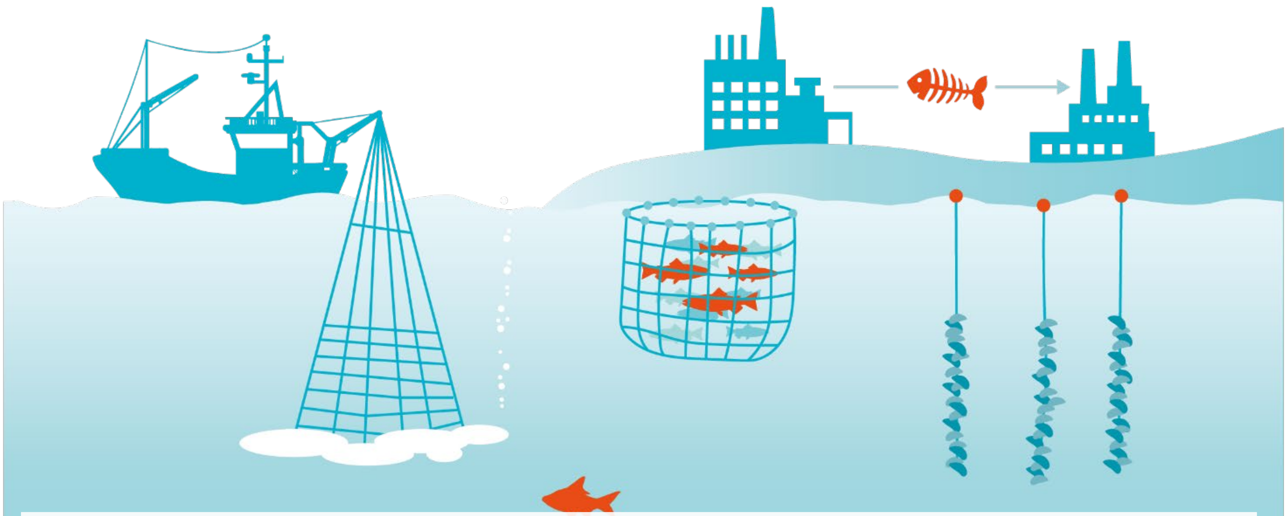
Optimal utilization of seafood side-streams through the design of new holistic process lines

# D4.1 New Bio-based Value Chains



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# Executive Summary

Deliverable 4.1 shows the high potential added-value concepts that can be processed from side-streams from fisheries. They include savoury concepts enriched in glutamic acid as well as proteins, antioxidants and mineral powders enriched in $CaCO_3$.

The selection of the value streams was based on different aspects, such as added-value ingredient potential, feasibility of the process as well as sustainability. The market potential and technical data were investigated for each final WASEABI concept in order to find a place into the market. This approach and prioritization were needed to create a pole position of the project outcomes into the market.

Next to market and feasibility aspects, also potential legal bottlenecks were considered.

Finally, the pragmatic sequencing of the process units within the bio-based value chains needs to be monitored. In that context, the Value Chain Navigator was designed and will be used and further explored in tasks 4.2 – 4.6 and the outcome hereof will reported in the final report of WASEABI. When all criteria are met successfully within the Value Chain Navigator, there should be a green light towards successful implementation. When a red flag is shown, meaning one or more criteria were not met, the bio-based value chain has a high risk to fail. In this deliverable 4.1, an example for the bio-based value chain of Royal Greenland is elaborated upon. From such bio-based value chain, successful products can enter the market via a business-2-business business plan (out of scope of the WASEABI project).

In deliverables 4.2 to 4.6, different bio-based value chains will be illustrated and results obtained will be used for the feasibility study using the Value Chain Navigator with inputs from WP5. Final results will be reported in the final report of WASEABI.

# 1. Introduction

Deliverable 4.1. describes the process towards bio-based value chain definition based on target concepts with added value, and how the bio-based value chains are secured towards viability. The content of this deliverable was created based on task 4.1 of the WASEABI project.

