UNIVERSITÀ DEGLI STUDI DI PADOVA

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in Italian Food and Wine

Investigating stakeholders and consumers' perception about the use of insect meal in the aquaculture sector

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Abstract

Aquaculture is nowadays an important source of food, contributing for almost 50% of the word's fish production and is expected to continue growing in the next years. On the other hand, this sector faces some challenges, including the aquafeed currently used, which are mainly based on fish meal, fish oil and soybean meal, which have a production system not sustainable in the long term, making it necessary to research and develop alternative solutions. Insects could be a valid substitute to conventional feeds, as they meet animals' dietary requirements, can be grown on organic side streams and have environmental benefits. On the other hand, their use and consumption in Western societies are negatively perceived, creating barriers for their production and trade.

This thesis aims to explore stakeholders and consumers' perceptions regarding the use of insects as feed for aquaculture fish, investigating the potential and limitations of this product. Individual interviews and focus groups were used as methods to collect information, conducted in collaboration with the University of Parma and Pisa, within the InsectFish project, which objective is to investigate the quality, nutrition profile, sensory evaluation, and consumer perception of fish fed with insect meal compared to a traditional fish.

The literature review includes the exploration of the use of insects as food and the related regulatory framework, the characteristics of aquaculture and consumer perceptions of insect consumption. The results of the interviews and focus groups highlighted some recurrent topics among participants, first of all the key role of the price during fish purchase, the lack of knowledge and interest for the feeds and the importance of communication to inform about this topic. On the other hand, the low number of participants and their involvement in the agri-food sector are some of the limits of this study, which do not allow to have representative results.

Acknowledgements

Writing the thesis in English is less difficult than writing acknowledgements in English, but I'll try.

My first thanks go to my parents and my brother, who have been my reference of this university journey. It is becoming less and less clear what I want to do when I grow up, but nevertheless they continue to motivate and support me.

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This master's degree brought me also to Dijon where, in addition to eating a dangerous amount of cheese and croissants, I also met some crazy and cool new friends who gave further meaning to my Erasmus.

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These two years went by too fast, but they were the best experience.

Table of Contents

Chapter 1 - Introduction

Aquaculture is nowadays an important source of food, its production constantly increased since 1990s and is expected to continue growing in the next years. Seafood has a central role in the human diet because they are rich in proteins, bioavailable micronutrients and essential omega-3 fatty acids, but there are some sustainability, efficiency and social challenges relate to their production (FAO, 2022b). Among the others issue, the aquafeed currently used in aquaculture, mainly based on fish meal, fish oil and soybean meal, have a production system which is not sustainable in the long term (Tschirner & Kloas, 2017), making necessary to research and develop alternative solutions.

Insects could be a valid substitute to those raw materials as aquafeed ingredients, as they meet animals' dietary requirements, can be grown on organic side streams and have environmental benefits such as lower land consumption and water requirement compared to crops (Sánchez-Muros et al., 2014). On the other hand, their use and consumption in Western societies are negatively perceived, creating barriers for their production and trade.

This thesis aims to explore stakeholders and consumers' perceptions of the use of insects as feed for aquaculture fish, investigating the potential and limitations of this product at multiple stages of the supply chain and using individual interviews and focus groups as methods to collect information by participants.
The research was conducted in collaboration with the University of Parma and Pisa, within the InsectFish project[1], which objective is to investigate the quality, nutrition profile, sensory evaluation, and consumer perception of fish fed with insect meal compared to a traditional fish.

The literature review includes the exploration of the use of insects as food and the related regulatory framework, the characteristics of aquaculture and consumer perceptions of insect consumption. The research work includes interviews and focus groups, quantitative data and qualitative explanations and discussion of results; conclusions summarize the content of the research, highlighting its limitations and potential and proposing future studies that could be conducted to further develop the topic.

[1] https://insectfish.unipr.it/

Chapter 2 - Literature review

2.1 The use of insects as feed

With the growing world population, the demand for food is rapidly increasing, requiring the identification of alternative feed and food sources, without overexploiting natural limited resources and causing negative environmental effects.

Nowadays, the livestock feed production costs around 60-75% of the total budget for the livestock industry (Dewi Apri & Komalasari, 2020), it uses 80% of the agricultural land worldwide (Sogari et al., 2022b) and accounts for a high percentage of greenhouse gas (GHG) emissions (Mustapa & Kallas, 2023).

Soybean and fish meals are the two of the most used protein sources in aquafeed (Sánchez-Muros et al., 2014). The first has several nutritive benefits such as high quality and quantity of proteins and high digestibility (Sánchez-Muros et al., 2014); on the other hand, its production causes biodiversity loss and deforestation, it has high water consumption and, as other vegetable feedstuff, contains antinutritional factors for fish (Sogari et al., 2023b).

Fish meal is obtained from the fishery and is considered the best protein source for aquafeed because of its protein and amino composition (Mulazzani et al., 2023). In fact, about 70% of all fishmeal is used in aquafeed, while 22% is in pig feeds and 5% for poultry (Sogari et al., 2023b). On the other hand, also fishmeal cause important environmental issues such as depletion, eutrophication, and damage to water bodies (Sogari et al., 2023b) and since fishmeal depends on the catch, its production could vary in quantity and quality (Sánchez-Muros et al., 2014).

In this scenario, insects represent an important future sustainable raw material (Sogari et al., 2019), as they can be used to substitute or reduce other sources (Dewi Apri & Komalasari, 2020) as those aforementioned.

2.1.1 Environmental impact

Several insects have been tested as animal feeds and ingredients, and those most suitable for livestock seem to be the larvae of black soldier fly (*Hermetia illucens*), housefly (*Musca domestica*), and yellow mealworm (*Tenebrio molitor*) (Sogari et al., 2019).

Some insect species, like the ones mentioned, can be reared on organic side streams such as manure, pig slurry, compost and biowaste (FAO, 2013), transforming those substrates, which are unsuitable as food or feed ingredient for livestock, into high-quality protein feed, and potentially replacing other more expensive compound feed ingredient, as fish meal (Dicke, 2018).

This approach of using insects for biodegradation and biotransformation not only reduces environmental contamination but contributes also to the circular economy principle (Sogari et al., 2022b), giving insects new application possibilities and increasing their value (Menozzi et al., 2021) (Figure 1).

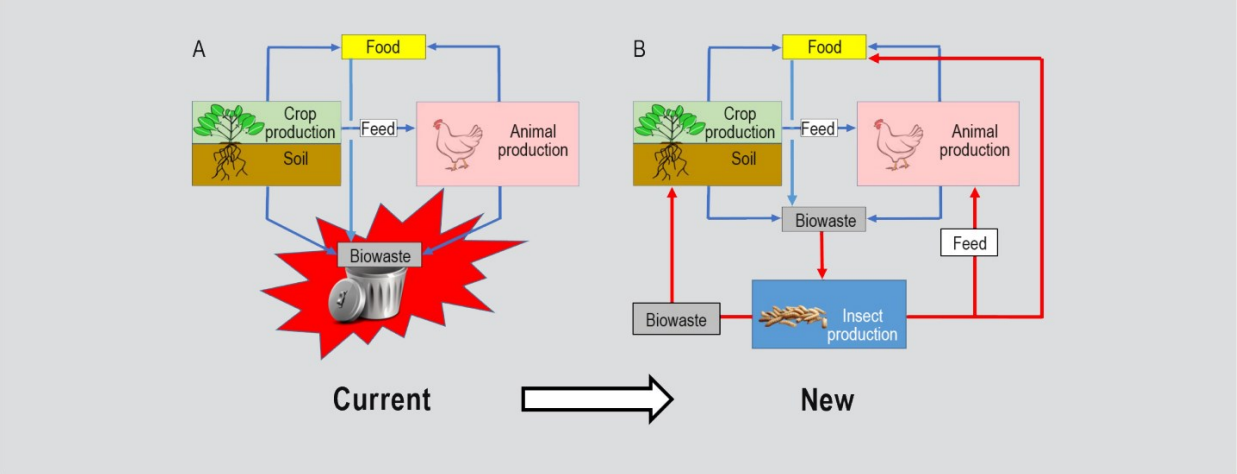


Figure 1 Circular economy models of insects for feed. (A) Current situation; (B) future situation, where red arrows indicate new biomass streams. Source: Dicke, 2018.

Moreover, insects are poikilotherms, so they don't need to use metabolic energy to maintain the body temperature constant as homeotherms do, therefore being able to invest more energy in growth, having a higher feed-conversion efficiency (van Broekhoven et al., 2015). This last define animal's capacity to convert feed into body mass, represented as kg of feed per kg of weight gain (FAO, 2013), meaning that insects need less amount of feed for the production of 1 kg of biomass (Rumpold & Schlüter, 2013) compared to other animals.

From an environmental perspective, insect rearing presents other advantages: it is usually performed in warehouses, which doesn't need large area or land utilization; it has a lower

greenhouse gas and ammonia emission (Sogari et al., 2022b) and less water consumption compared to traditional livestock or crops (Mustapa & Kallas, 2023).

2.1.2 Nutritional composition

Insect species that are potential sources of feed have good nutritional values and meet animals dietary requirements (Dicke, 2018). The protein content is one of the most important criteria for feed sources and most insect species have high protein quality and quantity (Sánchez-Muros et al., 2014). At the same time, insect protein content varies according to the species, the feed used (e.g. vegetables, grains or waste) and the insect stage (adults usually have higher protein content than instars) (FAO, 2013). Insects also have good amino acid composition, being rich in essential ones, different from vegetable protein sources which are usually lacking lysine, methionine and leucine (Sánchez-Muros et al., 2014).

