


# COST Action FA1305
# Draft White Paper on Aquaponics in the EU

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Contemporary aquaponics has developed over the last 40 years, combining aquaculture and hydroponic systems to farm mainly fish and vegetable produce. Developing from a number of often small-scale systems, this modern agricultural production system is at the brink of commercialisation. The EU Aquaponics Hub arose from a need to create a coordinated approach to the science and innovation of aquaponics in the EU, to connect as many people involved in aquaponics in the EU as possible, and to drive forward collaboration at all levels in aquaponics including entrepreneurship.

COST Action FA1305 has brought together a multidisciplinary and multinational hub of scientists and SMEs to better understand European and international knowledge in aquaponics and to expand and promote aquaponics research so that the EU can be competitive in this field when compared to the leading practitioners and researchers which were, until 2013, mainly located in the USA. One of the central tools of the COST Programme is the emphasis on the transfer of knowledge and education in science across the EU, Near Neighbour Countries and institutions and other International Partner Countries, and in particular the training and transfer of research skills, knowledge and experience to Early Career Researchers (ECRs). The Action has thus taken this opportunity and was as inclusive as possible. Over its four years it has drawn in researchers and practitioners from 28 EU and associated member countries and also from around the globe. In its role to bring science and practice together, the Action has been remarkably successful in including a good number of SMEs and entrepreneurs, who contributed relevant and important knowledge and experience back into the scientific community. This growing relationship between institutions and entrepreneurs has led to a number of projects within the EU, linking research and practice.

Science is always looking towards the future, and future development for the benefit of mankind, lies in the hands of today's early career researchers (ESR, PhD and postdoctoral) and their supervisors and institutions. Thus COST Action FA1305 has provided numerous and significant opportunities for expanding the knowledge and training of ECRs, and our conferences have provided yearly occasions for significant numbers of ECRs to present their research to their peers, to the COST membership and to the wider world. COST Action FA1305 has also facilitated capacity building through its 7 Training Schools and 20 Short Term Scientific

Missions (STSMs), providing ECRs with opportunities to work collaboratively with other experts and institutions beyond their home countries. The Action has also facilitated capacity building beyond researchers in institutions, to spread aquaponics knowledge to those who are involved in economic social and community enterprise. A total of 105 students and young researchers from 26 European countries have benefited from these educational opportunities.

COST Action FA130 has run for four years and it has many outputs, including a EU Aquaponics Hub website which provides a repository of information, the publication of collaborative review papers, and the hosting of international conferences, Training Schools and STSMs. Most importantly, through the publication of collaborative review papers, the participants of FA1305 have formulated the state of art as well as future development and research needs. The Action has been particularly successful in building cross-border links between EU scientific institutions and with institutions in the neighbouring countries of Israel and Egypt. We have also involved partner institutions from further afield, in Australia, South Africa, and Brazil and we have hosted academic and professional experts from these countries as well the USA at our conferences in order to spread knowledge and facilitate collaboration.

This White Paper is one component of the final outputs of COST Action FA1305, and it is intended to be an important part of its legacy. While the four-year networking Action has come to an end, there is an on-going need to promote aquaponics as a means for productive, sustainable food production in the EU, and to ensure that the high quality research continues, whilst the acquired knowledge is transferred to the SMEs and to larger entrepreneurial ventures. This White Paper is also a means to highlight the great need for joined up thinking in policy making and focusing attention on aquaponics in the EU as a highly relevant and important new way of providing sustainable, healthy and nutritious food for EU citizens. The advantages of aquaponics and what we do in aquaponics must be brought to the attention of policy makers and funders in the EU. The four Working Groups of COST Action FA1305 have therefore identified 8 key recommendations based on the experience of their individual members, trends within current research and entrepreneurship, and the directions being investigated by ECRs.