# 2. Selection process for bio-based value chains

In a first step, the selection of five (5) different value-chains was explored. Annex 1 illustrates the process starting from all information collected in WP1, 2, 3 and 5 to the final selection of the five bio-based added-value chains (see annex 2). In order to transform all information into final high-impact value chains, a three-step approach was applied. Based on the outcome of the meeting on January 20 2021 with the WASEABI review committee, it was decided to create bio-based value chains based on highest added-value, in terms of economic value and technical feasibility of the corresponding processing of the WASEABI side-streams. This way, the first selection criteria was value-added ingredient potential defined by its application, followed by feasibility expressed in terms of CAPEX availability for fast implementation as well as legislation, and finally contribution to offering a sustainable solution compared to existing benchmarks. The process as summarised in Annex 1 is further elaborated in the next sections of deliverable 4.1.

Important to mention are also potential hurdles and bottlenecks towards implementation. These were defined in WP1 mainly as citizen sensitivity, but difficult to take into account during the course of the WASEABI project due to culture and country differences. After discussion with some external and internal experts, it was clear that potentially these types of hurdles and bottlenecks can be mitigated, by organisation of information sessions with the relevant stakeholders in the bio-based value chain during their implementation.

A technique to convince people is described by ADKAR. ADKAR stands for Awareness, Desire, Knowledge, Ability and Reinforcement. More in detail, Awareness of the need for change, Desire to participate and support the change, Knowledge on how to change, Ability to implement desired skills and behaviours and lastly Reinforcement to sustain the change (*The Prosci ADKAR® Model | Prosci*, n.d.). For that reason, and because out-of-scope within WASEABI, selection of value-chains was only based on market value, technical feasibility and the legal frame.

# 3. Market value as first selection criteria

Based on potential outcomes from WP3, following four added-value concepts were further targeted, explored and quantified:

## 3.1. Savoury ingredient concept enriched in Monosodium Glutamate (MSG)

When looking today for MSG, as basic reference for the glutamic acid rich flavour enhancer, its market value is estimated to about 3.8 billion dollar annually and it is suspected to grow at a CAGR (Compound Annual Growth Rate) of 3.3% to 4.7 billion dollars in 2027 (Monosodium Glutamate (MSG) - Market Study by Global Industry Analysts, Inc., n.d.). The market of the flavour enhancers are estimated to grow from 5.8 billion dollar (in 2020) to 6.09 billion dollar in 2026, which is a CAGR of 4.5% (*Flavor Enhancer Market 2021 Is Estimated to Clock a Modest CAGR - WBOC TV*, n.d.). Some of the market leaders are Cargill, Aiinomoto and so forth (*Global Monosodium Glutamate Market | Growth | Trends | Forecast*, n.d.).

This means that there is a high market potential when producing glutamic acid based concepts because the market value is even expected to grow. Figure 1 visualises the market value of glutamic acid in the current market of artificial sweeteners.

