American Journal of Multidisciplinary Research and Innovation (AJMRI)

ISSN: 2158-8155 (ONLINE), 2832-4854

VOLUME 3 ISSUE 1 (2024)

PUBLISHED BY: E-PALLI PUBLISHER, DELAWARE, USA

American Journal of Multidisciplinary Research and Innovation (AJMRI)

Volume 3 Issue 2, Year 2024
ISSN: 2158-8155 (Online), 2832-4854 (Print)
DOI: https://doi.org/10.54536/ajmri.v3i2.2388
https://journals.e-palli.com/home/index.php/ajmri

Exploring the Intersection of Aquaponics and Ornamental Fish Culture in Italy's Aquaculture Evolution: A Review of Innovative Integration

Benedetto Sicuro[1], Kazi Rabeya Akther[1], Valentina Tafuro[1], Nirmal Chandra Roy[2*]

Article Information

Received: December 18, 2023

Accepted: January 22, 2024

Published: February 28, 2024

Keywords

Aquaponics, Aquaculture, Innovation, Ornamental Fish Culture, Sustainable Production

ABSTRACT

The global imperative for sustainable food production has ignited a surge in interest and creativity at the nexus of aquaculture and agriculture. Italy, renowned for its historical embrace of aquaculture, has become a focal point for innovation through the fusion of aquaponics and ornamental fish farming. This review extensively explores Italy's dynamic aquaponics landscape, with a specific spotlight on the integration of ornamental fish into closed-loop systems. The study delves into the intricate relationship between fish culture and plant development within aquaponic systems, presenting a comprehensive approach to nutrient recycling in the realm of sustainable agriculture. This symbiotic interaction not only enhances resource efficiency but also provides a pragmatic means to counter the environmental drawbacks associated with conventional aquaculture methods. Furthermore, the review assesses the financial ramifications of incorporating decorative fish species into aquaponic systems, shedding light on the economic viability of this innovative approach. Based on a careful review of 27 research articles about the integration of aquaponics and ornamental fish culture in Europe, specifically in Italy, as well as 20 articles about aquaponics with edible fish, two about perspectives on hydroponics, and five about the integration of aquaponics and ornamental fish culture perspectives in Europe, Asia, and other regions, the study clarifies the efforts of Italian farmers. This review seeks to contribute to the ongoing success of this creative integration by synthesizing current knowledge and outlining critical avenues for future research.

INTRODUCTION

Due to the necessity of meeting the growing demand for seafood around the world and the pursuit of sustainable techniques, aquaculture the cultivation of aquatic organisms has undergone tremendous change over the years. Italy is leading the way in this evolution of aquaculture, known for its exquisite food customs and love of beautiful fish. This analysis explores the creative fusion of ornamental fish culture and aquaponics, a paradigm shift that has positive implications for the long-term sustainability and financial viability of Italy's aquaculture sector. Aquaponics is a system created to compensate for the negative impact that both traditional agriculture and aquaculture have on the environment. Traditional agriculture refers to the cultivation of plants on the ground with the use of artificial irrigation, fertilizers, and pesticides (AlShrouf, 2017). Due to the rapid world population growth, the characteristics of this type of agriculture have become negative, as there has been an excessive use of land, water, fertilizers, and pesticides. For this reason, a system has been studied in which plants can grow without soil, in each solution with the addition of nutrient fertilizers (AlShrouf, 2017). This is the hydroponic system. The same problem is also present in aquaculture in fact, there are two different types of farming: "flow-through" and "RAS", created to replace the first type of farming. "Flow-through" is the most common type of farming in aquaculture and is characterized by an open system in which clean water flows into the tanks once and then is poured into a river, taking with it all the substances present in the fish tanks (residues of unconsumed feed, high concentrations of phosphorus and nitrogen, and possible antibiotics used during the production cycle) (Calone *et al.*, 2019). The "RAS" (Recirculating Aquaculture System), on the other hand, is a closed system in which water is filtered to eliminate all substances present and to be continuously recirculated within the system, with a daily water waste of less than 10% (Calone *et al.*, 2019). Aquaponics is the union of the two best systems present in agriculture and aquaculture; hence, it represents the union between hydroponics and RAS (König *et al.*, 2018). In this integrated system, plants and fish are raised at the same time, always using the same recycled water (Rossi *et al.*, 2021). A nitrification process aided by bacteria (nitrosomonas and nitrobacter) allows the nitrogenous materials removed by the fish to be absorbed and utilized by the plants as food. The water filtered and purified by the plants is then conveyed into the fish tanks (Maucieri *et al.*, 2018; Rossi *et al.*, 2021). Aquaponics is therefore defined as the integrated multitrophic production of plants and fish in an almost closed recirculating system, which aims to drastically reduce production inputs and waste, while maximizing total food production (Maucieri *et al.*, 2018; Rossi *et al.*, 2021).