The lipid fraction of insects has high levels of polyunsaturated fatty acids, as the essential linoleic and α-linolenic acids (FAO, 2013), which can be applied in animal feeding to provide energy and valuable fatty acids (Menozzi et al., 2021). As for proteins, the quantity and quality of lipids in insects change with the developmental stages and can be modified during the insect growth (Sánchez-Muros et al., 2014) being influenced by the substrate on which insects feed. On the other hand, the presence of unsaturated fatty acids can cause rapid oxidation of insect products during processing, leading to a quick rancidity (FAO, 2013). Insects are also rich in micronutrients such as zinc, iron and vitamins, which are important for animal health and development (Dicke, 2018), and contain significant amounts of fibre. The most common form of fibre in insects is chitin, which is the main component of the exoskeleton and has been associated with a positive effect on immune systems, but also with some allergic reactions in humans (FAO, 2013).

Insects nutritional quality, but also growth rate and body composition can be modified by diet, offering the opportunity to better meet consumer needs (van Broekhoven et al., 2015).

2.1.3 Obstacles to insects use

There are some potential obstacles to the diffusion and use of insects for feed and food. First of all, at the moment the costs of insect as raw materials are still higher than those of other ones, limiting the possibility for producers to access them (Lambert et al., 2021). Another aspect to take into consideration is the rate of conventional protein sources that could be replaced by insect products (Sogari et al., 2023b), and whether the animal performance justifies

the higher price of insect products. Insects can also be vectors of contaminants such as heavy metals, pesticides and bacteria, and antibiotic-resistant genes and can generate aversive human attitudes, which potentially represents an obstacle for the sector (Lambert et al., 2021).

2.2 Legal framework

Insects represent a traditional food category in many areas of the world such as Africa, Asia or Latin America, but their consumption is still a recent and new culinary phenomenon in Western Countries (Lotta, 2019). However, the interest in insect-based feed and food has increased during the last few years, driven by the potential benefits that these products could offer from an environmental, economic and nutritional point of view (Mancini et al., 2022). This situation poses important questions regarding the risks derived from insect production, processing and consumption (Mancini et al., 2022). It has attracted the attention of legislators, especially in Europe where there was legal uncertainty. In fact their regulatory classification has been quite controversial (Lotta, 2019) for insects both as food and feed. Moreover, Countries outside Europe are adopting different legislative solutions and legal systems, that could represent a potential obstacle to the promotion and commercialization of insect-based products (Sogari et al., 2023a).

2.2.1 Europe

The evolution of the regulatory framework in Europe has been different regarding insects as feed or food. The first challenge that insects as feed had to face was the TSE[2] Regulation (Reg. EC No. 999/2001) adopted in 2001 (Sogari et al., 2023a) after the issue of Bovine Spongiform Encephalopathy (BSE) which had posed a serious threat to consumer safety and health (Sogari et al., 2019). Because of this problem, the use of Processed Animal Proteins (PAPs) as feed for farmed animals was banned, causing a significant slowdown in the development of this market in the EU (Sogari et al., 2023a).

Regulation (EU) No 2017/893 caused an important change in this scenario, it allowed the feeding of non-ruminant processed animal protein and in particular the feeding of seven insect species to aquaculture animals: black soldier fly (*Hermetia illucens*); common housefly (*Musca domestica*); yellow mealworm (*Tenebrio molitor*); lesser mealworm (*Alphitobius diaperinus*);

[2] EFSA (2023, November 28). Transmissible spongiform encephalopathies (TSEs). https://www.efsa.europa.eu/en/topics/topic/transmissible-spongiform-encephalopathies-tses

house cricket (*Acheta domesticus*); banded cricket (*Gryllodes sigillatus*); and field cricket (*Gryllus assimilis*) (Lähteenmäki-Uutela et al., 2021). Moreover, in the same year Regulation (EU) No 2017/1017 authorized live terrestrial invertebrates and dead terrestrial invertebrates used, with or without treatment as feed materials (Sogari et al., 2019).

In 2021, there was another turning point with the entry into force of Regulation (EU) No 2021/1372, which has allowed the use of insect PAPs also in poultry and pig feeding (Sogari et al., 2022a), and Regulation (EU) No 2021/1925, which authorises the use of silkworm (*Bombyx mori*) expanding the list from seven to eight authorised species (IPIFF, n.d) (Figure 2).

As for insects for human consumption, in Europe they are considered novel foods (NFs), meaning foods not consumed by a significant amount of people in a country, region or area in the EU before 15 May 1997 (European Commission, n.d.).

In 2015, the European Food Safety Authority (EFSA) published its first scientific opinion about farmed insects as feed and food, focusing on the risks associated with their consumption and production (Mancini et al., 2022). According to EFSA, chemical, biological and environmental hazards related to the consumption of insects depend on many aspects as the type of insect species, substrate used, production methods or stage of harvesting (Committee, 2015), concluding that as long as insects are fed with allowed feed materials, the possible occurrence of microbiological hazards is no greater to other non-processed sources of protein of animal origin (Mancini et al., 2022). This scientific opinion helped the development of a new European regulation on insects as novel foods, Regulation (EU) No 2015/2283, which entered into force 1 January 2018 (Sogari et al., 2023a). Under this new Regulation, insect food products may only be commercialized if authorized by the European Commission (EC) (Mancini et al., 2022) and after a safety assessment by the European Food Safety Authority (EFSA) (Lähteenmäki-Uutela et al., 2021). Moreover, it specifies the insects that can be used as novel foods (Mancini et al., 2022) and the mandatory labelling indications (e.g., allergen labelling, among others) (Sogari et al., 2022a).

In June 2021, the EU Commission Implementing Regulation (EU) No 2021/882 approved the marketing of dried yellow mealworm (*Tenebrio molitor*) (Sogari et al., 2023a), in November 2021 dried and frozen migratory locust (*Locusta migratoria*) were allowed and in February 2022 it was the chance of dried, ground and frozen house cricket (*Acheta domesticus*). More recently EFSA authorized also frozen and freeze-dried formulations of lesser mealworm (*Alphitobius diaperinus)* as Novel Food. Besides these, new applications for food products

from other species have been submitted and are now pending authorization as the honey bee (*Apis mellifera*), black soldier fly (*Hermetia illucens*), banded cricket (*Gryllodes sigillatus*) (Lähteenmäki-Uutela et al., 2021).

In Europe, the production and commercialization of these products are still at the beginning, probably also slowed down by bureaucracy and restrictive regulations, but these procedures also enable the governments to ensure safety and traceability to consumers (Mancini et al., 2022).

Insects as feed - **Regulation (EU) No 68/2013** on the Catalogue of feed materials and in accordance **with Regulation (EC) No 999/2001 and Regulation (EC) No 1069/2009**	Ruminant animals	Aquaculture	Poultry	Pigs	Pets	Fur and other animals (e.g. zoo)	Technical uses(e.g. cosmetic industry, bio-based fuels, production of other bio-based materials such as bioplastics)
Insect proteins (under entry 9.4.1. 'Processed animal protein')	✗	✓ **	✓ **	✓ **	✓	✓	✓
Insect fats (under entry 9.2.1 'animal fat')	✓	✓	✓	✓	✓	✓	✓
Whole insects (untreated) (under entry 9.16.2. 'terrestrial invertebrates, dead')	✗	✗	✗	✗	✓ ***	✓ ***	✓
Whole insects (treated- e.g. Freeze drying) (under entry 9.16.2.'terrestrial invertebrates, dead')	✗	✗	✗	✗	✓ ***	✓ ***	✓
Live insects (under entry 9.16.1 'terrestrial invertebrates, live')	✗	✓ *	✓ *	✓ *	✓ ***	✓ ***	✓
Hydrolysed insect proteins (under entry 9.6.1. 'Hydrolysed animal proteins')	✓	✓	✓	✓	✓	✓	✓

*if authorised by the national competent authority of the Member State where the product is being commercialised
** Limited to Black Soldier Fly (*Hermetia illucens*), Common Housefly (*Musca domestica*), Yellow Mealworm (*Tenebrio molitor*), Lesser Mealworm (*Alphitobius diaperinus*), House cricket (*Acheta domesticus*), Banded cricket (*Gryllodes sigillatus*), Field Cricket (*Gryllus assimilis*) and Silkworm (*Bombyx mori*).
*** if authorised by the national competent authority of the Member State where the product is being commercialised, under the specific conditions applicable to processed pet food (in case the product is intended for use as processed pet food)

Restriction to insect species (insect PAPs for aqua feed)- Regulation (EU) **No 142/2011; Annex X Chapter 2 Section 1, A.(2).** - Insect PAPs must be produced in **processing plants approved** in accordance with Article 24(1)(a) of Regulation (EC) No 1069/2009 and **dedicated exclusively** to the production of products derived from farmed insects **'Regulation (EC) No 999/2001; annex IV, chapter IV, Section F, 1 (a).** - Insect PAPs must be produced according to **processing methods 1 to 5** or **processing method 7 (Regulation (EU) No 142/2011, Annex X, Chapter II, Section 1, B (2).**
No restriction as to the insect species (provided that these are not pathogenic to humans and animals)

Figure 2 EU regulatory possibilities for using insect products as feed.
Source: IPIFF 2022 (p. 25), https://ipiff.org/wp-content/uploads/2019/12/IPIFF-Guide-on-Good-Hygiene-Practices.pdf

2.2.2 North America: United States and Canada

Insects and insect-based foods are becoming more widespread in the US, with products such as protein bars and snacks, but the regulatory framework is still not clear (Lotta, 2019).
The authority in charge of the stewardship of insect feed and food is the Federal Food and Drug Administration (FDA). It also collaborates with the Association of American Feed Control Officials (AAFCO), which is focused specifically on feed regulations and new feed ingredients (Sogari et al., 2019). In the United States, edible insects are considered food additives, they require scientific evidence of their safety (Lähteenmäki-Uutela et al., 2018), and the ones reared for human consumption have to follow good manufacturing practices (GMPs) (Lähteenmäki-Uutela et al., 2021). For insects as feed, today only black soldier fly (*Hermetia illucens*), in the form of dried whole larvae and meal, is allowed in aquaculture for salmonoids such as salmon, trout and char (Lähteenmäki-Uutela et al., 2021). On the other hand, insects are also considered pests, whose presence may cause contamination, food adulteration and unfit for consumption (Lotta, 2019).