The recommendations of the Management Committee of COST Action FA1305 are:

1. **The promotion of continued research in aquaponics**

*In order for aquaponics to realise it's socio-economic potential and to maximise the beneficial impacts it can have on the environment compared to other production methods, especially in regard to societal challenges such as phosphorus peak, ground water pollution and water scarcity, aquaponics research needs to be promoted, increased and accelerated. In order to achieve this, institutions need to increase their capabilities and capacities and funding agencies need to accelerate research through their Calls.*

The widespread popularity of Aquaponics contrasts significantly to the strength of research actually being done and published (Junge et al., 2017). If aquaponics is to fulfil its *'promise of sustainability'* (König et al 2018) as one of the *'Ten technologies which could change our life'* (Van Woensel and Archer, 2015), then the research is by no means at the end of the road, but only at the beginning. The first scientific papers on aquaponics were published in the 1970s and early 80's such as by Naegel in 1977, but aquaponics research only 'took off' after 2010 (Junge et al., 2017). Nevertheless, the number of papers is still several orders of magnitude lower, especially when compared to aquaculture and hydroponics which number in the thousands per annum. Over 20 peer reviewed, collaborative papers (with 3 or more Management Committee (MC) members contributing) have been produced as a direct result of COST Action FA1305 and many more (as individuals or with two collaborative MC members) have been published over this period. However, many areas still need to be investigated and developed through scientific research where this is also transferred into the commercial sector. The scope and need for aquaponics research is still extensive and across a wide range of topic areas from economics and Life Cycle Analysis (LCA) to infrastructure development, microbiological transformations in the system, fish and plant health, marketing and pedagogy. Young scientists and the future generation need to be encouraged to get involved. Funding is required for research to be effective, and national, regional as well as EU funding agencies need to be encouraged to provide specific calls for aquaponics research.

2. **The commercialisation and funding of aquaponics – the next stages**

*The aquaponics as commercial operations should focus on increased sustainability in food production, minimising negative environmental impacts in farming and providing healthy, nutritious local food, which additionally reduces the carbon and ecological footprints of food. Depending on the site and market conditions, smaller scale as well as large- scale aquaponic operations can be commercially viable. In order to maximise aquaponics impact and*

*outreach, larger scale systems need to be developed and built in order to realise the socio-economic and environmental benefits that can be achieved. In order to do this there needs to be clear EU wide legislative and planning guidance, based on the knowledge gained through FA1305, with clear protocols and guidelines that entrepreneurs and investors can rely upon, and incentives for investors to fund aquaponic developments.*

Although the interest in aquaponics has been growing globally over recent years and the methodology is becoming known in all European countries, the commercialisation of aquaponics in Europe is in a very early phase (Thorarinsdottir et al., 2015). Aquaponics systems have been built all over Europe, but they are still mostly very small pilot units or they are used for research or training. A few entrepreneurs have started production at rather small scales of a few hundred square meters and only a handful of companies have reached the scale of a thousand square meters. Commercial systems of this size cannot yet compete with the large aquaculture and hydroponic production systems. At present the successful aquaponics ventures rely also on additional revenue streams, from selling equipment, design and build services, providing training, education or experience tourism. One reason for this is under developed market for aquaponics products and its unique advantages over regular agricultural products. There is no doubt that interest in aquaponics is growing and many entrepreneurs are planning to build systems for commercial production. In many cases the focus is on urban food production, with a number focusing on rooftop farming in cities. However, there are also a number of companies that are developing large scale decoupled aquaponics systems where the fish provide nutrients to the growers of vegetables or algae but the water is not returned to the fish. There are also other systems that combine fish production with regular farming practices.

There is an urgent need for increased support for the development of aquaponics technology into commercialisation and optimizing production. These systems should function also as demonstration systems to encourage the spread of this technology into the existing value chains. The novelty of the production method is attracting people´s interest in general, but at the same time the novelty together with the complexity and multidisciplinary issues is also one of the main market barriers to attract investors. There are still several risks –technical, financial as well as marketing – that have to be resolved. These include, for example, consumer acceptance and standardisation / labelling of

aquaponics produce according to sustainability and/or organic standards (Miličić et al., 2017).