In particular, the benefits that aquaponics brings with it are:

[1] Department of Veterinary Sciences, University of Torino, Italy
[2] Department of Fish Biology and Genetics, Faculty of Fisheries, Sylhet Agricultural University, Sylhet-3100, Bangladesh
[*] Corresponding author's e-mail: ncroy@sau.ac.bd

Reduced Water Usage
Aquaponic systems use up to 90% less water than traditional aquaculture (Calone *et al.*, 2019; König *et al.*, 2016).

Reduced Pesticide Use
Aquaponic systems are naturally pest-resistant, so there is no need to use harmful pesticides (König *et al.*, 2016; AlShrouf, 2017).

Increased Yields
Aquaponic plants grow faster and produce higher yields than plants grown in soil.

Improved Nutrient Quality
Aquaponic plants are grown in nutrient-rich water, which results in higher quality fruits and vegetables.

Reduced Environmental Impact
Aquaponic systems are a closed-loop systems, so there is no waste runoff (König *et al.*, 2016).

Social Sustainability
Aquaponics is already taught at the primary and secondary school levels and in vocation training (König *et al.*, 2016).

Sustainability Aspects in Urban Environments
Aquaponics help alleviate food deserts, it is an educational tool in schools; anterior greening (providing a better climate in public buildings and homes), and a unit in social institutions (in Italy, a psychotherapy hospital implements aquaponics in rehabilitation for people after shock (Dr. Maurizio Borin, personal communication on April 24, 2015)) (König *et al.*, 2016).
Combining aquaponics with ornamental fish culture is a progressive method that not only increases output but also solves major issues with conventional aquaculture systems. The biological symbiosis that exists between fish and plants is the basis of this synergistic relationship. Fish waste is used in an aquaponic system as a nutrient-rich fertilizer for the plants, and the plants themselves filter the water before it is returned to the fish tanks. This closed-loop system, which uses less water and requires less external fertilizer, is an example of a sustainable and environmentally beneficial concept.
This analysis looks at the current situation of ornamental fish farming and aquaponics in Italy, highlighting the benefits and problems that come with combining the two. We aim to provide a thorough understanding of how this convergence could influence aquaculture in Italy going forward and possibly act as a model for sustainable practices globally by exploring the scientific, economic, and environmental elements. We will discover the possible advantages, technological breakthroughs, and ramifications for the future of Italian aquaculture as we negotiate the complex dynamics of this creative integration.

MATERIALS AND METHODS

In accordance with the guidelines outlined by Haddaway *et al.* (2015), this review work involved a systematic review of the literature, focusing on peer-reviewed studies, doctoral and master's theses, and scientific reports related to relevant databases such as PubMed, Scopus, and academic journals. Use keywords including "aquaponics," "ornamental fish culture," and "Italy" in various combinations. Include filters for publication date, ensuring the inclusion of recent and seminal works. Perform a thorough review of both peer-reviewed articles and literature. The scope of our investigation encompassed materials written in English and available online, as depicted in Figure 1. The search for relevant data was executed across three comprehensive scholarly databases: Web of Science, Google Scholar, and Scopus, spanning from November to December 2023.

Figure 1: Focused study area of this review paper (bing.com)

To optimize our search strategy, a preliminary assessment of a subset of articles preceded the main search, guiding the selection of search-string combinations. Each search string underwent individual testing to ensure precision and relevance, with examples including terms such as" aquaponics," "ornamental fish culture," and "Italy" in various combinations. The results of our search yielded more than 100 peer-reviewed papers from Google Scholar, Web of Science, and Scopus, respectively. Subsequently, a thorough evaluation of all obtained results was conducted to ensure relevance and to exclude papers unrelated to our specific focus for each search string. Following this rigorous screening process, we identified and reviewed a total of 27 papers (Figure 2).

