).

Some of the freshwater species have advantages over marine species in a RAS. The levels of dissolved oxygen don't need to be as high for eel (Degani, Horowitz, and Levanon 1985) and Learmouth bass (Tidwell 2019), and both Largemouth Bass (Tidwell 2019) and Pikeperch (Schram et al. 2014) are more resistant to toxicity by ammonium and/or nitrates and nitrites.

Certification

Certification is also a concern by most of the interviewees, and we agree with them. The EU position needs to be reviewed, otherwise the EU country lose competitiveness and face an investment barrier, which is already causing disillusionment between potential investors (Turnsek et al. 2020). Organic aquaponics is regulated in the USA and Australia. (Fruscella, Kotzen, and Milliken 2021), however in the EU barriers are raised both in the hydroponics and in the RAS components. (Fruscella, Kotzen, and Milliken 2021) reviewed these aspects in detail, however we can refer the main aspects. Organic aquaculture needs a fish welfare friendly environment, which accordingly to the organic rules cannot be obtained in a RAS. A RAS is energy intensive and needs higher densities of fish to be viable. Also the tanks not allowing an interaction of the fish with a soil based bottom raises lack of enrichment issues. On the other hand the main problem with hydroponics is that organic vegetables are a soil-based production. To overcome these issues the authors propose the enrichment of the aquaculture tanks and a fertirrigation system of a soil-based vegetable production.

Many scholars, some cited already in this article, are in favour of solving the organic certification issue for aquaponics. The advantages of the system in terms of the UN

sustainability agenda overtake any eventual disadvantage. Many certification schemes are self-imposed and regulated. We propose, therefore, that those interested in aquaponics in Portugal, and beyond in the EU associate themselves to create a new certification scheme. The designation "Organic" is known in other countries as "Biologic". A solution could be certificate has "Biologic Aquaponics" in the former countries and "Organic Aquaponics" in the later. In Portuguese would become "Produzido em modo de Aquaponia Orgânica", traduced into English as "Produced in Biologic Aquaponics Mode", and so on for the other languages.

Another option that producers may want to consider is the Aquaculture Stewardship Council (ASC) certification. This certification recognises fish "farmed responsibly" and has an excellent worldwide reputation. The ASC standards "*address the most pressing environmental and social impacts of aquaculture*" (ASC 2022). The local food movement is gaining momentum together with the ethicalities of food production, such as, the local production, and the sustainable satisfaction of ethical concerns about environmental and human health, social justice, and economic welfare (Tookes, Barlett, and Yandle 2018).

In fact, organic fish has not been a key priority even for specialised organic retailers in the EU. This is the result a study promoted by the European Commission (EUMOFA 2017). "*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*", concludes this study.

The Portuguese entrepreneurs may find advantageous to enter in a deal with supermarkets willing to source their products locally. The report of EUMOFA (2017) refers the case study of the large-scale retailer Jerónimo Martins (JM) in guarantying their internal needs from local suppliers. In 2015 this retailer sourced 84% of their products from local suppliers. "*For JM the issue of organic farmed fish will be addressed later on. The current*

need is the supply of fish, independently from its organic or conventional characteristics, as fish is essential in the Portuguese diet. This is why the company has started to invest in fish farming companies and is looking for other aquaculture possibilities in the Mediterranean or somewhere else". As such the Portuguese entrepreneurs may also find here an opportunity for a partnership.

Conclusion

Aquaponics is a food production system with potential to check the ethical, social, and sustainable agenda. Particularly in Portugal there are niche markets with great potential to welcome these products. Some of the interviewees in this study have identified some administrative and financial difficulties to overcome. Some of the interviewees have also identified convenient freshwater fish species as illegal; however as discussed there are many freshwater fishes allowed for use in a RAS with a good market potential. The inexistence of organic certification in aquaponics products was also identified as a constraint; however as discussed there are solutions. The interviewees have the perception that the Portuguese consumer is not aware of what aquaponics is. There is a marketing potential to be used based on the ethicalities of the system, and in a self-regulated certification.

The investment in a pilot farm could be an interesting solution to create awareness. Could also allow research, knowledge building and transfer, and demonstration. Could also serve as the meeting point of stakeholders to encourage discussion forums and cooperation of professionals. Professional cooperation and lobbying in Portugal and beyond in the EU is paramount to build out awareness and develop aquaponics.

