The use of insects and brewery waste for the production of sustainable fish feed

Team name: Waste-based fish feed

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Abstract

The current way of fishing is unsustainable. Even though this source of protein has the lowest carbon footprint within the animal protein group, the current level of consumption, driven by population growth and socio economic changes, is posing a threat on the long-term management of marine resources. Aquaculture which was aimed to be a solution for the marine resource depletion, actually became a driver of overfishing. Currently, aquaculture supplies almost 50% of the seafood demand and it depends heavily on wild fish stocks. ⅓ of wild fish stock captured is used to produce feed meal for aquaculture production. As a result, the price of fishmeal is continuously rising as demand for fish is higher than demand (fish stock regeneration). An alternative and more sustainable source of nutrition to replace fishmeal is the breeding of insect from waste stream. Furthermore, the waste yeast of breweries can be used as a source of nucleotide-rich yeast extract which makes the fish healthier and grow more quickly. This way, no antibiotics are needed. The end results of our technology is a feed for healthy, and faster growing fish that will then be sold to fish farmers.

1. Problem definition

The world population is expected to increase by 2 billion people in the next 30 years, achieving 9.7 billion people in 2050 (United Nations, 2019). In addition to growth population, an increase demand for protein is expected, once it is driven by socio-economic changes, including rising income, urbanization and aging population (Henchion et al., 2017). Within the field, sea food is the largest source of protein, with more than 3 billion people depending on the oceans as their primary source of protein (UN, 2019). This seafood demand resulted in unsustainable fish management practices with a large portion of commercial fish species being endangered and in risk of depletion.

An alternative found by the industry is Aquaculture, which consists in the farming of aquatic organisms (Bush et al., 2013). According to them, this economic activity supply close to 50% of the world's supply of seafood or up to 13% of the world’s animal source protein (excluding dairy and eggs), with a value of US 125 billion. Although its positive economic impacts are widely recognized, employing roughly 24 million people, the activity is well known for its environmental impact and social impact, which include water pollution, degradation of ecosystems and violation of labor standards (Bush et al., 2013). Furthermore, the activity which was claimed to be the solution of overfishing, in fact aggravates the problem of overfishing, due to requirement of wild fish to feed captivated fish stock (Good Fish Foundation, 2019). Although the industry has improved the efficiency of feeding process, the current demand for fish meal is still 6 million tons (Cashion, quoted in National Geographic, 2018). Therefore, one of the attempts to address the problem is the development of sustainability certification for the sector. ASC – Aquaculture Stewardship Council, is one example of certification scheme developed to address the most pressing environmental and social impacts of aquaculture. The scheme recognizes within its seven principles and criteria, the importance of responsible sourcing and use of animal feed and other resources (ASC, 2019).

So far, 90 % of current fish feed is produced from oily species such as anchovy and sardines. The remaining 10 % are made from white fish offal. In sum, fish meal production uses one third of the whole fish captured worldwide every year (Barlow, 2003) Fish are mainly carnivorous,and need protein rich food, certain fatty acids and minerals. In order to replace the current source for fish feed with more sustainable nutrients, digestible proteins from meat and not only from plants are needed. This could be for example insects. (Smetana,2019)

1.1. Sustainability of sources of protein

The use of fish is more sustainable as it has a smaller carbon footprint. As can be seen in figure 1.1, fish have a lower carbon footprint than other food sources. The large range of fisheries comes from the different sources of fish and different methods of fishing methods.(Nijdam,2012)

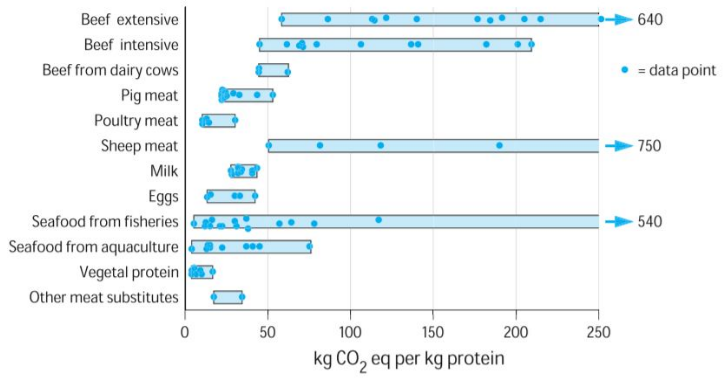


Figure 1.1 Footprint of several food sources. Taken from (Nijdam,2012).