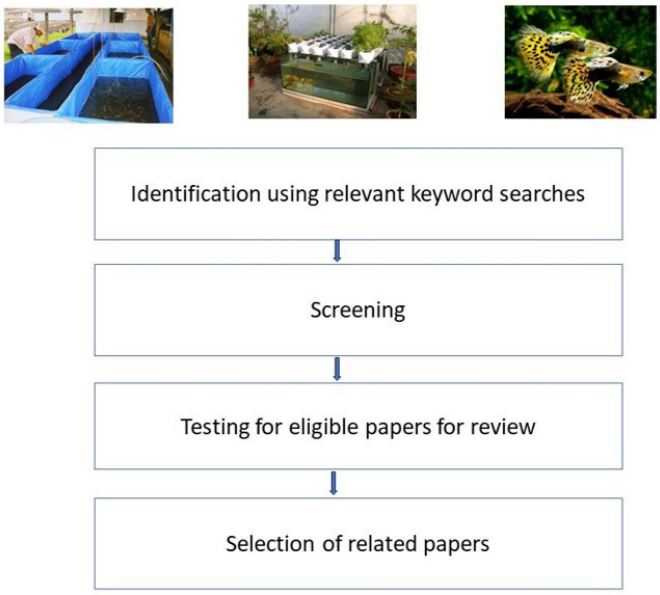


Figure 2: Flow chart for screening and identification of the relevant publications.

RESULTS AND DISCUSSION

Research Gap and Challenges

The research gap identified by AlShrouf (2017) in the field of hydroponics, aeroponic, and aquaponic systems as compared with conventional farming lays the foundation for subsequent studies that contribute valuable insights to agricultural practices. This research paves the way for a comprehensive understanding of alternative cultivation methods and their impact on resource efficiency, crop yield, and sustainability. Furthering the discourse, Asciuto, Schimmentia, Cottone, and Borsellino (2019) conduct a financial feasibility study on aquaponic systems in a Mediterranean urban context, highlighting the need for economic assessments of unconventional agricultural approaches. The study by Santos (2018) explores innovative methods by utilizing Google Trends to nowcast and forecast aquaponics trends in European countries, showcasing the intersection of technology and agriculture. Additionally, the work of Forchino, Lourguioui, Brigolin, and Pastres (2017) and Fronte, Galliano, and Bibbiani (2016) delves into the sustainability aspect of aquaponics, comparing different techniques and expanding the knowledge base on environmental considerations. Konig, Janker, Reinhardt, Villarroel, and Junge (2018) and Konig Junge, Bittsanszky, Villarroel, and Komives (2016) contribute to the discourse on aquaponics sustainability, presenting an analysis of aquaponics as an emerging technological innovation system. Korner, Bisbis, Baganz, Staaks, Monsees, Goddek, and Keesman (2021) extend the discussion to the environmental impact assessment of local decoupled multi-loop aquaponics in an urban context, emphasizing the need for sustainable practices in agriculture.

Furthermore, Luo, Rauan, Xing, Sun, Wu, and Ji (2021) provide insights into the influence of dietary Se supplementation on aquaponic systems, focusing on the growth performance, ornamental features, and health status of Koi carp, and Maucieri, Nicoletto, Zanin, Xiccato, Borin, and Sambo (2020) explore the composition and quality traits of vegetables grown in a low-tech aquaponic system at different fish stocking densities. The multifaceted nature of aquaponics is evident in studies such as Settanni, Lombardo, Tamborra, and Orsini (2020); Suarez-Caceres, Lobillo-Eguíbar, Fernandez-Cabanas, Quevedo-Ruiz, and Perez-Urrestarazu (2021), and Turnsek, Joly, Thorarinsdottir, and Junge (2020), which investigate aquaponic systems for integrated fish and plant production, polyculture production for self-consumption, and challenges faced in commercial aquaponics in Europe, respectively.

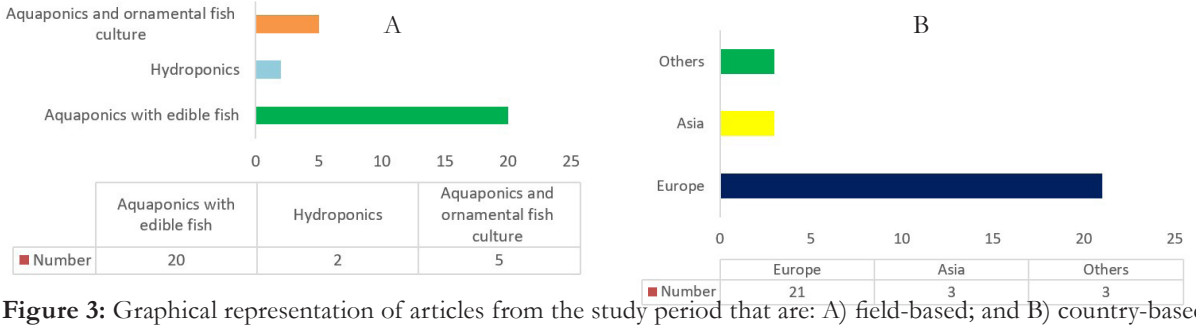


Figure 3: Graphical representation of articles from the study period that are: A) field-based; and B) country-based in research