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Notes

[1]A good approach for this calculation may be done with the integration of a world population curve. If you draw a bissectrice you will realise that both halves of the graph overlap each other almost perfectly.

[2]Should you want to satisfy curiosity, use your web search engine with the words (in Portuguese) “festival do peixe do rio”, translated as freshwater fish festival, and see what you get.

[3]Appart from nitrogen, plants also need other macronutrients, namely phosphorus and potassium, which, together with micronutrients, can also be uptake from the RAS recycling water.

[4]Lieve van Woensel and Geoff Archer, Scientific Foresight Unit, European Parliament Research Services, January 2015, page15.

[5]Answer given by Ms Damanaki on behalf of the Commission (25 June 2014) in Written questions by Members of the European Parliament and their answers given by a European Union institution (2014/C 413/01).

[6]The species referred here are those with potential to be used in a RAS. Other freshwater species are highly appreciated as delicacies in the Portuguese gastronomy, namely lamprey (*Petromyzon marinus*), and allis shad (*Alosa alosa*). Despites not being entirely freshwater species they live an important part of their life cycle in freshwater, just like eels. In the case of the allis shad, there is a phenomenon observed in a Portuguese dam. When it was constructed, landlocked a population of these fish. These have adapted completely to freshwater reproducing and growing well (Collares-Pereira et al. 1999).

References

Alves, Agostinho Leal. 2015. "A Economia do Mar em Portugal: a estratégia ea realidade, num retrato doméstico e comunitário." *EEF Mercados Pinanc*: 35-45.

Apostle, Richard. 2017. "A Typology for Investigating the Effects of Sturgeon Aquaculture on Conservation Goals." *Culture, Agriculture, Food and Environment* 39 (1): 53-57. https://doi.org/10.1111/cuag.12077

ASC. 2022. "15 facts about the Aquaculture Stewardship Council." ASC. Accessed 13 September 2022. https://www.asc-aqua.org/what-we-do/about-us/15-facts-about-the-asc/

Collares-Pereira, M. J., I. G. Cowx, T. Sales Luís, N. Pedrosa, and M. Santos-Reis. 1999. "Observations on the ecology of a landlocked population of allis shad in Aguieira Reservoir, Portugal." *Journal of Fish Biology* 55 (3): 658-664. https://doi.org/10.1111/j.1095-8649.1999.tb00706.x

Davenport, Sarah Grace, and Joanna Mishtal. 2019. "Whose Sustainability? An Analysis of a Community Farming Program's Food Justice and Environmental Sustainability Agenda." *Culture, Agriculture, Food and Environment* 41 (1): 56-65. https://doi.org/10.1111/cuag.12227

Davison, Andy. 2018. *Recirculating Aquaculture Systems: A guide to farm design and operations*. Farmfish LLC.

Degani, Gad, Avshalom Horowitz, and Dan Levanon. 1985. "Effect of protein level in purified diet and of density, ammonia and O2 level on growth of juvenile European eels (Anguilla anguilla L.)." *Aquaculture* 46 (3): 193-200. https://doi.org/10.1016/0044-8486(85)90205-4

dos Santos, Maria José Palma Lampreia. 2016. "Smart cities and urban areas—Aquaponics as innovative urban agriculture." *Urban Forestry & Urban Greening* 20: 402-406. https://doi.org/10.1016/j.ufug.2016.10.004

Drisko, James W., and Tina Maschi. 2016. *Content analysis*. Pocket Guide to Social Work Research Articles.Oxford University Press.

Ebeling, James M., and Michael B. Timmons. 2012. "Recirculating Aquaculture Systems." In *Aquaculture Production Systems*, 245-277. John Wiley & Sons, Inc.

Eding, E., and A. Kamstra. 2001. "Design and performance of recirculation systems for European eel and African catfish." *Aquaculture Engineering* 9 (3):187-207. https://doi.org/10.1016/0144-8609(90)90005-K

EUMOFA, European Market Observatory for Fisheries and Aquaculture Products. 2017. *EU Organic Aquaculture.* (European Comission). https://www.eumofa.eu/documents/20178/84590/Study+report_organic+aquaculture.pdf

FAO Food and Agriculture Organization of the United Nations. 2020. "The State of World Fisheries and Aquaculture 2020 (Sustainability in Action)." *Rome*.