In Canada, insects are considered novel foods, meaning that are not ingredients with a history of safe consumption (Sogari et al., 2019) and for this reason they must be evaluated before they enter the market and notified to Health Canada (Lähteenmäki-Uutela et al., 2018).
Each registration proposal needs separate authorisation regarding the rearing condition, the insect species and the substrate used. In 2016 Canadian Food Inspection Agency authorised the use of dried whole black soldier fly larvae in broiler chicken feed, extending it then to farmed salmonoids such as salmon trout and arctic char and in 2018 also for tilapia and poultry (Lähteenmäki-Uutela et al., 2018).

2.2.3 Asia

Asian countries are historically used to insects, not only in consuming them as feed and food sources but also in other fields, such as medicine (Lähteenmäki-Uutela et al., 2021).
In China there are no specific laws for insect regulation, in fact authorisations have general applicability. In Japan, pre-market authorisation is not required, while novel additives do (Lähteenmäki-Uutela et al., 2021). North and South Korea have different approaches to insect feed: the first considers insects as animal-based protein and, for this reason, they are banned in animal feed; on the contrary, for South Korea, insects are historically part of the human diet and so they are allowed to be included in animal feed (Sogari et al., 2019).

Thailand is the biggest producer of cricket in the world, and it follows a specific Standard[3] for its farming, which is important for the export of the product to foreign markets such as the EU. This Standard defines the different aspects to comply with such as the feed to use, animal health or farm management, to assure quality and safety for the consumers. Thailand is working on insects as feed for fish aquaculture, to try to replace fishmeal which is not sustainable, but nowadays standards for insect feed are still lacking (Lähteenmäki-Uutela et al., 2021).

[3] Thai agricultural standard (2017). Good agricultural practices for cricket farm. Accessed 20th March 2024, from https://www.acfs.go.th/standard/download/eng/GAP_CRICKET_FARM-ENG.pdf

2.3 Aquaculture

Aquaculture is the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants (FAO, n.d). Its practise has constantly increased with an average rate of 6.7% per year over the period 1990–2020, decreasing the speed of growth but increasing world production in absolute terms over three decarruades (FAO, 2022b) (Figure 3). This trend is expected to intensify in the future due to population and income growth, change of consumers' preferences, advances in technology and health benefits associated with fish consumption (Forleo et al., 2019).

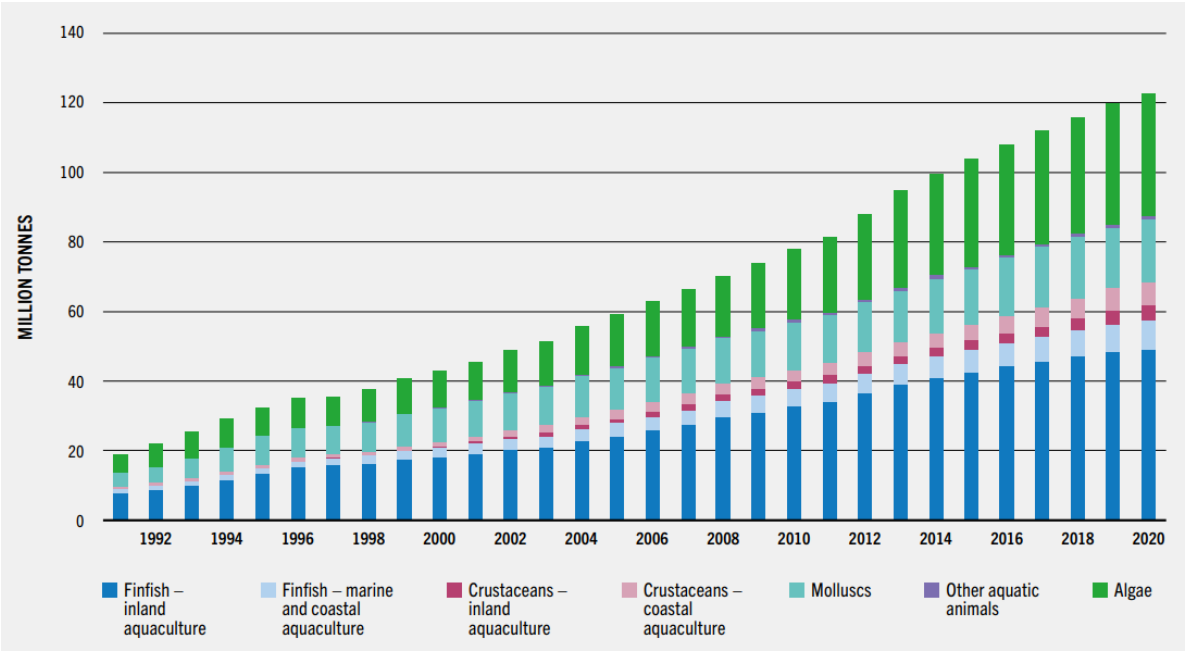


Figure 3 World aquaculture production, 1991–2020. Data exclude shells and pearls. Data expressed in live weight equivalent. Source: FAO, 2022b.

The production of farmed fish varies a lot across countries and regions. Asia is one of the major producers in this sector, particularly China, Vietnam and Bangladesh, whereas other countries such as Egypt and Chile are specialized in farming finfish species with sea cages, as Atlantic salmon (FAO, 2022b). In Europe, the five most important countries for aquaculture production are France, Greece, Italy, Spain and United Kingdom, accounting for 74% of the total EU aquaculture production by weight and 73% of the total EU aquaculture production value (Forleo et al., 2019). Although Italy is one of Europe largest finfish producers, it needs to import fish and fish products yearly to meet domestic demand, as the self-supply of fishing and aquaculture chain is the lowest among the animal food chains (around 38%) (Parisi et al., 2014). Italian aquaculture farms are traditionally small to medium size, often family-run and have a

good technology level both for land-based plants and sea cages (Barazi-Yeroulanos, 2010). They can be divided into three types of farming system: intensive farming (land-based and off-shore plants), semi-intensive farming (land-based farms), and extensive farming (land-based farms) (Parisi et al., 2014). Land based farms allow greater on-growing densities compared to sea-based cages, meaning greater productivity, but they imply a strict management of water flow and quality, addition of pure oxygen in the basins and control of animal welfare, stress levels and diseases (Barazi-Yeroulanos, 2010). The primary focus of aquaculture in Italy lies in the cultivation of shellfish, mainly mussels and clams, but there is also a large production of juveniles for the European seabass and gilthead seabream sector, which are mainly exported to Greece (Barazi-Yeroulanos, 2010), and rainbow trout, which is the most important freshwater species cultured in Italy.

2.3.1 Aquaculture products

Aquatic food products are rich in protein, essential fatty acids, vitamins and minerals and their consumption is also associated with health benefits such as prevention of heart-related diseases for some vulnerable groups (Subasinghe et al., 2009). In particular, they are high in omega-3 polyunsaturated fatty acids (PUFAs) and other healthful compounds such as vitamin D, selenium and iodine, and their protein have important biological functions such as cholesterol reductions and antihypertensive effects (Arshad et al., 2022).

However, aquatic products can accumulate potentially harmful substances derived from chemical, microbial and environmental origin, which are potentially harmful substances for the human health (Arshad et al., 2022). Contaminants such as toxic chemicals and heavy metals can be released in the environment and then be present in the fish, particularly in its fatty tissues, due to their lipophilic properties (Gómez et al., 2019). Moreover, aquatic products are quite perishable, being much more spoiled than other food groups, causing more easily economic losses. This is due to their intrinsic characteristics such as the high moisture content, protein profile, high level of PUFAs and several bacterial groups (Gómez et al., 2019).

Rainbow trout

Rainbow trout mainly inhabits fresh water, but can adapt to sea water through a gradual increase in salinity of its rearing water, making this fish suitable for farming (Webster & Lim, 2002). It has streamlined body shape, blue-green body colour with a characteristic reddish-pink band along the lateral line, and the head, back and sides presents small black spots (Parisi et

al., 2014). It grows rapidly and can tolerate wide range of water temperatures; its natural food comprehends aquatic and terrestrial invertebrates, small fish and terrestrial insects, and shrimps, which contains carotenoid pigments responsible for the orange-pink colour in the flesh under wild conditions (Parisi et al., 2014). In aquaculture trout can be reared to have pigmented (pink) or non-pigmented (white) flesh, depending on the diet (Webster & Lim, 2002). Feeding is the most expensive part of its production, covering 40–60% of the cost, and is made by compound pelleted and/or extruded diets including fish meal, fish oil and other ingredients (Parisi et al., 2014). In Italy rainbow trout is perceived as a "traditional" product (Roncarati & Melotti, 2007) and the most common farming method is monoculture. This fish is particularly appreciated by consumers because of its lean flesh and for the tenderness, juiciness, and flavour of the fillet (Parisi et al., 2014).

European sea bass

The European sea bass is the main commercial marine fish species reared in Europe, especially in the Mediterranean area by Greece, Turkey, Italy, Spain, Croatia, and Egypt (Webster & Lim, 2002). Its domestication is quite recent; it was the first non-salmonid marine species commercially cultured in Europe (Vandeputte et al., 2019). It has an elongated body, a rather high tail and is covered by large, regular scales; it has a dark grey colour on the back, grey-silver sides and white-silver or pale-yellow abdomen (Parisi et al., 2014). The sea bass reaches the commercial size in 18-24 months and is able to adapt to plant-based diets, which is an important feature to reduce the use of fishmeal and fish oil in fish feeds (Vandeputte et al., 2019). In Italy it is mainly marketed as a whole, fresh fish with an average size between 300 and 500 g. Moreover, the one caught in the wild has a premium price than the farm-raised one, because its quality is perceived as higher and there is relative scarcity of large-sized of it (Parisi et al., 2014).