In conclusion, the compilation of research studies on hydroponics, aeroponics, and aquaponics from various geographical locations, including Italy, China, India, Romania, and Europe at large, underscores the global significance of these alternative agricultural methods. The diverse range of topics covered in these studies collectively contributes to bridging the research gap and advancing our understanding of sustainable and efficient agricultural practices (Figure 3).

This research is centered on evaluating the integration of aquaponics with ornamental fish culture, specifically in Europe, with a particular focus on Italy. The assessment is grounded in a thorough analysis of existing literature, encompassing 27 research articles. Additionally, the review incorporates 20 articles that delve into aquaponics involving edible fish, 2 articles offering hydroponics viewpoints, and 5 articles exploring perspectives on the integration of aquaponics and ornamental fish culture. The geographical distribution of the literature includes 21 papers from Europe, 3 from Asia, and 3 from other regions (Figure 3).

Aquaponics

Aquaponics is a hydroponic and aquaculture hybrid agricultural method that is used to grow plants and aquatic animals. In aquaponics systems, crop plants, fish, and bacteria form a closed circuit that cycles nutrients. Fish waste is converted by the system's nitrifying bacteria into nitrates for plants, which clean the fish's water (Dubey, 2023) (Figure 4). The FAO and the European Commission define aquaponics as one of the most promising food production technologies both in terms of sustainability and efficiency (Raulier *et al.*, 2023), but, nevertheless, there are no data and statistics regarding developments or plants in the world on the FAO website. On the other hand, there are many articles or books on what an aquaponics system is (Forchino *et al.*, 2017), on how to reproduce it on a small scale (Suarez-Caceres *et al.*, 2021), on which plants and fish live best in symbiont (Calone *et al.*, 2019; Maucieri *et al.*, 2020; Nicolae *et al.*, 2015; Mohapatra *et al.*, 2023), on the economic aspect (Turnsek *et al.*, 2020; Miličić *et al.*, 2017), on environmental and social impact (König *et al.*, 2016; Korner *et al.*, 2021), etc.

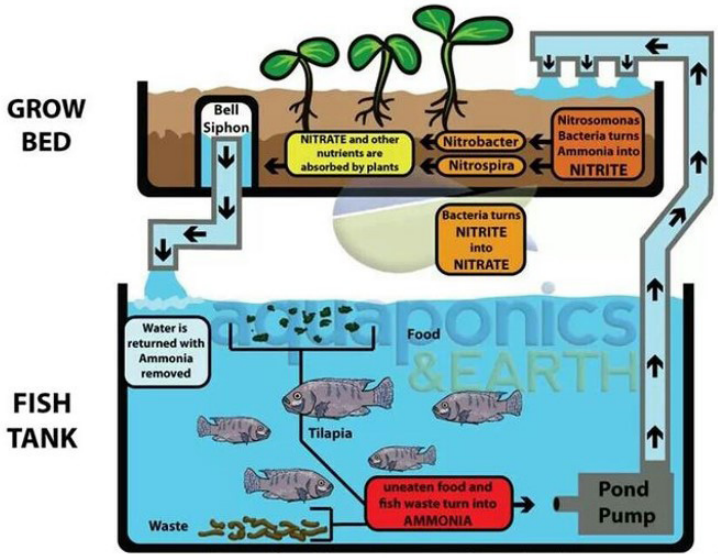


Figure 4: Aquaponics system (systemaqua.blogspot.com)