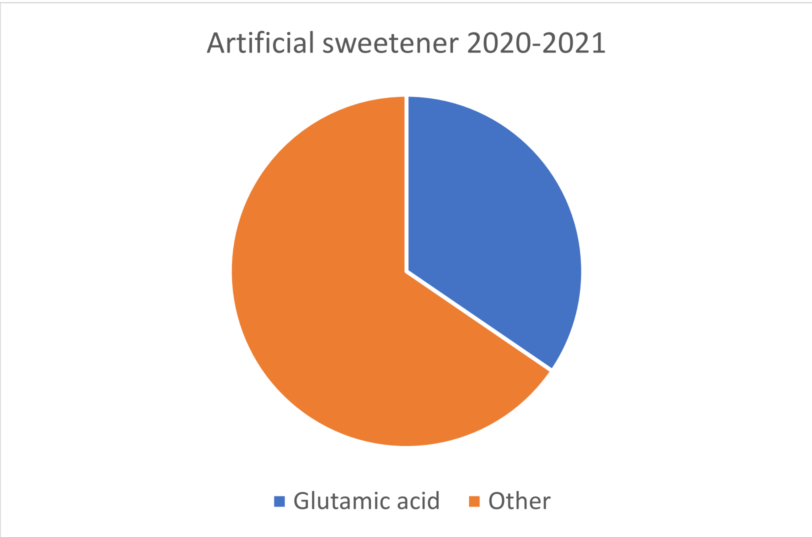


*Figure 1: Market share glutamic acid versus other flavours*

MSG is used as a flavour component as it gives the umami taste and is widely used in the food industry as a flavour enhancer. Asian countries hold a high market share in the MSG area as it is used in meats and other high protein foods. In the food industry, it is frequently produced by the use of fermentation. This is also from a sustainability perspective better than chemical production. Corn can be used as the substrate in the fermentation. In comparison to using corn for example, the method used in WASEABI based on enzymatic hydrolysis is more sustainable because the starting material is a side-stream. Alternatively, from WP3 it was clear that glutamic acid enriched flavour concepts can be produced from mussel cooking water and the solid side streams of cod, hake and salmon which makes it a valuable bio-based value chain. In WASEABI, glutamic acid rich flavour enhancer is targeted including peptides and free amino acids and no specifications are available in the market for that ingredient. However, the market specifications for pure glutamic acid are known and given in figure 2 and can be used as best available benchmark to check market fit. The closer WASEABI meets these goals on relevant parameters, the better the economic feasibility and public acceptance (Information & Crystal, n.d.). However, it should be borne in mind that these specifications are for pure MSG, whereas the glutamic acid rich flavour enhancer from WASEABI are dried hydrolysates rich in free glutamic acid.

| Requirements | | Specification | Test Method |
|---|---|---|---|
| Assay | | Not less than 99% | HPLC analysis |
| pH (5% solution) | | 6.7 ~ 7.2 | pH meter |
| Loss on Drying | | Not more than 0.5% | Moisture meter |
| Specific Rotation | | Between +24.8° - +25.3° | Polari meter |
| Chloride | | Not more than 0.04% | IC analysis |
| Pyrrolidone carboxylic acid | | Not more than 0.2% | HPLC analysis |
| Lead (Pb) | | Not more than 1.0 mg/kg | ICP |
| Arsenic (As) | | Not more than 1.0 mg/kg | ICP |
| Cadmium (Cd) | | Not more than 1.0 mg/kg | ICP |
| Mercury (Hg) | | Not more than 0.1 mg/kg | ICP |
| Particle Size | Medium Crystal | +45 | Mesh range (70% min): ASTM E-11 |
| | Regular Crystal | -25 ~ +60 | Mesh range (70% min): ASTM E-11 |
| | Small Crystal | -45 ~ +100 | Mesh range (70% min): ASTM E-11 |
| | Fine Crystal | -60 ~ +120 | Mesh range (70% min): ASTM E-11 |
| | Powder | -100 | Mesh range (60% min): ASTM E-11 |

*Figure 2: Specifications for MSG*

## 3.2. Proteins

Looking at the market value of protein, in 2021 the size value was 42.5 billion US dollars. And since humanity is in continue search for novel protein sources to cope with global population growth, this is expected to grow to 85.5 billion dollars in 2028, which is a CAGR of 10.5% (figure 3). This is an interesting market to invest in because there is a need to provide sustainable alternatives to meat and plants as protein sources for human food. In the market for proteins, there is more and more need for replacing the current protein, which are mainly animal protein, with new sources. The use of side-streams as new protein sources will increase the sustainability. Protein is an essential part of human food, as well for animal feed (*Global Protein Ingredients Market Size Report, 2021-2028*, n.d.). Specifications are less driving, compared to glutamic acid enriched flavour concept.