Gilthead seabream

The gilthead seabream has an oval compressed body; it is silvery-grey coloured and has small eyes with a golden band between them, edged by two dark areas (Pavlidis & Mylonas, 2011). It is mainly carnivorous, eating shellfish including mussels and oysters, but accessorily herbivorous (Sola et al., 2007). In aquaculture it is fed with commercial diets containing 45-50% of protein and about 20% of lipids, both mainly coming from fishmeal and fish oil (Pavlidis & Mylonas, 2011). The gilthead seabream is the most intensively cultivated fish

species in the Mediterranean area with seabass and in Italy more than half of its total production comes from offshore facilities characterized by low to medium production capacities (Parisi et al., 2014). It usually takes 18 to 24 months to reach 400 g from hatched larvae and the average commercial size can go from 250 g to 1.5 kg (Pavlidis & Mylonas, 2011), even though nowadays some producers expand the on-growing period up to 40 months or more to harvest larger fish. This is due to some changes in the market, such as consumer's preferences, product diversification and higher prices, that shift the production to large-sized (>800 g) fish (Parisi et al., 2014).

2.3.2 Feeding in aquaculture fish

An adequate and well-balanced feeding of aquatic animals is important to obtain a healthy and high-quality product. Commercial aquafeeds are designed considering different factors: the species-specific nutritional requirements (Boyd, 2015) which depends also on the fish life of stage and the rearing system (Craig et al., 2017); the physiological and environmental factors and the husbandry factors such as feeding time, rate and frequency (Gómez et al., 2019). These aspects have an impact on the final quality of the farmed fish, such as the size and weight, the chemical composition or the characteristics of the flesh (Figure 4).

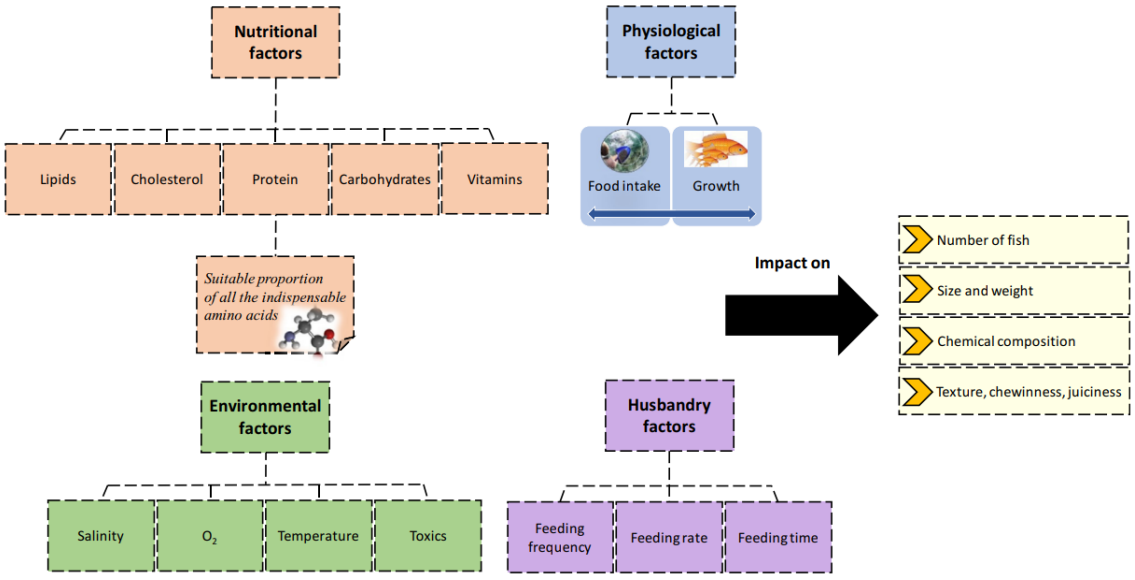


Figure 4 Factors to consider in aquaculture feeding. Source: Gomez et al., 2019

Aquafeeds usually include a wide range of ingredients such as fish meal, fish oil, vegetable oil, plant meals, vitamins, mineral supplements and others; then fish is produced as extruded or

pelleted form with different pellet diameter and length to suit various species and growth stages for which they are intended (Boyd, 2015).

In terms of quality and quantity of protein, the nutritive requirements of fish, in particular of carnivorous ones, are quite high (Gasco et al., 2016), ranging from 25% for some herbivorous or omnivorous species to 55% for certain carnivorous ones (Boyd, 2015), decreasing as the fish grows; protein requirements are also higher for marine species than freshwater fish (Henry et al., 2015). Protein is the most expensive component of fish feed, so it is necessary to determine the correct requirement for each species and life stage reared to avoid wastage (Craig et al., 2017).

Lipids make up about 7-15% of fish diets (Craig et al., 2017) and are included to provide energy and essential fatty acids. They usually come from vegetable oil, fish or other marine oil, or a combination of both sources (Boyd, 2015). Marine fish generally require the dietary inclusion of highly unsaturated fatty acids; freshwater fish polyunsaturated ones (PUFA) (Henry et al., 2015). Other nutritional factors relevant in fish feeds are carbohydrate (15-20%), minerals, and vitamins (Craig et al., 2017).

2.3.3 PROs and CONs of aquaculture

The aquaculture sector contributes almost 50% of world's fish production (FAO, 2013), playing an essential role in the seafood market by meeting the demand for fish that cannot be met with capture (Barroso et al., 2014). It is an important source of available protein in human diet, representing around 8-9% of the animal protein intake of humans (Boyd, 2015) and it produces higher biomass than wild seafood or beef (Gómez et al., 2019). The practice of aquaculture could alleviate the problem of overfishing of wild fish stock, which is not sustainable for the environment and the marine biodiversity where it seems that inland waters and oceans have almost been fished to their limit (Boyd, 2015). On the other hand, aquaculture faces different challenges, first of all regarding the feeds used, mainly fish meal, fish oil and soybean meal. The production systems of these feed components is critic from an environmental point of view (Tschirner & Kloas, 2017), and fishmeal prices are on the rise, making it less accessible for small farmers (FAO, 2013). In this perspective, future fish meal and oil availability could be a major bottleneck for continuing growth of the aquaculture industry (Boyd, 2015). There are also market challenges, as overproduction which saturated the market resulting in price reductions and consequently lower profit margins for the producers (Parisi et al., 2014).

In order to strengthen the competitiveness and long-term sustainability of the aquaculture sector, there are some strategies and innovative systems that can be considered, such as the adoption of certification system for responsible and sustainable aquaculture practices, the optimization and development of alternative feed sources or the attention to consumer concerns regarding ethics and animal welfare (Parisi et al., 2014). Another practice could be the land-based recirculating aquaculture systems (RAS) in combination with hydroponic systems, so called aquaponic systems, which optimised water use by continuous recycling, resulting in lower emissions and better feed utilisation (Tschirner & Kloas, 2017; Bordignon et al., 2024).

2.4 Consumers' perception and acceptability

Investigate stakeholder's perception and acceptance of edible insects is important to understand not only the future prospect of entomophagy (Mancini et al., 2019), but also the potential success of insect-based feeds and products (Sogari et al., 2022a).
In Western societies, differently from other areas in the world, the practice of entomophagy is not part of the culinary tradition, leading to unfamiliarity for insects consumption, that seems to be one of the reasons for the low acceptance of these products (Sogari et al., 2022a).

There are different factors that can affect the perception of food derived from insects and animals with fed insect-based diets. From a psychological perspective, food neophobia and disgust are the main influencing factors: the first is the aversion or the unwillingness of trying unfamiliar foods (La Barbera et al., 2018), while the disgust is linked to the instinct of protection from potentially contaminated or harmful substances that leads to avoid the ingestion of some foods (Egolf et al., 2019). Those two factors play an important role in consumers acceptance. In fact it has been shown a correlation between food neophobia and disgust and the rejection of insect-based food: the less the level of those feelings, the stronger the willingness to try new foods (Pakseresht et al., 2023).

The environmental concern is another important issue influencing consumer attitude towards their purchase decisions (Mustapa & Kallas, 2023). The increasing interest for environmental sustainability could lead to a greater acceptance by consumers for insect-based products, such as insect-fed fish or eggs from hens fed insects (Pakseresht et al., 2023), but studies shown also how this positive attitude may not turn into concrete acts, underling a difference between interest and actual willingness to buy (Mancuso et al., 2016).

When dealing with food products, the sensorial characteristics, nutritional values and quality are usually attributes taken into account by consumers. Visual features, such as the colour, are the first perceived when approaching food, and in products as insects-fed livestock, appearance has been classified as the most important characteristic (Pakseresht et al., 2023). Taste also plays an important role on consumers' willingness to try insect-based foods, especially among those who don't know or are not used to them. In this case consumers could be more prompt to eat something insect-based as long as the insect taste is not dominating (Bazoche & Poret, 2021); some studies showed how a partial or total replacement of conventional protein sources with insects ones has limited impact on the sensorial characteristics of the final animal food product (Sogari et al., 2022b), and communicate this aspect results relevant to decrease disgust

and increase acceptance among consumers (Menozzi et al., 2021). Moreover, while nutritional values are higher as perceived in insect-fed animal by some stakeholders, at the same time there are concerns about potential allergic reactions (Pakseresht et al., 2023), that together with food safety and health risk worries can represent a barrier for the commercialisation (Sogari et al., 2022a). For these reasons, labelling and certifications are considered important attributes in order to make information as accessible as possible (Pakseresht et al., 2023).