In Europe, the first research on aquaponics started a little later than in other countries, because the first research carried out in Europe dates to 2009, while worldwide the first research dates to 1977 (Raulier *et al.*, 2023). Speaking of research related to aquaculture, a study carried out by Hao *et al.*, in 2020 identifies 2 institutes as the leading experts in this area; in particular, the University of Zurich is the most influential institution, while the University of Wageningen is the most productive. However, the research that these 2 institutes carry out is different, as the University of Zurich studies the factors that affect plant production, while the University of Wageningen focuses mainly on the commercial and promotional aspects of aquaponics. Returning to the subject of statistical data regarding aquaponics developments or plants in the world, as we said before, they are not present in the FAO databases, but on the other hand several studies have been carried out to understand the state and trend of aquaponics in Europe. Research carried out in 2014-2015 using questionnaires reported the presence of about 20 European commercial aquaponic farms (Villarroel *et al.*, 2016). In 2016, on the other hand, as many as 45 trading companies were counted, but this number is unfortunately not reliable, as non-European companies and companies that have ceased their activity were also included in the total (Raulier *et al.*, 2023). A further study regarding the development of aquaponics was carried out by Palma Lampreia Dos Santos (2018), using Google Trends as a survey method and not questionnaires. This study confirmed an increase in the interest and importance of aquaponics for European countries but also pointed out that there is still a long way to go to

market aquaponics-derived products (Palma Lampreia Dos Santos, 2018). Be that as it may, these articles have also highlighted which bodies and structures are most involved in the development of aquaponics, and in the same way they have shown which plant and fish species are most used in this system. According to Villarroel *et al.* (2016), universities (42.6%), businesses (19.1%), non-profit organizations (14.7%), and vocational schools (8.8%) in Europe carried out aquaponics activities. Several fish species were involved in these activities, in particular tilapia (27%), catfish (10%), ornamental fish (8%), trout (7%), bass (4%), and perch (2%), while the most cultivated plant species were herbs (58%, including basil), lettuce (47%, including salad greens), and tomatoes (32%) (Villarroel *et al.*, 2016).

A study conducted between 2015 and 2020 showed how the percentages of aquaponics activities have changed compared to previous studies; in particular, aquaponics studies were carried out by non-profit entities (13%), primary and secondary schools, universities, and research centers (26.1%), and finally production, sales, and consulting activities (60.9%) (Raulier *et al.*, 2023). It can therefore be seen that commercial activity has increased significantly compared to previous studies. The same change can also be appreciated for the fish species used in aquaponics; in fact, Raulier *et al.* (2023) show that the most used species were trout (47.8%), followed by carp (30.4%), and tilapia (21.7%). The same goes for the plants that were grown: aromatic herbs (45.5%), tomatoes (37%), and lettuce (32.6%) were the most used. This radical increase in trout production compared to other fish was simply driven by consumer interest.

Water Quality for Aquaponics and Ornamental Fish Culture

Table 1 presents key water quality parameters for three distinct fish species: goldfish (*Carassius auratus*), Koi carp (*Cyprinus carpio var. Koi*), and guppy fish (*Poecilia reticulata*). For goldfish in a 10 m^3 volume, the parameters include a pH of 8, dissolved oxygen levels ranging from 7.26 to 6.55 mg/l, and specific ammonia (NH_4), nitrite (NO_2), and nitrate (NO_3) concentrations. Koi carp, in a 0.15 m^3 volume with a temperature range of 16–26.5 °C, exhibits varying nitrate concentrations from 5 to 150 mg/l. Guppy fish, in a 0.1 m^3 volume, maintain a pH range of 6.0 to 7.8 and dissolved oxygen levels between 4.5 and 7.8 mg/l. These parameters are critical for the well-being of each species. Notably, references such as Settanni *et al.* (2020), Patil *et al.* (2019), Nicolae *et al.* (2015), Luo *et al.* (2021), and Mohapatra *et al.* (2023) provide the sources of this valuable information, aiding aquarists and researchers in creating and maintaining suitable aquatic environments for these diverse fish species.

Table 1: Water quality parameters for ornamental fish culture in aquaponic system

Fish Species	Water Quality Parameters						Others	Reference
	Volume (m^3)	pH	DO (mg/l)	NH_4 (mg/l)	NO_2 (mg/l)	NO_3 (mg/l)		
Goldfish (*Carassius auratus*)	10	8		0 - 0.1	0 - 0.01	10	*KH: 8	Settanni *et al.*, 2020
	0.05	7.26	6.55	0.13	0.012	0.23	Temperature 27 °C	Patil *et al.* 2019
	0.4			< 0.3	< 0.3	> 30		Nicolae *et al.*, 2015
Koi carp (*Cyprinus carpio,* var. Koi)	0.15		> 5.00	< 1.0	< 1.0	5 – 150	Temperature: 16 - 26.5 °C	Luo *et al.*, 2021
	10	8		0 - 0.1	0 - 0.01	10	*KH: 8	Settanni *et al.*, 2020
Guppy fish (*Poecilia reticulata*)	0.1	6.0 - 7.8	4.5 - 7.8	0.5	1.0	0.5		Mohapatra *et al.*, 2023