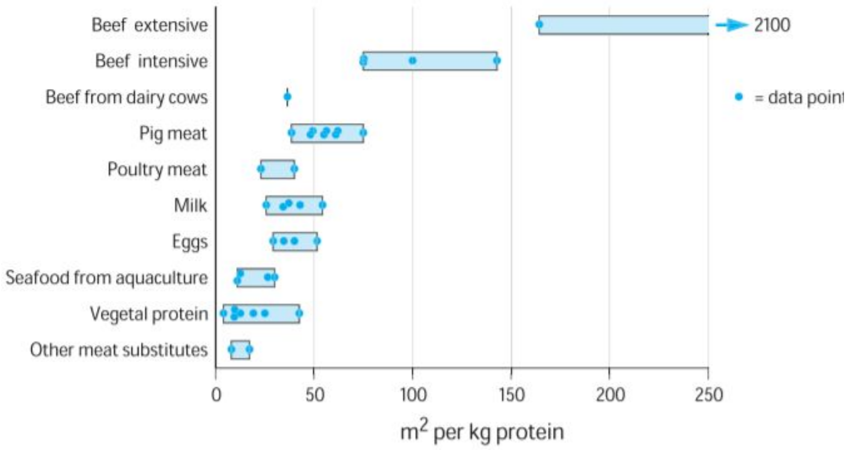


Figure 1.2 The land use of several food sources Taken from (Nijdam,2012).
As can be seen in figure 1.2, the seafood from aquaculture is lower than the other animal based foods.

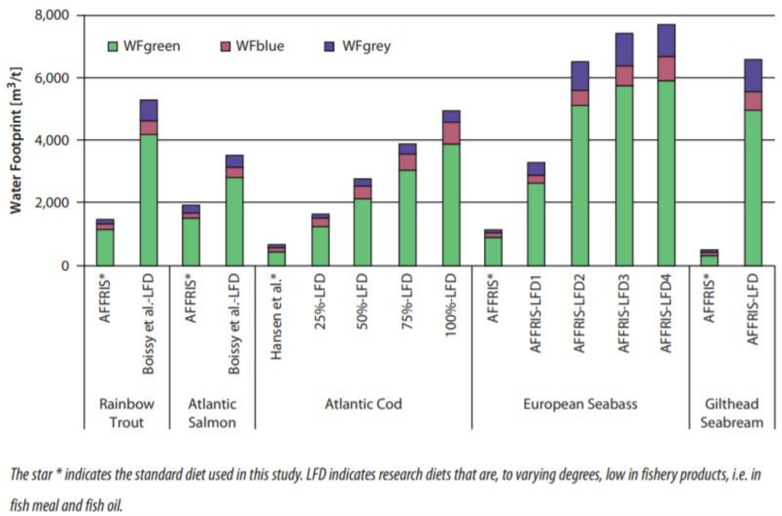


Figure 1.3 The water footprint of several fish. Taken from (Pahlow,2015).
The water footprint of bovine, pig and chicken meat is 15145,5988 and 4325 litre per kilogram respectively (Mekonnen,2010). The water footprint of fish ranges from 500 to 8000 litre per kilogram. Therefore, fish can use less water than the other meats.

The fish meat is more sustainable than chicken, pork or bovine meat.

2. Solution

2.1 Insect meal

Breweries produce a lot of yeast and malt waste (marc) worldwide. As an example, the brewery Warsteiner produces 2 Mio. hl beer yearly. This causes 100 tonnes of yeast waste (with 13 % of dry material) and 700 tonnes of marc (80 % of dry material) (stakeholder talk to Warsteiner brewery). The total beer produced world wide was 1.94 bio. hl in 2018, which caused an estimated amount of 430,000 tonnes wasted yeast (the dry material) (Mathias, 2017). The estimated amount for the malt waste is 32 mio. tonnes worldwide (Koroneos et al.,2005) . The malt waste is more protein rich than the untreated grain, because the carbohydrates get extracted during the brewing process and the

remaining malt has a higher percentage of Proteins. This Protein source can be used for insect farming to provide “meat” protein.
A promising alternative to fishmeal is using insect meal, which is rich in protein and fatty acids that are digestible to many fish species. Personal communications with Jouni Vielma, scientist at the Natural Resources Institute of Finland, revealed that the current supply of fish meal is only a fraction of the demand. The exact nutritional profile of these insect meals is also dependent on the substrate the insects are growing on (Ebertz, 2019). Some possible insect species that can be grown are mealworm larvae (*Tenebrio molitor*) and back soldier fly (*Hermetia illucens*). More R&D is required to optimize the exact feed composition for certain fish species. The insect farming industry is still very young and there can be challenges with competition with fishmeal producers, legislation and product consistency (Fletcher & Howell, 2019). However, researchers are optimistic about insect meal as a sustainable fishmeal alternative and in the long-term, aquaculture industries will switch to insect meal (Brady, 2018).