Eating habits also have an impact on the level of acceptance of novel foods. Western societies are mainly used to consume meat, dairy, eggs or fish protein sources, and the introduction of alternative proteins as insect ones can be seen with scepticism by consumers, also because of the belief that insect products will hardly achieve meat appearance, taste and texture (Sogari et al., 2022a). For this reason, the entomophagy practice could be easier to introduce among flexitarians, people that are primarily vegetarian but with occasional inclusion of meat or fish (Derbyshire, 2017), than convinced meat eaters (Sogari et al., 2022a). It has been shown that people with low consumption of meat products are more likely to adopt insect-based foods (Kornher et al., 2019), whereas strong attitudes towards meat sources may lead to a weaker predisposition to try insect foods (Sogari et al., 2022a).

The use of insects as feed for farmed animals is differently accepted depending on the kind of animal fed: it is higher understood for fish and poultry compared to pigs and cattle (Domingues et al., 2020). This could result from the fact that insects are considered part of the normal environment and diet of fish and poultry, whereas are something more uncommon for pigs and cattle (Pakseresht et al., 2023). However, the price of alternative feeds is nowadays still higher than the one already in use (Mulazzani et al., 2023) such as fishmeal, which is currently more price-competitive that the one insect-based, even if the over-exploitation of fish is expected to rise the fishmeal prices in the future (Pakseresht et al., 2023). This could discourage the stakeholders to buy insect-based products, for this reason would be important to keep alternative feeds prices lower or similar to the conventional ones (Sogari et al., 2022a).

The influence of socio-demographic factors, such as gender, age, income or educational level, for acceptance on the use of insects as feed and food is still not clear (Sogari et al., 2023a). Some studies highlighted that men and younger consumer are more likely to accept those kind of products (Sogari et al., 2022a) and the intention to purchase is stronger among respondents with a higher education level (Menozzi et al., 2021), which could be explained by their exposure to scientific research and knowledge on this topic (Mustapa & Kallas, 2023). On the

other hand, some others did not identify statistically significant difference between demographic groups (Pakseresht et al., 2023).

The form in which insects are presented (e.g whole insect or processed) to consumers has an impact on consumers' engagement: making the insect not recognisable or identifiable inside the food product through the production process is associated with higher levels of consumer acceptance (Pakseresht et al., 2023), especially when used in familiar foods as biscuits, bread, sauces or soups (Sogari et al., 2022a). For this reason, the insect-based products should start to be commercialised with powdered or minced insects, rather than the whole visible ones (Caparros Megido et al., 2016).

An important driver that could increase consumers' willingness to try insects-based products is to provide them information about the different aspects of this topic. Currently, Western consumers do not have an in-depth knowledge about animal nutrition and entomophagy, which may act as significant obstacle to product acceptance (Pakseresht et al., 2023). It has been confirmed that providing information about insects as alternative protein source and on the positive outcomes of new feeds, leads to reduce the disgust regarding the inclusion of these animals in the food supply chain (Menozzi et al., 2021). This information can be communicated in different ways, such as through informative seminars, which for example positive influenced all entomophagy opinions lowering insect food rejection in the study of Mancini et al. (2019). Another way is reducing information asymmetry, using appropriate labels that explains the production methods and feed ingredients (Altmann et al., 2022), also because the lack of transparency in supply chains lower the trust in the food industry (Pakseresht et al., 2023), making the consumer more sceptical about the product. In particular, social benefit messages (Sogari et al., 2023a), nutritional benefits of insects as animal feedstuff, environmental values (Pakseresht et al., 2023) and health aspects seems to be the key factors that could affect consumers' perception of edible insects (Mancini et al., 2019).

Chapter 3 - Methodology

In the research developed in this Thesis, firstly individual interviews and then focus groups were used to evaluate stakeholders and consumers' point of view about the research topic.

3.1 Individual interviews

Individual interviews were applied as a first investigation method. Individual interviews are used in qualitative research to collect participants' thoughts, attitudes, beliefs and knowledge about a given topic (Lambert & Loiselle, 2008)

A list of possible national and international stakeholders to contact was drawn up, including professionals from each stage of the food supply chain, to have as much as possible a complete and comprehensive perception of the subject. The final consumers were the only category excluded from the beginning for individual interviews.

Each stakeholder selected was contacted explaining the topic and the purpose of the research. After agreeing to participate, a meeting was scheduled, online or in person, and starting from a reference model (Table 1) a list of 8-10 questions was developed for each stakeholder, from general questions to more specific ones according to the field of interest of the interviewee.

A total of nine interviews were conducted with an average duration of 30 to 50 minutes each, held in Italian or English depending on the interviewed people, and recorded to allow the review and transcription of information. Each interview was summarised and the most relevant information consistent with the research was qualitatively selected. Tables were then created to catalogue the information.

Table 1 Question guide used to develop the interview questions

What contributions do you believe the use of insects as feed could bring to the aquaculture sector?
What do you perceive to be the main challenges or obstacles for [fish producers/insect producers/etc.] in facilitating the diffusion and uptake of this technology?
In your opinion, are there any changes needed in the current policy instruments to better support this technology? If so, please specify.
What new policy instruments, if any (e.g., a specific labeling system, economic incentives for producers), would you suggest supporting this technology?
In your opinion, what are the essential research questions that need to be addressed to foster policy innovation in support of this technology (e.g., food safety, consumer perception)?

Which key stakeholders do you believe should be involved in policy development and implementation to support this technology?
Do you have any additional comments or suggestions regarding the technologies and policy support?

3.2 Focus groups

Two focus group sessions were scheduled. Focus groups are helpful to gather insights and in-depth information regarding attitudes, perceptions, opinions of participants about a topic of interest (Sogari et al., 2018; Guerrero & Xicola, 2018). An interview guideline was created (Table 2).

The participants were recruited through a form which they have filled to take part in the focus group. The sessions took place in a quiet room in the University Campus in Parma; they involved from 6 to 7 people each and lasted approximately 90 minutes. At the beginning, each participant filled in a form for the collection of socio-demographic data and was assigned an identification code to ensure anonymity in the other phases of the study.

The interview guideline comprehended semi-structured questions, firstly to introduce the topic and then to deepen the participants' point of view about it.

After the ice-breaking questions, the topic of fish products was introduced, while images related to it were projected to give context to the participants. The discussion moved to aquaculture, to understand the participants' familiarity and opinion about it, and then the topic of the use of insects as aquaculture feed was introduced, deepening motivations or barriers to the hypothetical consumption of an insect-fed fish. Concluding questions were aimed at summarising the salient points that emerged during the focus group.

Different projective techniques, such as word association and completion techniques, were used during the focus groups. Those are used in qualitative research to get around participants' conscious defences and better understand non-communicable, unconscious information (Banović et al., 2016).

The audio was recorded during the whole session to allow review and transcription of the discussion and gadgets were distributed at the end to all participants.

The transcription allowed for the qualitative identification of relevant themes that emerged from the participants during the focus groups, while the results of the projective techniques were analysed quantitatively, through the calculation of averages, percentages or medians, or qualitatively, through word clouds, depending on the activity considered.

Table 2 Questions developed for the focus groups

Question Type	Questions
Socio-demographic data collection	Individual questionnaire
Opening and ice-breaking questions	Names, degree courses, city of origin, age What is your favourite dish with fish and why?
Introduction to fish products topic	What information do you look for or what do you pay most attention to when buying fish? Is there any information that is not present or not provided, but you would like to receive during the purchase of the fish?
Projective technique	On a scale of 1 (not at all important) to 5 (definitely important), how important do you consider the following factors to be when purchasing fish products?
Questions on aquaculture	Do you ever buy farmed fish? Why?
Projective technique	Word association about aquaculture
Discussion	Were you aware of the practice of aquaculture? What about the three types of aquacultures? If yes, in what context did you hear about it? Do you think there are differences between farmed and caught fish?
Transition questions (to move into key questions)	What do you think fish feed on in nature? What do you think fish in aquaculture feed on?
Projective technique	Word association about insects as feed
Discussion	What do you think about using insects as fish food?
Projective technique	For each proposed label, write whether you would be willing to buy a fish with the described characteristics and why
Main key questions	What are your motivations for buying insect-farmed fish? What are the barriers that would make you not buy it?
Associations with environment	If you knew that an insect feed has a lower environmental impact than conventional protein sources, would you be more inclined to buy it?
Associations with taste	Do you think an insect-fed fish tastes different than the same conventional product?
Associations with health	What do you think about the nutritional value of an insect-fed fish?

Ending questions	What information do you think is important to compulsorily communicate on a fish label? Which ones can be optional? Do you consider it important to fund research into new feed protein sources? Do you have any additional comments or questions?

Chapter 4 - Results

4.1 Individual interviews

A descriptive table (Table 3) of the stakeholders interviewed was created, classifying them based on the typology (e.g. producers, organizations) and field of activity, if they have public or private relevance, their target (national or international), the date and the modality of interview (online or in person). The stakeholders interviewed were: three chefs; three fish producers; one producer of insect-based foods; one officer from an organisation for insects' study and promotion and one officer from FAO, which is the only one among the stakeholders working in a public body. Four interviewees have an Italian target, while the others an international one; the interviews were conducted between February and April 2024, all online except two of them. Distribution channel stakeholders were not reached to conduct interviews, which represents a limit of the study.

Then, an informative table (Table 4) was created to outline the key information of each interview. Each stakeholder was classified on a 3-level approach (high, medium, low) based on their level of interest and influence in the project. Depending on the level of interest, it was pointed out how to increase it in case it was medium or low and in what aspects of the research stakeholders can be more interested in. Some of them can be interested in the sensory evaluation of the final products and in the consumer acceptance, while others in the insect feed efficiency and acceptability of insect-fed fish.

Then, based on the influence, times or contexts were evaluated in which stakeholders could have more or less impact over the outcomes of the research. One stakeholder specifically could have a major influence at the beginning of the study, providing the current framework of insects as feed, while all the others can have more relevance for the networking among producers and for the communication, or when the product is available.

Relevant sentences and comments were also reported to get an idea of the content of the interviews, and some common themes emerged from the different stakeholders.