**KH: Carbonate hardness*

Ornamental Fish Culture

Also, due to consumer interest, there are few studies in which ornamental fish are used, as the contribution of the ornamental fish market to world trade is very small compared to the food fish market (Patil *et al.*, 2019). This, however, does not stop some researchers, who, by experimenting with the various combinations of ornamental fish species and plant species, can give citizens a way to get closer to nature, enjoy a beautiful ornamental aquarium, and without having production costs, always have fresh herbs at home that can be used in the kitchen (Nicolae *et al.*, 2015).

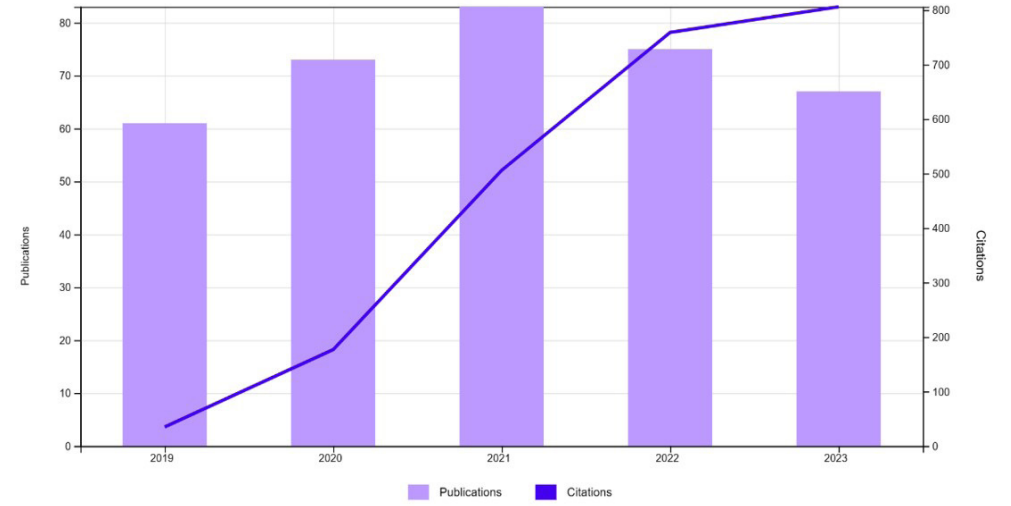
Integration of Ornamental Fish Culture in Aquaponics System

The few studies developed on the interaction between aquaponics and ornamental fish almost all come from Asian countries, because the production of ornamental fish is an important component of their economy and because the cultivation of ornamental fish in aquaponic systems is an ever-increasing hobby in Asian countries (Patil *et al.*, 2019). In particular, the ornamental fish studied are goldfish (Nicolae *et al.*, 2015; Patil *et al.*, 2019), guppy fish (Mohapatra *et al.*, 2023), and koi (Luo *et al.*, 2021). The same thing cannot be said for Italy, because there is

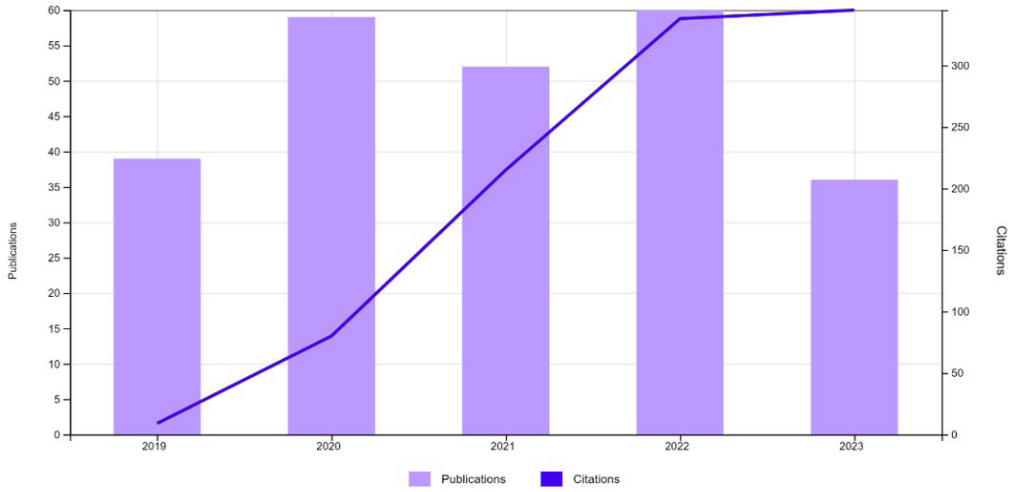
one article regarding the interaction between aquaponics and ornamental fish.