Fruscella, Lorenzo, Benz Kotzen, and Sarah Milliken. 2021. "Organic aquaponics in the European Union: towards sustainable farming practices in the framework of the new EU regulation." *Reviews in Aquaculture* 13 (3): 1661-1682. https://doi.org/10.1111/raq.12539

Goddek, Simon, Alyssa Joyce, Benz Kotzen, and Gavin M. Burnell. 2019. *Aquaponics food production systems: combined aquaculture and hydroponic production technologies for the future*. Springer Nature.

Greenfeld, Asael, Nir Becker, Jennifer McIlwain, Ravi Fotedar, and Janet F. Bornman. 2019. "Economically viable aquaponics? Identifying the gap between potential and current uncertainties." *Reviews in Aquaculture* 11 (3): 848-862. https://doi.org/10.1111/raq.12269

Gunning, Daryl, Maguire Julie, Burnell Gavin. 2016. The Development of Sustainable Saltwater-Based Food Production Systems A. Review of Established and Novel Concepts. *Water* 8 (12). https://doi.org/10.3390/w8120598

Joly, Agnes, Ranka Junge, and Tomás Bardocz. 2015. "Aquaponics business in Europe: some legal obstacles and solutions." *Ecocycles* 1 (2): 3-5. https://doi.orf/10.19040/ecocycles.v1i2.30

Junge, Ranka, König Bettina, Villarroel Morris, Komives Tamas, and Jijakli M. H. 2017. "Strategic Points in Aquaponics." *Water* 9 (3): https://doi.org/10.3390/w9030182

Kledal, Paul Rye, Bettina König, and Daniel Matulić. 2019. "Aquaponics: The Ugly Duckling in Organic Regulation." In *Aquaponics Food Production Systems: Combined Aquaculture and Hydroponic Production Technologies for the Future*, edited by Simon Goddek, Alyssa Joyce, Benz Kotzen and Gavin M. Burnell, 487-500. Cham: Springer International Publishing.

Madsen, Ana Oliveira, and Valentina Chkoniya. 2019. "Fish consumption in the age of the information society-the evolution of the fish sector in Portugal." *European Journal of Social Sciences* 2 (2): 36-50. https://doi.org/10.26417/ejss-2019.v2i2-63

Migliore, Giuseppina, Pietro Romeo, Riccardo Testa, and Giorgio Schifani. 2019. "Beyond Alternative Food Networks: Understanding Motivations to Participate in Orti Urbani in Palermo." *Culture, Agriculture, Food and Environment* 41 (2): 129-139. https://doi.org/10.1111/cuag.12229

Miličić, Vesna, Thorarinsdottir Ragnheidur, Santos Maria D., Hančič Maja T. 2017. "Commercial Aquaponics Approaching the European Market To Consumers' Perceptions of Aquaponics Products in Europe." *Water* 9 (2): https://doi.org/10.3390/w9020080

Moro, Elisabetta. 2016. "The Mediterranean diet from Ancel Keys to the UNESCO cultural heritage. A pattern of sustainable development between myth and reality." *Procedia-Social and Behavioral Sciences* 223: 655-661.

Pelic, Dragana Ljubojevic, Milos Pelic, Suzana Vidakovic Knezevic, Milica Zivkov Balos, Sandra Jaksic, Jasna Kureljusic, and Nikola Puvaca. 2021. "Slaughter yield and chemical composition of Siberian sturgeon reared in a recirculating aquaculture system (RAS)." In IOP Conference Series: Earth and Environmental Science, vol. 854, no. 1, p. 012055. IOP Publishing. https://doi.org/10.1088/1755-1315/854/1/012055

Podduturi, Raju, Mikael Agerlin Petersen, Martin Vestergaard, and Niels O. G. Jørgensen. 2020. "Geosmin fluctuations and potential hotspots for elevated levels in recirculated aquaculture system (RAS): A case study from pikeperch (Stizostedion lucioperca) production in Denmark." *Aquaculture* 514: 734501. https://doi.org/10.1016/j.aquaculture.2019.734501

Portuguese Parliament. 1999. Decreto-Lei nº565/99 de 21 de dezembro. edited by Ministry of the Environment of Portugal. Lisbon, Portugal: Imprensa Nacional Casa da Moeda.