Price was indicated as a crucial parameter by many stakeholder categories. Chefs underlined its importance for the fish purchase: *"At the supermarket, price is the main driver"* (SH5), while fish producers its role in the adoption of insect meal, whose price is perceived as high compared to other feed sources: *"A big issue for farmers [about insects as feed] is pricing. Pricing would be a limitation. Farmers want to change to insect meal, but the price,*

growth rate etc. need to be similar to traditional feed" (SH3); "*The problem with insects is to produce them, at a market price and in sufficient quantities"* (SH8).

The type of feed used for fish rearing is not so relevant for the chefs, which are more concerned in other features of the fish such freshness, species and origin: "*You are not asked what type of feed is used, but the quality of the final product is assessed"* (SH2). For other stakeholders the focus the type of feed is not an issue, but its communication is crucial, especially to involve consumers: "*Need to communicate it and to find a nice storytelling for consumers […] about the positive externalities associated to such model"* (SH9); *"When it comes to feeding in aquaculture, communicating the feed source (insects) could lead consumers to a negative feeding, even though it might be more "natural" (actual behaviour). For farmers, this is not a problem"* (SH3). Another frequent topic was "sustainability", that seems to be a key aspect in all stages of the agri-food chain, from consumers to distribution and producers: *"Consumers and retailers are paying a lot of attention to the term 'sustainability'. It is a factor in consumer choice for the product'"* (SH7).

The stakeholders were then categorized into four groups (involve, collaborate, inform, consult) (Durham et al., 2014) using a stakeholder map (Figure 5), a visual representation based on the level of interest and influence assigned in the Table 4. Only one stakeholder had low interest and influence over the study, while four of them had both parameters high; the other stakeholders were position in a medium level.

Finally, the contributions or role that each stakeholder might have in each stage of a project (before, before/during, during, during/after, after) (Durham et al., 2014) was defined and reported into a Table (Table 5). Most of them might have a role in the starting phase of the project, taking part in the development of the research question, the project design and the networking. Some could contribute to the focus groups and sensory evaluation, while all of them could help in the communication and dissemination of the results after the end of the study.

Table 3 Description of the stakeholders interviewed and the time and modality of each interview

ID	Stakeholder	Description	Private/ Public body	National/ International target	Interviewee	Date	In person/ Online
SH1	School of culinary arts	International educational and training centre for Italian Cuisine and Hospitality that could provide insights into the final product preparation and sensory evaluation	Private	International	Chef/Teacher	05-02-24	Online
SH2	School of culinary arts	International educational and training centre for Italian Cuisine and Hospitality that could provide insights into the final product preparation and sensory evaluation	Private	International	Chef/Teacher	08-02-24	In person
SH3	Fish producer	Aquaponic company focused on sustainable fish production with alternative feed proteins	Private	International	CEO, Aquaponics project manager	19-02-24	Online
SH4	Producer of insect-based foods	Company that produces and markets insect-based foods, mainly online and in Italy	Private	National	E-commerce manager	20-02-24	Online

SH5	Chef	Restaurant chef and president of a consortium for the valorisation of culinary culture	Private	National	Chef	21-02-24	In person
SH6	FAO	International agency for the assurance of food security, defeat hunger and develop agriculture	Public	International	Livestock Production Officer in the Animal Production and Health Division	26-02-24	Online
SH7	Fish producer	Aquaculture company specialised in breeding sea bass and sea bream in Tuscany area	Private	National	Biologist	05-04-24	Online
SH8	Fish producer	Aquaculture company specialised in breeding sea bass, sea bream and gilt-head bream in Tuscany area	Private	National	CEO of the company	05-04-24	Online
SH9	Organization for insects' study and promotion	Non-profit organization that promotes the use of insects for human consumption	Private	International	Organization' secretary-general	20-03-24	Online

Table 4 Evaluation of stakeholders' interest and influence on the study; key messages extracted from each stakeholders' interview

ID	Interest (H/M/L)	What aspects of the research are they likely to be interested in?	If interest is L/M how might we motivate engagement with the research?	Key messages from our research to this group	Influence (H/M/L)	Comments on influence	Relevant sentence(s)	Comments/ Messages after the interview
SH1	M	Sensory evaluation of the final products/consumer acceptance	Through the interview to explain the added value of insect-fed fish	More appealing to consumers in terms of sustainability	M	More involved in the second phase of the project (when the product is available)	In catering, the type of feed *[in aquaculture]* is not so relevant. GDO is an important stakeholder to consider for the adoption of this product	Is taught the origin, method, seasonality
SH2	M	Sensory evaluation of the final products/consumer acceptance	Through the interview to explain the added value of insect-fed fish	More appealing to consumers in terms of sustainability	M	More involved in the second phase of the project (when the product is available)	Feed is fundamental but not directly asked this information; is assessed the quality of the final product. It is important to start at the point of origin to get all the information and communicate it to consumers	The key is the quality of the final product
SH3	H	Insect feed efficiency and acceptability of insect-fed fish	---	Stakeholders can be a driver for insect-based products	M	Networking with other producers to share the value of the insect-fed fish	Important elements for consumers are price, freshness, and familiarity *[of fish]*, not sustainability. Communicating the feed source (insects) could lead consumers to a negative feeding	Fish farmers are central stakeholders

SH4	L	Marketability of insects-feed products	Explaining the potential of alternative feeds	Insects can be used as feed to produce sustainable food products	L	During the communication phase of the final product	Communication is fundamental. Retailers are difficult stakeholders to deal with for this kind of products	Important to find the correct channels and way to communicate
SH5	M	Sensory evaluation of the final products/consumer acceptance	Through the interview to explain the added value of insect-fed fish	More appealing to consumers in terms of sustainability	M	More involved in the second phase of the project (when the product is available)	Price *[of fish]* is the main driver for the consumer. The trust in the supplier is important	Important the communication
SH6	H	Acceptability of insect-fed fish	---	Stakeholders can be a driver for insect-based products	H	At the beginning, providing the current framework of insects as feed	Legislative limits for feeds, economic problem and information for producers are currently the major limitations	Policymakers have major role now
SH7	H	Insect feed efficiency and acceptability of insect-fed fish	---	Insects can be a valid implementation in fish feeds	H	Networking with other producers to share the value of the insect-fed fish	Obstacle in producing insect feed is to standardise it and have it in sufficient quantities (always available and with same characteristics)	Prices are still high to use insects feed
SH8	H	Insect feed efficiency and acceptability of insect-fed fish	---	Insects can be a valid implementation in fish feeds	H	Networking with other producers to share the value of the insect-fed fish	The problem with insects is to produce them at a market price and in sufficient quantities	The key in the future is sustainability
SH9	H	Acceptability of insect-fed fish	---	Stakeholders can be a driver for insect-based products	H	In communicating the benefits of insects as feed	Price will remain a major driver for the use of insect feed. Need to find a nice storytelling to communicate this product to consumers	Good communication is crucial

Table 5 Contributions or role that each stakeholder might have in each stage of the study

Project phase/ Stakeholder ID	Before	Before/During	During	During/After	After
SH1	Research question Project design Networking	-	Participation in the focus groups and sensory evaluation	-	Communication and Dissemination
SH2	Research question Project design Networking	-	Participation in the focus groups and sensory evaluation	-	Communication and Dissemination
SH3	Research question Project design Networking	-	-	-	Communication and Dissemination
SH4	-	-	Participation in the focus groups and sensory evaluation	-	Communication and Dissemination
SH5	Research question Project design Networking	-	Participation in the focus groups and sensory evaluation	-	Communication and Dissemination
SH6	Research question	Networking Recommendations	-	-	Communication and Dissemination
SH7	Research strategy Networking	-	-	-	Communication and Dissemination
SH8	Research strategy Networking	-	-	-	Communication and Dissemination
SH9	Research question Project design	Networking Recommendations	-	Implementation of project	Communication and Dissemination Identifying future research questions

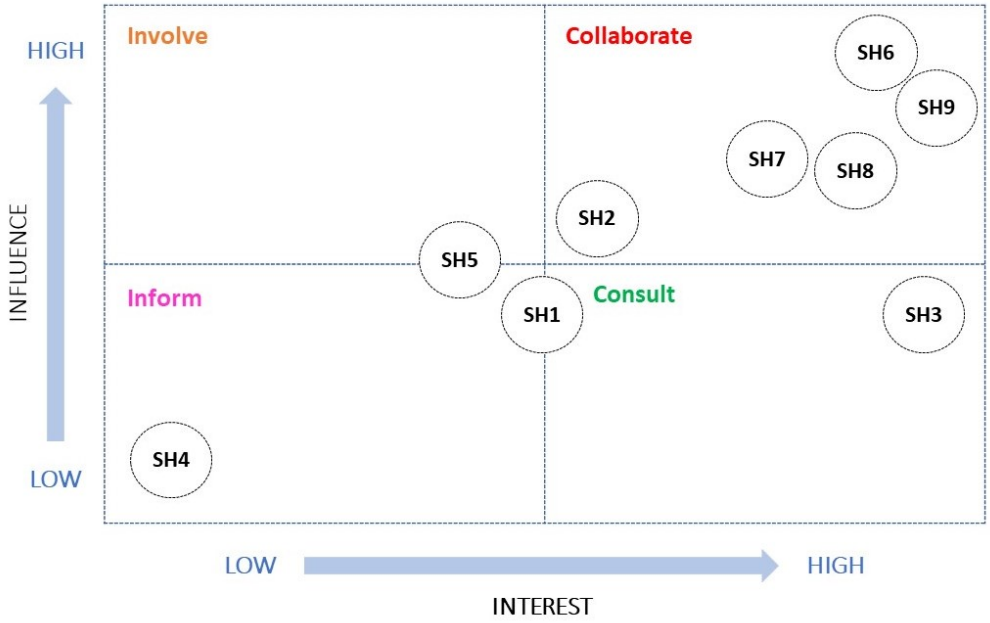


Figure 5 Map showing the level of interest and influence that each stakeholder might have in the study

4.2 Focus groups

For this study, a total of 13 people took part in two sessions of focus group. The average age was 25±2 years; most of them were omnivorous. These data highlight one of the limits of this study, which have low number of participants, all in the same age group (20-30) with higher education and involvement in the agri-food sector. Almost half of the participants (54%) buy fish 2-3 times per month and most of them consume fish from 2-3 times per week (38%) to 2-3 times per month (46%). Participants were also asked questions regarding animal welfare and concern for the environment. The characteristics of the sample are summarized in Table 6.