It is relatively easy to grow insects using waste streams, for example malt waste (marc) from breweries, which is rich in protein and other organic nutrients for growing insects efficiently (Bland, 2017; Smetana, 2019). Breweries have various waste streams that are sometimes used in animal feeds for cattle, pigs and chickens but often discharged into the environment (Devolli *et al.,* 2018). Our insect farm needs a few simple plastic containers stacked vertically. For example, a mealworm farm needs one container for breeding beetles, one for eggs, one for just hatched eggs (nursery) and two for the growing mealworm larvae. At the bottom, a container for collecting feces is placed. Figure 2.1 shows this design in practice.
After harvest, the insects are ground and dried into a powder and mixed with the other important component in our feeds: nucleotide-rich yeast extract.

Figure 2.1: Vertical mealworm farm (Velacreations, 2019).

2.2 Yeast extract

Brewer’s yeast (*S. cerevisiae*) is readily available from breweries as a waste stream (Devolli *et al.,* 2018) and figure 2.2 shows how to extract the valuable nutrients from yeast cells. This extraction process is necessary because yeast cell walls are very rigid, making the nutrients in the cells unavailable when the cell walls aren’t removed.It was found that yeast proteins are very digestible for rainbow trout (*Onchorynchus mykiss*) and can replace up to 75% of the fishmeal content in trout feeds (Einstein-Curtis, 2018). In food for human babies and for athletes, nucleotides are already used to boost health and performance. Nucleotides as a dietary supplement are more and more known to also boost the immune system in various fish species (Li & Gatlin, 2006; Huu, 2016 & Krüger & van der Werf, 2018), thus reducing the need for water treatment chemicals and reducing the required fish health management. This also means the fish are able to invest more of their absorbed energy into

growth rather than maintaining their health, especially in stressful situations (Krüger & van der Werf, 2018).
In other words, this feed supplement reduces the amount of feed required to produce a certain amount of fish, also known as the feed conversion ratio (FCR). The final fish feed should only contain a few percent of this yeast extract to have a positive effect on fish health and FCR.

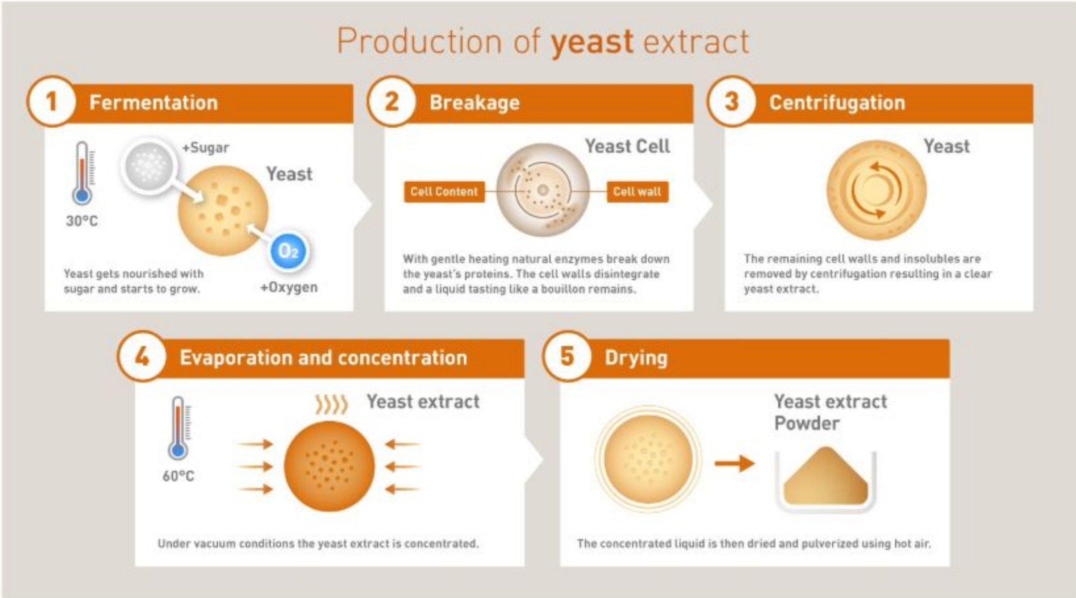


Figure 2.2: Production of nucleotide-rich yeast extract.

3. Business/operation model

Key Partners

- Breweries (provides extra yeast and marc)

Key Activities

- Collecting waste stream
- Processing waste streams into a final fish feed product
- Distributing our product
- R&D (experimental fish farm)
- Quality management

Key Resources

- Marc and yeast
- Fish waste
- R&D, patents, infrastructure and tools etc.