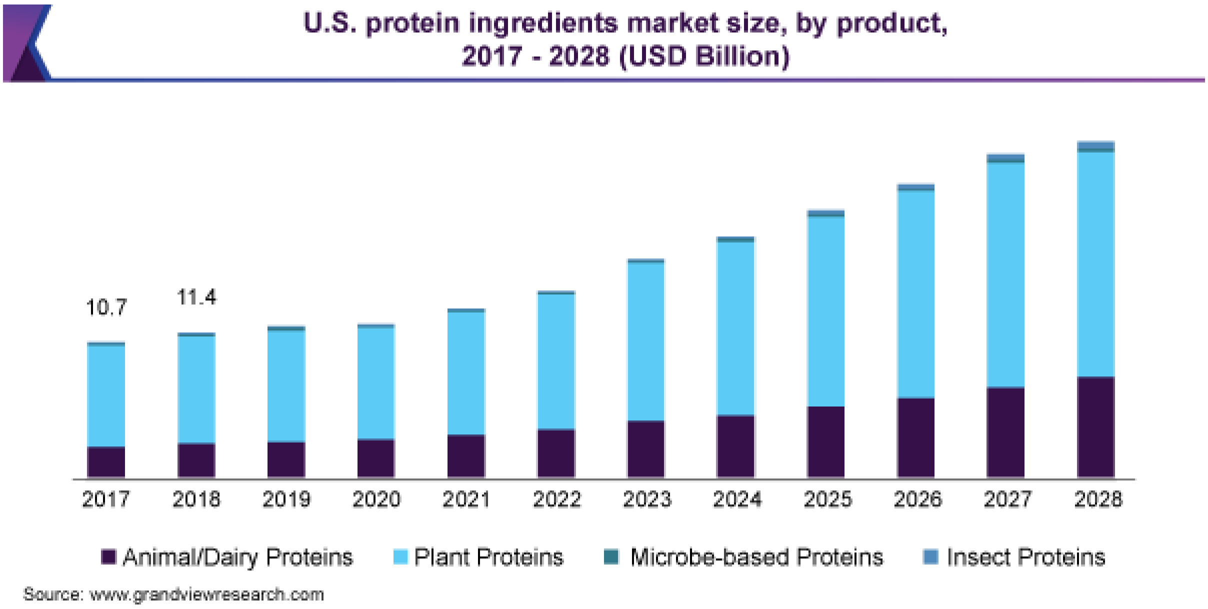


*Figure3: Graph U.S. protein ingredient market*

Figure 3 also shows the U.S. protein ingredients market size, by product between 2017 and 2028. The increase in protein market size will mostly be contributed by the increase in plant proteins as the growth of animal/dairy proteins is less substantial. There will also be a small increase in the use of microbe-based protein and insect protein (*Global Protein Ingredients Market Size Report, 2021-2028*, n.d.). In WP3, the consortium discovered the potential of herring side-streams and cod liquid side-streams as extra protein sources to cope with today's potentials. This resulted in one of the targeted bio-based value chains within WASEABI.

Further on, today's proteins used in the feed are mostly soy based, which uses land and needs transportation, which is not sustainable. In addition, fishmeal for example can be produced from fish side-stream (which is good from a sustainable perspective) or fresh raw fish, which can no longer be used for human consumption (which is bad in a sustainability perspective). This way, the protein produced using a side-stream in WASEABI, which uses no land and has no competition with human food and thus scores better on a sustainability aspect.

## 3.3. Antioxidants

The natural antioxidant market is set to reach 1.7 billion dollars in 2019 and is expected to grow to about 3 billion dollars in 2029. This is a CAGR of about 6% (figure 4). This has also been a determining factor of choosing to produce antioxidants based on the positive outcomes in WP3. Antioxidants can be used among others as a supplement to feed.