Puccinelli, Martina, Fierro-Sañudo Juan F., Bibbiani Carlo, Fronte Baldassare, Maibam Chingoileima, Dubois Theo, Pardossi Alberto, Incrocci Luca, Rossi Lorenzo. 2022. "Multi-Criteria DEXi Analysis for the Selection of Crop Species for Saltwater Aquaponics. 2022." *Horticulturae* 8 (8): https://doi.org/10.3390/horticulturae8080703

Pungrasmi, Wiboonluk, Phenphitchaya Phinitthanaphak, and Sorawit Powtongsook. 2016. "Nitrogen removal from a recirculating aquaculture system using a pumice

bottom substrate nitrification-denitrification tank." *Ecological Engineering* 95: 357-363. https://doi.org/10.1016/j.ecoleng.2016.06.094

Sabino, C. 2016. *Sustentabilidade do Peixe Português: Estudo de Mercado.* (Castelo Branco, Portugal: APTECE –Associação Portuguesa de Turismo de Culinária e Economia). https://rotadopeixe.com/wp-content/uploads/2016/08/Sustentabilidade-do-Peixe-VF.pdf

Schram, Edward, Jonathan A. C. Roques, Tiedo van Kuijk, Wout Abbink, Jan van de Heul, Pepijn de Vries, Stijn Bierman, Hans van de Vis, and Gert Flik. 2014. "The impact of elevated water ammonia and nitrate concentrations on physiology, growth and feed intake of pikeperch (Sander lucioperca)." *Aquaculture* 420-421: 95-104. https://doi.org/10.1016/j.aquaculture.2013.10.027

Serra-Majem, Lluís, Antonia Trichopoulou, Joy Ngo de la Cruz, Pilar Cervera, Alicia García Álvarez, Carlo La Vecchia, Aicha Lemtouni, and Dimitrios Trichopoulos. 2004. "Does the definition of the Mediterranean diet need to be updated?" *Public Health Nutrition* 7 (7): 927-929. https://doi.org/10.1079/PHN2004564

Sicuro, Benedetto. 2019. "The future of caviar production on the light of social changes: a new dawn for caviar?" *Reviews in Aquaculture* 11 (1): 204-219. https://doi.org/10.1111/raq.12235

Somerville, Christopher, Cohen Moti, Edoardo Pantanella, Austin Stankus, and Alessandro Lovatelli. 2014. *Small-scale aquaponic food production: integrated fish and plant farming*. In *Fisheries and aquaculture technical paper 589 (2014): I.* Rome, Italy: FAO Food and Agriculture Organisation of the United Nations. https://www.fao.org/3/i4021e/i4021e.pdf (accessed 5 August).

Tidwell, James. 2019. *Largemouth bass aquaculture*. 5m Books Ltd.

Tookes, Jennifer Sweeney, Peggy Barlett, and Tracy Yandle. 2018. "The Case for Local and Sustainable Seafood: A Georgia Example." *Culture, Agriculture, Food and Environment* 40 (1): 55-64. https://doi.org/10.1111/cuag.12106

Trichopoulou, Antonia, Tina Costacou, Christina Bamia, and Dimitrios Trichopoulos. 2003. "Adherence to a Mediterranean diet and survival in a Greek population." *New England Journal of Medicine* 348 (26): 2599-2608. https://doi.org/10.1056/NEJMoa025039

Turnsek, Maja, Agnes Joly, Ragnheidur Thorarinsdottir, and Ranka Junge. 2020. "Challenges of commercial aquaponics in Europe: beyond the hype." *Water* 12 (1): 306. https://doi.org/10.3390/w12010306

UNDESA, and United Nations Department of Economic and Social Affairs. 2022. *World Population Prospects 2022: Summary of Results.* United Nations (New York, USA: United Nations Publication).

Villarroel, Morris, Junge Ranka, Komives Tamas, König Bettina, Plaza Ignacio, Bittsánszky András, Joly Agnès. 2016. Survey of Aquaponics in Europe. *Water* 8 (10): https://doi.org/10.3390/w8100468

Zeller, Dirk, and Daniel Pauly. 2019. "Viewpoint: Back to the future for fisheries, where will we choose to go?" *Global Sustainability* 2: e11. https://doi.org/10.1017/sus.2019.8