Value Proposition

- Waste disposal is reduced for breweries and fisheries
- Innovative fish feed that is a cheaper alternative protein source to regular fish meal
- Healthier, faster growing fish
- Better food conversion rate
- Sustainable alternative

Customer Relationships

- Data-driven customer service
- Subscriptions

Channels

- Word of mouth marketing
- Conferences
- Specialized web content

Customers

- Fish farmers

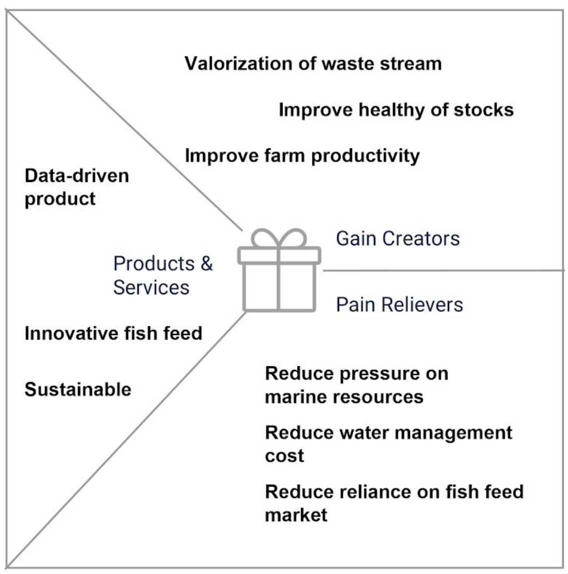
Cost Structure

- Infrastructures (labs etc.)
- Human resources
- Logistics and legislations
- R&D
- Marketing expenses

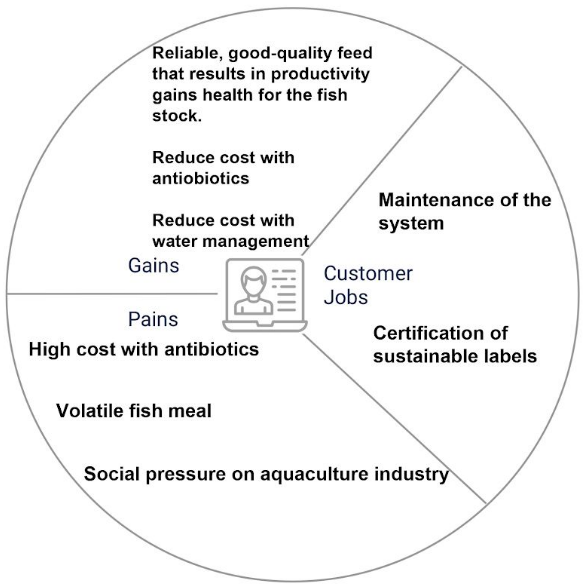
Revenue Streams

- Cheaper, better and more sustainable fish feed
- Higher productivity
- Direct sales, retail

Value Proposition



Customer Profile



4. Next steps

4.1. Plans for next week

The first step is to make a pilot scale setup to prove the feasibility of producing enough high-quality insects and yeast extract. This pilot scale setup will have a small insect farm, a aquaponics tank and some catfish. This will be the basic start of the R&D department. Based on these results an economic analysis and further improvements could be made. Furthermore, new ideas or new potential markets can be discovered.

In order to prevent expensive design changes, regulations about food safety and labels should be researched as soon as possible.

4.2. Plans for next months

After proving the technical feasibility of our technology, patents can be made in order to prevent hostile parties to take our technology. Several articles can be published in scientific journals after submitting the patent. This is the first step of our marketing and might already result in contacts from interested people. Furthermore, some conferences might be interested in our technology and might provide a discount for the conference. Even though they might not give discount, this still is a nice way to meet potential customers.

The next step is to get funding. Several funding agencies exist. For example, this project is applicable to get funding from the European Life or Horizon 2020 program. When using these two sources we can directly work with the stakeholders.

The final step is to leave the funding stage and go more and more to the sustainable business model that is described in the previous chapter.

The technology can also be further expanded to include aquaponics. This will be cheaper and is more sustainable than conventional aquaculture. Aquaponics also provides significant income from the harvested plants.

4.3 Biggest uncertainties

For now it is not known which nucleotide composition should be used for catfish or trout specifically. Furthermore, the reaction of the fish not completely certain. For example, the fish might get sick when switching suddenly from conventional feed to our feed. It is also possible that the fish won't eat the new feed because they don't like the smell or taste. This largely depends on the composition of the fish feed and this is an area where more research is needed.

No information was available about the willingness to change of the fish farmers. They are currently using their respective fish feed and they might be skeptical of our feed. Moreover, the fishes are expensive and an increase in mortalities due to the new feed is a risk the fish farmers must take during initial trials.

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