## 3. Urban aquaponics – promotion of aquaponics as social enterprise

*Urban aquaponics can provide fresh healthy local aquatic protein and vegetables particularly to niche markets in urban areas where customers will pay a premium for these freshly produced products. Urban aquaponics also has the potential to reskill and educate community groups and to rehabilitate individuals with key skills and experience. Urban aquaponics as part of urban agriculture can also provide young people the experience of growing food and a better realisation of food production, its needs and consequences. Urban aquaponics should be promoted and encouraged through urban planning frameworks and incentives.*

It is estimated that about 54,6 % of the world's population today live in cities (UN). By 2050, this could rise to 66%. According to the UN (United Nations), the world's population is expected to reach 9.6 billion inhabitants by 2050, which means that 6.3 billion people will live in cities (UN). This urban population expansion requires enormous amounts of food to be transported from country to city, with all its environmental effects, which is part of the reason for the great and increasing interest in growing food in our cities. Whilst we cannot grow all our food in urban areas, it is possible to grow some foods locally, which helps to reduce food miles and thus $CO_2$ and ecological footprints, whilst at the same time increasing food security and health and wellbeing of local people. Urban aquaponics is unique as it can grow two types of food within an integrated system and these can be located anywhere where there is secure, flat, unoccupied space such as on rooftops, in courtyards, on vacant lots and yards, sheds, underground tunnels, warehouses, shipping containers etc. The minimum requirements are power for lighting heating and pumping, lighting, (natural and/or artificial), a clean water supply, and a connection to water drains and waste services.

Urban aquaponics has the potential to provide fresh, local food of known provenance to local markets and restaurants as well providing local jobs. By providing for niche markets, where premium prices are paid for fresh, wholesome locally produced food, urban aquaponics enterprises could be run at smaller scales. A number of successful aquaponic focused urban social enterprises show that aquaponics can provide a means for education and rehabilitation in the community and this side of urban aquaponics should be

encouraged. In the developing world urban aquaponics can provide a way for urban families to feed themselves as well as creating an income. There is a need to establish demonstration aquaponics systems in urban areas in order to expose people and especially the younger generation to this modern method of food production.

## 4. Developing world aquaponics and refugees

*Aquaponics has the ability to provide healthy nutritious food for agricultural communities worldwide that may need to leave the land due to the diminution in soil quality and lack of water. Knowledge transfer is essential to disseminate this methodology. In refugee centres, aquaponics can provide local food and experience and new knowledge for refugees. Suitable pilot areas should be identified in developing countries and in refugee centres to enable local food production and knowledge transfer. Following these pilots, aquaponic systems can be expanded to help greater numbers of people to stay on the land and produce food for their families and to generate income.*

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Aquaponics has the ability to provide highly valuable aquatic protein and vegetables within the same system. This function is unique in farming and the FAO (Food and Agricultural Organisation of the United Nations) has recognised this in their publication on *'Small scale aquaponic food production'* (FAO, 2014). We suggest that many people have and are leaving the land in rural and village areas in developing world countries because of land degradation brought about by drought and water scarcity, (perhaps exacerbated by climate change) and non-sustainable land management practices, which has reduced soil and land quality for growing, with little or no supplies of water. Aquaponics, which usually does not use soils, minimises water use, grows both fish and vegetables using the same water. Small scale farming units could keep people in their local communities where they want to stay, providing food for themselves as well as providing fish and other vegetable crops for sale. Developing world aquaponics should be encouraged with the assistance of developed world institutions and governments to set up pilot aquaponic projects. Following the experience and lessons learnt, aquaponic systems and training can be spread and develop over time to meet the needs of local people. As refugees and refugee camps grow, there is a great and increasing need to provide education and knowhow to these people for the future and to help them be productive in the time they are in refugee camps and in the future. It is a tragedy that refugee camps are mostly generally bleak areas without much vegetation and greenery, although there are cases where refugees have started their own vegetable plots

to grow food for themselves and for the market. Aquaponics can provide food and occupation for refugees and significant knowledge and experience which they can use when they leave the camps.

## 5. Aquaponics policy and legislation

*The lack of specific EU wide aquaponics legislation and planning guidance impedes commercialisation and entrepreneurship. A coordinated EU legislative and planning response is required. Compliance with clear statutes directly aimed at aquaponics and aquaponics produce will increase clarity for farmers and promote aquaponics to funders as well as consumers, with a win, win, win outcome.*