Prospects of Innovative Protocol of Ornamental Culture in Aquaponics System

In Italy, the prospects for an innovative protocol of ornamental culture within aquaponics systems are promising. Fueled by robust market demand driven by both hobbyist communities and commercial interests, the ornamental fish and plant industry presents fertile ground for innovative approaches. Emphasizing sustainability is key, as Italy increasingly values environmentally friendly practices, and aquaponics, with its closed-loop system, aligns well with this trend. Collaboration among aquaculture experts, horticulturists, and researchers is essential for the research and development of such protocols, with universities and research institutions playing a pivotal role. Navigating the regulatory landscape is crucial for success, as is educational outreach to farmers and the public. Economic viability, technology integration, and adaptability to local conditions will be decisive factors in ensuring the success of the ornamental culture protocol. Networking and collaboration, market differentiation, and continuous innovation will contribute to its standing out in a competitive landscape. Overall, a well-crafted, adaptable, and sustainable protocol has the potential to revolutionize ornamental culture within the aquaponics sector in Italy. It was also found that the research trend was increasing in aquaponics and ornamental fish culture according to the Web of Science (Figure 5).



(A)



(B)

Figure 5: Trend of research, A) aquaponics, and B) ornamental fish culture based (web of science)

CONCLUSION

In conclusion, studying the connection between aquaponics and ornamental fish culture in Italy's aquaculture history may lead to the development of efficient and sustainable aquacultural practices. Aquaponics is a synergistic approach that combines hydroponics and aquaculture to enhance resource utilization and minimize environmental impact. Additionally, the evaluation can highlight how crucial it is to carry out more research and development in this area to handle any obstacles and maximize the fusion of aquaponics and ornamental fish production. The effective use of these cutting-edge techniques can be facilitated by

cooperation between academics, industry professionals, and policymakers, which will support the development of a more robust and sustainable Italian aquaculture industry. A potential path for the advancement of Italian aquaculture could involve combining aquaponics with the rearing of ornamental fish. Adopting and developing these integrated approaches can improve economic growth, environmental sustainability, and the overall resilience of Italy's aquaculture sector.

REFERENCES

AlShrouf, A. (2017). Hydroponics, aeroponic and aquaponic as compared with conventional farming. *Am. Sci. Res. J. Eng. Technol. Sci, 27*(1), 247-255.

Asciuto, A., Schimmenti, E., Cottone, C., & Borsellino, V. (2019). A financial feasibility study of an aquaponic system in a Mediterranean urban context. *Urban Forestry & Urban Greening, 38*, 397-402.

Calone, R., Pennisi, G., Morgenstern, R., Sanyé-Mengual, E., Lorleberg, W., Dapprich, P., ... & Gianquinto, G. (2019). Improving water management in European catfish recirculating aquaculture systems through catfish-lettuce aquaponics. *Science of the total environment, 687*, 759-767.

Dos Santos, M. J. P. L. (2018). Nowcasting and forecasting aquaponics by Google Trends in European countries. *Technological Forecasting and Social Change, 134*, 178-185.

Dubey, A. (2023, November 14). aquaponics. Encyclopedia Britannica. https://www.britannica.com/technology/aquaponics

Forchino, A. A., Lourguioui, H., Brigolin, D., & Pastres, R. (2017). Aquaponics and sustainability: The comparison of two different aquaponic techniques using the Life Cycle Assessment (LCA). *Aquacultural Engineering, 77*, 80-88.

Fronte, B., Galliano, G., & Bibbiani, C. (2016). From freshwater to marine aquaponic: New opportunities for marine fish species production. In *Conference VIVUS–on Agriculture, Environmentalism, Horticulture and Floristics, Food Production and Processing and Nutrition. With Knowledge and Experience to New Entrepreneurial Opportunities (Vol. 4, pp. 514-521). Biotechnical Centre Naklo.*

Haddaway, N. R. (2015). A call for better reporting of conservation research data for use in meta-analyses. *Conservation Biology, 29*(4), 1242-1245.