Table 6 Characteristics of focus group participants (n = 13)

Sample characteristic	Responses	Results
Age	Mean±SD	25±2
Gender	Male Female Other	46% 46% 8%
Diet	Omnivore Flexitarian	92% 8%

Food purchase responsibility	Always Often Sometimes	54% 15% 31%
Fish purchase	2-3 times a week 2-3 times a month 1 time per month	31% 54% 15%
Fish consumption	Every day or almost 2-3 times a week 2-3 times a month 1 time per month	8% 38% 46% 8%
Region (Italy)	North-East North-West Centre South	62% 15% 8% 15%
Education	Bachelor's degree Master's degree Postgraduate degree	15% 31% 54%
Work	Full-time student Part-time student Researcher	38% 8% 54%
Family unit	1 component 3 component 4 component ≥5 components	23% 31% 31% 15%
Animal welfare	Median	6
Eco-concern	Median	3

The first part of the focus group introduced the topic of fish products.

In the projective technique used (Supplementary Table 1), participants had to rate from 1 (not important) to 5 (very important) a list of fish purchasing factors (Table 7). The most relevant parameters resulted to be price (Mean value=4.69; SD=0.48), freshness (Mean value=4.46; SD=0.66) and origin (Mean value=4.31; SD=0.63), while certifications (Mean value=4.00; SD=0.91) are often noticed, even without knowing the meaning or what they refer to: *"I see them, but I cannot differentiate between the various labels and their meaning"* (M08). On average, the least important parameter for participants is the type of feed used (Mean value=3.00; SD=0.91), is which is not information of interest or taken into account for the fish

purchasing criterion, together with the fact that it is whole (Mean value=3.15; SD=0.8) and farmed (Mean value=3.46; SD=0.97).

Table 7 Rating of factors for purchasing fish products

Purchasing factor	**Mean±SD**
Price	4.69±0.48
Fresh	4.46±0.66
Origin	4.31±0.63
Species	4.08±0.86
Filleted	4.08±0.86
Certifications	4.00±0.91
Size	3.85±0.69
Frozen	3.69±0.63
Wild-caught	3.54±0.97
Farmed	3.46±0.97
Whole	3.15±0.8
Type of feed used	3.00±0.91

Average calculated with values from 1 (not important) to 5 (very important)

Then the topic of aquaculture was discussed starting from the projective technique of word association (Appendix 1). The most frequent words were "farming", "human being" and "control" (Figure 6). Most of the participants were aware about the existence of extensive and intensive aquaculture, but not about the semi-intensive one, and some of them had a negative opinion about this practice, as reported with some words such as "unsustainable", "diseases" or "unnatural".

Others find it more productive and sustainable than captures of wild fish: "*Obviously with aquaculture you produce a lot more and the sustainability is not easy, because there are many factors to consider. But aquaculture seems more sustainable than wild-caught"* (M02).

Some participants reported organoleptic differences between farmed and wild-caught fish, such as the fat content or the texture of the flesh, but others recognize they would not be able to discriminate the two types of fish by the taste.

The information they have about aquaculture mainly comes from television documentaries, which particularly emphasises its negative aspects, or from university or visit they have done to farms.

Figure 6 Results of the word association conducted during the focus groups with stakeholder discussion about the practice of aquaculture

According to participants, fish in nature tend to feed on other fish, algae, molluscs and plankton, while in aquaculture on feed, antibiotics or waste from other processes.

The most frequent words associated with "insect as feed" were "sustainability", "innovation", "affordability", "protein source", "well-being" and "nutrient" (Figure 7; Supplementary Table 2). Almost all participants agreed about the use of insects as feed in aquaculture, they are seen as an unexplored source that could be used in the industry and a natural component of the fish diet: *"I would say it is something more natural, I have the idea that the fish eats the insect. In my opinion it should be said that the fish was fed by insects, without having to specify the species"* (W09). Others consider insects more common in poultry diet than fish one.

They also underlined that cultural barrier could hinder consumer acceptance of the product, especially among elderly people.

Figure 7 Results of the word association conducted during the focus groups with stakeholder discussion about the use of insects as feed in aquaculture

For the last activity during the focus group, participants had to say, for each label proposed by the interviewer (Figure 8; Appendix 2), whether they would be willing to buy a fish with the described characteristics and why (Table 8). Two labels were proposed and the difference between the two labels was the type of feed used for feeding fish: one included fishmeal, the other used insect meal.

Nobody wrote that they didn't want to buy insect-fed fish, confirming that the type of feed used is not relevant for the choice: "*I answered yes and put the same reason for both: the low cost, the scientific name and the ability to cook it because I know it as a fish"* (M01). One participant focused on the graphic used to communicate insect meal, suggesting that the image of the insect could discourage consumers to buy the product, rather than if there were only the text.

Participants were interested more in traits such as price, judged fair for a farmed fish; origin, considering Italy as country of origin an added value; and species, which is well-known and consumed. Some participants would have liked to have more detailed information about the label, in particular about the type of aquaculture where the fish was produced and the type of insect used for feeding the fish.

At the end of the focus group, asking about strategies to increase the acceptance of insects as feed, the ideas suggested were: communication and education campaigns about environmental; nutritional aspects; and more research on new feed protein sources.

Figure 8 Fish labels provided for discussion to participants during the focus groups asking whether they would be willing to buy a fish with the described characteristics and why

Table 8 Answers of focus groups participants on their purchasing preferences with respect to two hypothetical fish labels, differing only in the feed used, in one case fishmeal, in the other insect meal

Type of feed	Answer	Participant code[4]	
Fishmeal	*Yes, because*	M01	It is cheap, there is the scientific name of the species. It's a species I know and I know how to cook
		M02	There is all the information needed to understand the supply chain of the product and the fact that it is farmed, with even fishmeal as feed would be fine with me. I would put the type of fishmeal to be more transparent (in the case a fish is withdrawn from the market)
		M03	I like sea bream and the price is acceptable, then the origin is Italy
		M08	It respects all the factors and variables I look for when buying fish products
		W13	Is reported the origin and the fact that is fresh, the feed used is an additional information; perhaps I would prefer to know the type of farming
		W14	The product is the same as the others without unnecessary focus on information that is perhaps 'secondary' for an average consumer
		W15	Good price, origin of my territory, fresh
		W11	Feed is not a condition I take into consideration
		W10	It is cheap, it comes from Italy and I like sea bream; it is fresh but it is indifferent
	Yes, but	M06	I would prefer it to be caught

[4] M=participants in the first focus group
W=participants in the second focus group
Numbers are randomly assigned to distinguish each participant's answers

		M07	I would buy it depending on the actual quantity, although I don't like so much the fact that it is fed with meal from other fish
	Maybe, if	W09	Was the only option available and if I really needed to buy a sea bream
		W16	The price was lower
Insect meal	*Yes, because*	M01	It is cheap, there is the scientific name of the species
		M02	There is all the information needed to understand the supply chain of the product and the fact that it is farmed, with even insect meal as feed would be fine with me. I would put the type of insect to be more transparent (in the case of an insect recall)
		M03	I like the sea bream and the price is acceptable, then the origin is Italy
		M06	I want to buy it and it meets my personal requirements
		M08	It respects all the factors and variables I look for when buying fish products
		W15	Good price, origin in my area, fresh, different feed (curiosity)
		W16	It doesn't bother me that it is fed with insect meal, it is fresh and the price is right
		W11	The price seems low for the type of fish and for fresh (very good quality) and the origin Italy
	Yes, but	M07	I would buy it depending on the actual quantity
		W13	I would prefer to know the type of rearing; the feed used gives me important information about the rearing method, the sustainability and development of new approaches
		W14	Using a stylised image of an insect (especially a cockroach) does not entice the consumer
		W09	I would still have a bias on the breeding condition

Chapter 5 - Discussion

The results of this research confirmed some common topics emerged from stakeholders and consumers regarding the use of insect feeds for aquaculture fish.

As found by Mulazzani et al. (2023), consumers interviewed in the focus group showed no interest in the type of fish feed used, nor a preference for insect-fed fish, and their knowledge about what fish eat in nature or aquaculture was limited. Among the stakeholders interviewed, chefs' attention for the feed used was also low, although their knowledge on the subject was higher. It is an issue they take into account if the final quality of the fish changes modifying the feed used, in terms of organoleptic characteristics, texture or nutrition; otherwise the type of feeding became less important.

On the other hand, the idea of using insect meal as an alternative raw material in aquafeed did not cause rejection reactions among participants, which is an important indicator. As shown in previous research (Gmuer et al., 2016), this may be related to the fact that indirect entomophagy, such as the consumption of an insect-fed fish, is more easily acceptable than direct entomophagy, in which the contact with the insect may create disgust and negative reactions. Additionally, insects are perceived as natural component of the fish diet, as confirmed by Pakseresht et al. (2023), so introducing their use in aquaculture feeds might be more accepted than for other types of animals.