Aquaponics is a unique form of farming as it produces both aquatic and vegetal products in the same system, using the same water. Because aquaponics has its feet in the two camps of aquaculture as well as agriculture, it does not fall into only one legislative or policy area (Joly et al., 2015). This situation was possibly one reason why there is no coordinated EU wide policy and legislative framework and thus generally each EU state has its own policies when it comes to aquaponics. The United Kingdom has, however, at least recognised aquaponics as a form of production, as it requires producers to register using the form '*Register a fishery, cropping water or aquaponic system'*. In most cases commercial companies have set up their businesses using legislation that controls both fish farming in RAS (Recirculating Aquaculture Systems), and hydroponics cultivation. When processing of fish and vegetables occurs, the aquaponics producer normally follows the food hygiene and food safety legislation of each country, including its animal welfare rules. But this situation is complicated by the fact that most aquaponic projects embed a host of variable and complex attributes which may include characteristics such: rooftop or underground production, peri-urban, urban or rural production, staff that may include community based workers as well as others, and production for own use by restaurants and school canteens.

The background complexity of the legal and planning framework of many projects is thus known to impede entrepreneurship and has led to the abandonment of projects. However, as a result of the FA1305 COST Action a defined nomenclature has been established in Palm et all. 2018, allowing legislators and decision makers to set a firm regulatory framework. As

it is comprehensive this includes all scales and types of aquaponics including biotechnology and farming. The significant progress made by the EU Aquaponics hub and its position as a voice for aquaponics in the EU led to a significant meeting with the representatives of the EC Directorates-General for aquaculture (DC MARE), agriculture (DC AGRI) and research and development (DC RTD). The lack of dedicated aquaponics legislation and policy is seen as a bottleneck and a key priority for future aquaponics expansion. The meeting recognized the lack of dedicated aquaponics legislation and policy as a bottleneck and a key priority for future aquaponics expansion.

## 6. Aquaponics and education

*A future aquaponics industry will require trained practitioners to provide effective and sustainable food production. This is especially the case while combining regular agriculture practices or urban agriculture with aquaponics where the rise of new professionals, 'the aquaponic farmer', can be predicted. Aquaponics courses that already exist and/or are in the pipeline need to be encouraged and implemented. Fish management students should be trained in RAS and aquaponics to prepare a knowledgeable and experienced work force in aquaponics. Aquaponics is also interesting, and an effective and fun way to teach school children STEM and environmental subjects as well as animal husbandry and vegetable farming and thus aquaponics should be encouraged in schools.*

The European Commission notes that *'only 5.6% of all European farms are run by farmers younger than 35 while more than 31% of all farmers are older than 65. These figures raise concerns about the future competitiveness of European agriculture and guaranteed food production in the coming decades'* (EC, 2017). However, the online Brussels based weekly newspaper 'Politico', notes from a survey that was undertaken on whether technology was needed to save farming, that 70% of respondents said *'**yes** and that Europe must lead*' (Politico). Surveys also show that education in farming for young farmers is increasing and that 'improving the educational status of farmers and providing access to professional training remains thus a priority for policies aimed at viable food production and the sustainable use of natural resources' (EC, 2017). Professional as well as vocational training in aquaponics should be thus one of the pillars that will ensure not only the success of

aquaponics but also provide one of the foundations for the agriculture of the future as part of the EU's aim to increase sustainable food production and socio-economic wellbeing.

'Aqu@teach: Innovative educational tools to promote learning among European students using aquaponics', is an Erasmus + project and a spin off the EU Aquaponics Hub, that aims to design and implement a multidisciplinary aquaponics curriculum, focusing on the development of entrepreneurial skills through the use of innovative and student-centred didactic methods. Further tertiary educational courses have been and are being developed by a number of universities, but this is complicated, as the institutions need experience in both aquaculture as well as horticulture, which some institutions may not have. Experience shows that students of all ages are generally very keen on aquaponics, even if they are not keen on farming in general. Aquaponics offers considerable opportunities due to its complexities to use its systems and methods to facilitate the teaching of STEM (Science, Technology, Engineering, Maths) subjects both at primary and secondary school levels. Children also learn about animal husbandry and aquaponics can also be used to learn about chemistry, biology, horticulture, environment etc.