Hao, Y., Ding, K., Xu, Y., Tang, Y., Liu, D., & Li, G. (2020). States, trends, and future of aquaponics research. *Sustainability, 12*(18), 7783.

König, B., Janker, J., Reinhardt, T., Villarroel, M., & Junge, R. (2018). Analysis of aquaponics as an emerging technological innovation system. *Journal of cleaner production, 180*, 232-243.

König, B., Junge, R., Bittsanszky, A., Villarroel, M., & Kőmíves, T. (2016). On the sustainability of aquaponics. *Ecocycles, 2*(1), 26-32.

Körner, O., Bisbis, M. B., Baganz, G. F., Baganz, D., Staaks, G. B., Monsees, H., ... & Keesman, K. J. (2021). Environmental impact assessment of local decoupled multi-loop aquaponics in an urban context. *Journal of Cleaner Production, 313*, 127735.

Luo, X. L., Rauan, A., Xing, J. X., Sun, J., Wu, W. Y., & Ji, H. (2021). Influence of dietary Se supplementation on aquaponic system: Focusing on the growth performance, ornamental features and health status of Koi carp (Cyprinus carpio var. Koi), production of Lettuce (Lactuca sativa) and water quality. *Aquaculture Research, 52*(2), 505-517. map of italy - Search Images (bing.com)

Maucieri, C., Nicoletto, C., Junge, R., Schmautz, Z., Sambo, P., & Borin, M. (2018). Hydroponic systems and water management in aquaponics: A review. *Italian Journal of Agronomy, 13*(1), 1-11.

Maucieri, C., Nicoletto, C., Zanin, G., Xiccato, G., Borin, M., & Sambo, P. (2020). Composition and quality traits of vegetables grown in a low-tech aquaponic system at different fish stocking densities. *Journal of the Science of Food and Agriculture, 100*(11), 4310-4318.

Miličić, V., Thorarinsdottir, R., Dos Santos, M., & Turnšek Hančič, M. (2017). Commercial aquaponics approaching the European market: To consumers' perceptions of aquaponics products in Europe. *Water, 9*(2), 80.

Mohapatra, B. C., panda, S. K., chandan, N. K., & majhi, D. (2023). Current World Environment.

Nicolae, C. G., Popa, D. C., Turek, R. A., Dumitrache, F., Mocuţa, D., & Elia, E. (2015). Low-tech aquaponic system based on an ornamental aquarium. Scientific Papers. *Series D. Animal Science, 58*, 385-390.

Patil, P. A., Dube, K., Verma, A. K., Chadha, N. K., Sundaray, J. K., & Jayasankar, P. (2019). Growth performance of goldfish, Carassius auratus and basil, Ocimum basilicum in media bed aquaponics. *Indian Journal of Fisheries, 66*(1), 112-118.

Raulier, P., Latrille, F., Ancion, N., Kaddouri, M., Crutzen, N., & Jijakli, M. H. (2023). Technical and Business Evaluation of Professional Aquaponics in Europe. *Water, 15*(6), 1198.

Rossi, L., Bibbiani, C., Fierro-Sañudo, J. F., Maibam, C., Incrocci, L., Pardossi, A., & Fronte, B. (2021). Selection of marine fish for integrated multi-trophic aquaponic production in the Mediterranean area using DEXi multi-criteria analysis. *Aquaculture, 535*, 736402.

Settanni, L., Lombardo, F., Tamborra, G. M., & Orsini, F. (2020). Design of an aquaponic system for integrated fish and plant production in Bologna (Italy). *ACTA HORTICULTURAE, 1298*, 129-134.

Suárez-Cáceres, G. P., Lobillo-Eguíbar, J., Fernández-Cabanás, V. M., Quevedo-Ruiz, F. J., & Perez-Urrestarazu, L. (2021). Polyculture production of vegetables and red hybrid tilapia for self-consumption by means of micro-scale aquaponic systems. *Aquacultural Engineering, 95*, 102181. systemaqua.blogspot.com

Turnsek, M., Joly, A., Thorarinsdottir, R., & Junge, R. (2020). Challenges of commercial aquaponics in Europe: beyond the hype. *Water, 12*(1), 306.

Villarroel, M., Junge, R., Komives, T., König, B., Plaza, I., Bittsánszky, A., & Joly, A. (2016). Survey of aquaponics in Europe. *Water, 8*(10), 468.