Consumers interviewed in the focus group also pointed out that currently the use of insects as food and feed is not widespread in their cultural context, and the adoption of this type of product might not be accepted especially by older segments of the population. In fact, culture plays a significant role in food habits and acceptance (Mulazzani et al., 2023) and Western societies are only now coming to terms with the use of insects for food and feed. In this case, the potential market introduction and subsequent consumption of a product such as fish fed with insect meal may be slower and more difficult. Nevertheless, there are conflicting studies regarding the effects of cultural values in relation to insect-based fed animals (Pakseresht et al., 2023). The demographic influence on this topic is also still debated, with some studies finding no association, while others have reported higher acceptance among younger males compared to the other segments of the population (Pakseresht et al., 2023).

Price was found to be the major driver for consumers' choice of fish, and this may be a limiting factor for the purchase of insect-fed fish. The current price of insect protein is in fact much higher than fishmeal (FAO, 2022a) and, as a consequence, insect-based products will have a higher price than conventional ones, discouraging their purchase.

An increase in demand for insect products could lead to a decrease in the final price, making it more affordable for consumers. On the other hand, the findings of Arru et al. (2022) suggest that are policymakers who play a central role to push insect feed in the aquaculture sector, as “the higher price of insect feed than fish feed cannot be passed on to consumers, as they showed high price sensitivity”. Among stakeholders, also producers highlight price as an important attribute; in fact, they would be willing to adopt insect meal if it would be more competitive on the market.

In this context, as suggested by Sogari et al. (2022a), information to consumers could play a big role in explaining the added values of using insect meal, increasing acceptance among consumers who may base their purchasing decisions no longer only on price, but also on other attributes such as sustainability, taste or food safety.

The development of good communication and marketing campaigns were recurrent suggestions by stakeholders in the focus group, who consider them fundamental tools to increase awareness by all actors in the supply chain. It would be important for this purpose to increase the collaboration between different stages of the agri-food chain as well as to develop growth and mutual benefits.

As also demonstrated by Pakseresht et al. (2023), the adoption of specific certification and labelling could help convey information regarding fish fed with insect meal. In fact, their presence turned out to be quite an important criteria of choice of fish during purchase by consumers. Animal welfare, safety standards and environmental sustainability are some examples of certifications that could increase consumer perceived quality and confidence for the product.

On the other hand, attention should be paid with an excessive number of certifications or specific labels, which overexposure can lead to confusion and consequent rejection by consumers. Moreover, certifications represent a cost for the producers, which could be interested in those values, but the standard required for their adoption can be too high and not affordable.

At the moment, it is not compulsory to indicate the type of feed used for farmed fish in the commercial labels, but imagining the introduction of this information, it is important to reflect on what would be the optimal way to report and convey it. During the focus groups, it emerged that in a hypothetical commercial label of a fish, to indicate the type of feed, a stylised image of an insect could negatively influence the choice over written information. Although the image may be more immediate than the description, and thus be taken into consideration by more people (Gmuer et al., 2016), the acceptance for products in which insects are not directly visible could be greater.

Contrary to what Mulazzani et al. (2023) found, in our focus groups, a recurrent concern by interviewed consumers was the environmental impact of aquaculture and feeds. In fact, the most associated word with the use of insect meal was 'sustainability', showing how this topic is increasingly

of interest to consumers and more and more meaningful in the development of new products. The limitation of this result in our conditions is that the respondents study or work in the food industry and are therefore more exposed to information on this topic, which however, highlights once again how information influences the perception of products.

Stakeholders also underlined that policy makers and legislators play a crucial role in the definition of regulations of quality, safety and production standards. From the results obtained, in order to stimulate the production and use of insect feeds, it is crucial at the EU level to reduce production costs and, consequently, to increase market competitiveness, for example by improving technologies or expanding the possibility of using different substrates for insect farming and production. Furthermore, at national level, it is necessary to promote communication and dissemination not only to the final consumers, but also to other stakeholders in the supply chain. With this perspective, the role and contribution that the different stakeholders can bring to the project was identified during the study in order to enable its comprehensive and multi-sectoral development.

Today, the use of insects in the feed sector represents a potential valuable resource which is consistent with the European Green Deal and the Farm to Fork strategy, aimed at the development of a circular and sustainable food system. Nevertheless, the use of insects as feed in livestock and in aquaculture requires specific policies and measures that can incentivise its use and interest by all actors in the supply chain (Dicke, 2018; Sogari et al., 2023a).

On the other hand, the study also has several limitations for which it has to be considered as a pilot study which deserves further insights. Firstly, the low number of participants has to mentioned. Then, consumers involved were all in the same age group (20-30), studying or working in the agri-food industry and all of them had a university degree or higher. This therefore makes it impossible to give statistically significant and representative results. Furthermore, no representative of the distribution channel was interviewed among the stakeholders, making the point of view of an important part of the food chain missing.

Chapter 6 - Conclusions

This study was intended to give an overview of the stakeholders and consumers' perception regarding the use of insect meal feeds for aquaculture fish for then highlighting the most meaningful strategies to increase it under the current conditions of the European market.

The topic was firstly investigated in depth through literature review; then interviews were conducted with various stakeholders in the food supply chain and focus groups involving consumers. These techniques made possible to qualitatively study stakeholders' opinions on the use of insect feeds, highlighting the potential and limitations at different stages of the supply chain. On the other hand, focus groups investigated other aspects such as consumers' purchasing criteria for fish products, the relevance of feed information and the perception of insect use in food.

What emerged most was that, although the use of insects in aquaculture products has not been rejected by consumers, it is not an issue of interest for purchase, which is more driven by the price of the product. Among stakeholders, the use of insects as feed would be relevant if it would change the fish in terms of growth and yield for farmers, or texture and organoleptic properties for chefs. However, currently the higher price of insect meal compared to conventional feeds is a main limiting factor for its adoption and use.
This study involved national and international stakeholders, thus providing an overview not only in Italy, but also at a European level. Furthermore, most of the stages of the agri-food chain were represented, also including consumers' points of view through their participation in focus groups.

While it would be interesting to investigate through future research whether the perception of stakeholders and consumers towards the use of insect feed is different for other animals such as chickens or pigs, a relevant point that emerged from the study was the role of communication. Therefore it would be important to investigate how to convey awareness-raising campaigns on this topic. Furthermore, it might be useful to investigate the sensory impact of the use of insect feed on the product and whether and how this is perceived by consumers.

Supplementary Table 1

Projective technique used during focus groups.

On a scale of 1 (not at all important) to 5 (definitely important), how important do you consider the following factors to be when purchasing fish products?

	Not at all important (1)	**Not important (2)**	**Neither important nor unimportant (3)**	**Important (4)**	**Definitely important (5)**
Species					
Origin					
Type of feed used					
Price					
Size					
Fresh					
Whole					
Wild-caught					
Frozen					
Filleted					
Farmed					
Certifications (e.g MSC, sustainable aquaculture, Friends of the sea etc.)					

Supplementary Table 2

Projective technique used during focus groups.

Write the first 3 words you associate with the using of insects as feed:	
1.	
2.	
3.	

Appendix 1

During focus groups were used different projective techniques, including the following word association. The text, in which different types of aquaculture were defined and explained, was provided to each participant, who had first to individually read it and then write the first three words associated with this practice.

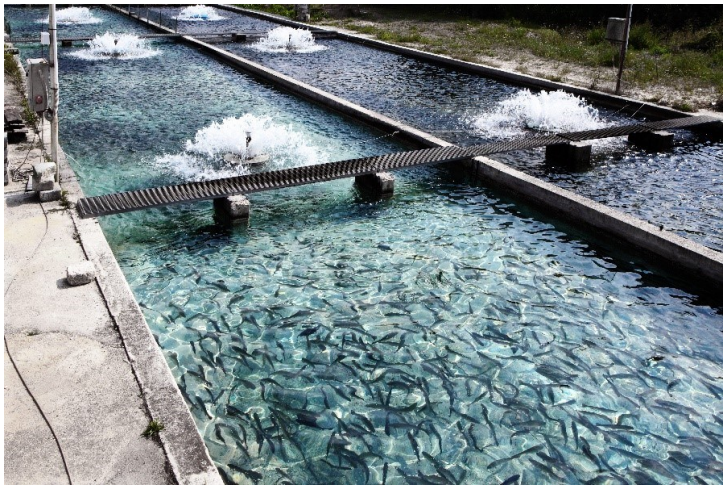
Definition of aquaculture

Aquaculture is the set of human activities, distinct from catch, practised for the controlled production of aquatic organisms. It can also be defined as the cultivation of salt, brackish or fresh water for the purpose of harvesting fish, molluscs, crustaceans and algae. Aquaculture can be carried out in the sea, rivers, lakes, ponds, lagoons and reservoirs and is practised all over the world. There are different types of aquaculture practices that can be distinguished according to the extent of human intervention and the aquatic organism reared.

Three types of aquaculture can be distinguished in relation to the extent of human intervention required:

- Extensive, when farming takes place in large expanses of water and the feeding of fish is based exclusively on the use of natural resources;

- Intensive, when the farming of saltwater, brackish or freshwater species is directly fed by humans; it takes place on land or at sea, through the installation of sea cages and usually concerns specialised and monoculture farms, i.e. dedicated to only one type of fish species;



- Semi-intensive, where man intervenes to supplement the diet of farmed fish with the aim of making it more complete and targeted to the growth of the species;

After reading this definition, write down the first 3 words you associate with the practice of aquaculture:	
1.	
2.	
3.	

Appendix 2

During focus groups different projective techniques were used, including the following, whose objective was to simulate a label present during the purchase of a fish in order to investigate the purchase criteria. Each participant was given two sheets with the following labels on them; for each one they had to indicate whether they were willing to buy that product, motivating the answers.

Below there is an example of a fish label.

Would you be willing to buy this product?

Choose **one** of the options and motivate your answer

- *Yes, because* _____
- *Yes, but* _____
- *Maybe, if* _____
- *No, because* _____

Below there is an example of a fish label.

Would you be willing to buy this product?

Choose **one** of the options and motivate your answer

- *Yes, because* _____
- *Yes, but* _____
- *Maybe, if* _____
- *No, because* _____

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