## 7. Aquaponics health and safety including fish welfare

*The increase in the number of aquaponic systems and increased public interest in aquaponics will necessitate a greater need to monitor fish and plant health, in order to minimise risks in non-infectious as well as infectious diseases which can result from problems in welfare and biosecurity. Losses in fish due to health and disease and any reporting of poor management practices and quality in produce, which could in a worst-case scenario affect human health, can lead to serious economic and reputational vulnerability for the aquaponics industry. Biosecurity measures and good farming practice are thus needed and need to be promoted to protect human health and consumer confidence as well as sustainable production in aquaponics. On the other hand, aquaponics production may have positive effects for the fish and improve animal welfare.*

Good practice and biosecurity in fish keeping and plant production are well known in both the RAS and horticultural fields, but these need to be formulated especially to cover the unique complexities in aquaponics, i.e. in the production of both fish and plants using the same water. For example, the application of UV-light for water sterilization of effluent water is not suitable as it reduces the beneficial effects of the RAS process water for plant growth.

Of particular concern is the treatment of fish inside a working aquaponics system to eradicate diseases or parasites. Some antimicrobial/antiparasitical agents or disinfectants that can be used for either prevention or treatment of diseases can be harmful to the microorganisms in the biofilter as well as the plants, and many chemicals and metals can also be absorbed and accumulated by the plants, restricting their use for consumption. Furthermore, the use of antimicrobial/antiparasitical agents or disinfectants may not be an option for prevention or prophylaxis on the fish production side of aquaponics, because these agents may be absorbed by the plants, thus causing periods when the plants cannot be sold and thus supply and marketing problems. It is thus important to clearly define specific preventive methods, using a combination of appropriate systems management and fish nutrition to avoid any form of direct chemical treatment. Natural bioactives in aquafeed (antioxidants, antiparasitic, immune enhancers etc.), with demonstrated benefits in fish behaviour and health (Rodríguez Lozano et al., 2017; Torrecillas et al., 2018), can also positively affect plant growth and thus strengthen the entire system performance. It is, however, important to further investigate the potential of adjusted feed formulas for its use in future aquaponics.

All farmed fish (along with along with other vertebrate species) are protected by the Council Directive 98/58/EC and, by the international standards of the World Organisation for Animal Health (OIE) on animal welfare, and by EFSA recommendations on slaughter (EC Directorate Health and Food Safety, 2017). All these require farmed fish, like other production animals, to be kept in an environment that provides good welfare for the entire lifespan, and for them to be slaughtered in an appropriate and accepted way. Aquaponics needs to follow these protocols but it has still to find its own niche in the 'sustainable', 'organic', 'eco-friendly', 'naturally farmed' world of marketing. New evidence suggests that the aquaponics itself has positive welfare consequences for the fish inside these systems (Baßmann et al. 2018). We have a strong conviction that aquaponics will meet the highest standards in fish welfare and in plant production so that i) there is high safety for consumers, ii) produce is known to be of a consistently high quality, and iii) fish welfare is also perceived by the public to be a high priority.

Whilst there is considerable knowledge and good practice guidance both in fish husbandry and in horticulture, there is no particular guidance aimed at the aquaponics farmer and entrepreneur. However, there is growing evidence of the beneficial effects of fish on plants as well as growing evidence pointing to the benefits that plants have on fish in RAS aquaponics systems. Causes of these effects either may be on the plant side, which could affect allelopathic substances released directly from the plants into the process water (Yavuzcan Yildiz et al., 2017), or on the microbes of the rearing systems. The microbiome, often subject to dynamic changes, is obviously unique in aquaponic systems, especially that of the rhizosphere (Schmautz et al., 2017). This area of science, needs further research and research funding and could be one of the unique attributes of aquaponics, which can be lauded, where plants help to provide a better rearing environment compared to traditional RAS systems.

As aquaponics advances and more aquaponics produce is sold there is an evident need for hygiene and welfare guidelines specifically designed for aquaponics in the EU, although these would be relevant anywhere in the world. These guidelines / health and wellbeing standards would help to create a recognised level of quality that can be upheld by a new aquaponics mark of quality. This mark/logo will denote that the production of the aquaponically produced food has been produced according to high quality and welfare standards.



## 8. Initiating the EU Aquaponics Association

*COST Action FA1305 created the Association of Commercial Aquaponic Companies (ACAC) to represent aquaponic SMEs across the EU. After bringing together the most important players in aquaponics within the EU, and on the completion of the Action, the time is right to initiate a EU centric aquaponics organisation which can promote aquaponics and aquaponics technology in the EU and assist in knowledge transfer and the promotion of high production and produce standards in EU aquaponics. We suggest a new EU Aquaponics Association (EUAA) that will form part of a worldwide aquaponics association with links to the 'Aquaponics Association' in the USA and new associations, which will be encouraged in South America, Africa, the Middle East and Asia.*

The EU Aquaponics Hub has set up an Association of Commercial Aquaponic Companies (ACAC) as a first step in providing a forum for discussion, and an organization, which

represents the interests of commercial aquaponics enterprise across the EU. As the EU Aquaponics Hub was limited to four years, it was always the aim to create a future, larger EU Aquaponics Association in which ACAC would form one key part, in order to maintain and grow research and enterprise in aquaponics in the EU and to provide a collaborative body out of it's existing membership. This body aims to provide an overarching forum for all aspects of EU aquaponics, including ACAC, and to and generate innovation in aquaponic research, science and education. This new organisation should be called the EU Aquaponics Association, with the already secured website "euaquaponicsassociation.com", and with the following objectives to:

- Organize and maintain the EU Aquaponics Association in order to promote aquaponics and aquaponics technology in the EU and globally;
- Encourage and promote the benefits of aquaponically grown food without exaggeration or 'hype';
- Encourage and promote aquaponic food quality, through good science and practice and the setting up and promotion of aquaponics standards;
- Build a platform to enable an exchange between aquaponists, aquaculturists, horticulturists, farmers, and other players to develop aquaponics in the EU;
- Support aquaponics farmers and entrepreneurs inside ACAC (the Association of Commercial Aquaponic Companies), which is a part of the EU Aquaponics Association;
- Encourage and promote the creation of aquaponic growers and systems of all sizes;
- Encourage and promote the education of consumers and food safety officials on the inherent benefits of aquaponically grown food;
- Encourage and promote the use of aquaponic technology as a viable choice for sustainable organic food production;
- Encourage and promote aquaponics in education, as a tool in STEM subjects at primary and secondary school levels; and
- Encourage and promote aquaponics education at University and college levels.

The new EU Aquaponics Association (EUAA) sees itself as an important part or chapter of a worldwide aquaponics association with links to the 'Aquaponics Association' in the USA and new associations, which will be encouraged in South America, Africa, the Middle East and

Asia. As a key remit of the EUAA is to promote and uphold aquaponics standards, a recognisable stamp/badge of authority has been devised. The next steps of the EUAA will be to set up its constitution and bylaws, to create a website and membership, to vote on the adoption of the objects and bylaws, to adopt the logo for the association and the badge of quality and, in a year's time, to vote in a new Steering Group.

**Concluding Statement of COST Action FA1305 and Opening Statement for the EU Aquaponics Association**

COST Action FA1305 has achieved its goal over it's life span of four years in bringing together most of the key researchers, entrepreneurs and institutions that are working in aquaponics in the EU. It has developed a vision to transfer the newly formed EU aquaponics community into the EU Aquaponics Association (EUAA). We see the following measures as necessary to allow aquaponics to develop as a part state-of-the-art agricultural practice in the EU in future.

The Action has facilitated a broad scope of research results that are available not only for other researchers, but for entrepreneurs and practitioners to help in their attempts to develop viable aquaponic business models. However, the research institutions still need substantial support to increase and provide a deeper understanding e.g. of nutrient pathways, the best suitable fish and plant species, disease and pest control, micobiological backgrounds etc.

It is important that the descendant EU Aquaponics Association (EUAA) should be developed over the next months and negotiations should be undertaken to investigate the potential to tie in meetings and conferences with the European Association of Aquaculture (EAS) and its annual meetings and conferences.

The EU Aquaponics Association should support the relevant EU bodies to work towards a harmonised aquaponics legislation throughout the different member states.

Apart from encouraging new aquaponic entrepreneurs and start up companies there is the opportunity to utilize existing value chains such as farmers and other fish and crop producers in order to provide a broader range of aquaponics produce and producers in the EU in future.

The EU should support the development of demonstration aquaponics units within and outside the EU (e.g. in developing countries and refugee camps) in order to educate the younger generation in this agricultural system of the future.

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