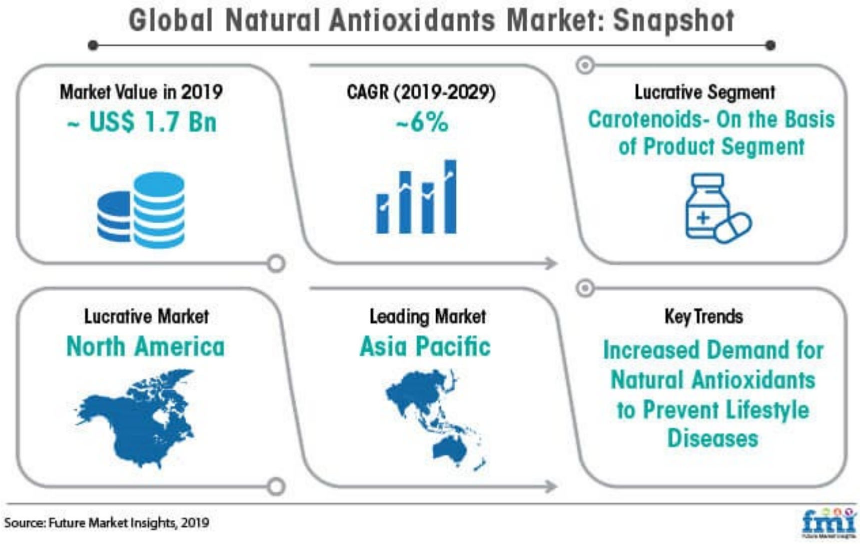


*Figure 4: Market antioxidants*

In addition, figure 4 also shows that Asia is the leading market and the lucrative market is in North America. The figure also shows that these natural antioxidants are used for supplementation in order to prevent lifestyle diseases, which explains the increasing demand (*Natural Antioxidants Market - Towards a Higher Quality Product Consumption*, n.d.). Due to sustainability and possible carcinogenic, synthetic antioxidants are being replaced by natural ones.

The production of antioxidant can be interesting from an industry standpoint. There are different kinds of antioxidants that can be used. Plant extracts are one of them. Again, the production of an antioxidant from a side-stream can be a very interesting process from a sustainability standpoint because there is no need to use land to grow the plants, for example, and thus this land can be used to produce food or other products.

Some of the major players in the antioxidant market are Ningxia Eppen Biotech Co., Cargill and Fufeng Group (*Natural Antioxidants Market - Towards a Higher Quality Product Consumption*, n.d.).

Technical specifications are important for successful valuing of antioxidants derived from the WASEABI project, and in that respect the specifications of some relevant natural antioxidants can give guidelines within WASEABI in order to create viable (process of natural) antioxidants from European origin (see figure 5). Specific examples on peptide derived antioxidant specifications are not easy to find.

| | | |
|---|---|---|
| **Composition and specifications** | Tannins content | min $75\%_w$ d.m. (ISO 14088) |
| | Fibre | max $2\%_w$ (Method Weende) |
| | Humidity | max $8\%_w$ (Method Tan/01) |
| | pH (sol. 10%) | max 4 (Method Tan/04) |
| | Solubility | water soluble |

*Figure 5: Specifications natural plant based antioxidant derived from grapes. Although most compositions are based on macro-composition, specific activity is considered as most differentiating. Example for that is for example be the DPPH scavenging properties of the antioxidant.*

## 3.4. Minerals ($CaCO_3$)

The last bio-based value chain deals with minerals, with CaCO3 as representative since it can be derived from (fish) bones. It’s today’s common substance found in rocks as the calcite and aragonite (most notably as limestone, which is a type of sedimentary rock consisting mainly of calcite). Local sourcing of minerals offers a solution, and when using bones from discards (underside hake) or from the rest material remaining after production of savoury ingredients or antioxidative peptides using enzyme hydrolysis, the minerals can be valorized and thus this is more sustainable than using the inorganic minerals.

The market size of the minerals, more specifically CaCO3 was valued at 43.89 billion dollar in 2019 and it is expected to grow at a CAGR of 2.8% from 2020 to 2027, in terms of revenue (Global Calcium Carbonate Market Size Report, 2020-2027, n.d.). Some players in the calcium carbonate market are IMERYS, kalk and okutama kogyo co., LTD (Calcium Carbonate Market Size, Growth & Trends| COVID-19 Impact Report 2021 to 2026 - Mordor Intelligence, n.d.).

Also here specifications are important. A technical sheet for CaCO3 can be found online (Product Specification CaCO3 , n.d.) (figure 6):

| | | |
|---|---|---|
| **Product Number:** | **239216** | $CaCO_3$ |
| CAS Number: | 471-34-1 | |
| MDL: | MFCD00010906 | |
| Formula: | CCaO3 | |
| Formula Weight: | 100.09 g/mol | |

| **TEST** | **Specification** |
|---|---|
| Appearance (Color) | White to Off-White |
| Appearance (Form) | Powder |
| X-Ray Diffraction | Conforms to Structure |
| Complexiometric EDTA (Dried Basis) | $\geq$ 99.0 % |
| Barium | $\leq$ 0.01 % |
| Iron (Fe) | $\leq$ 0.003 % |
| Potassium (K) | $\leq$ 0.01 % |
| Magnesium (Mg) | $\leq$ 0.02 % |
| Sodium (Na) | $\leq$ 0.1 % |
| Strontium (Sr) | $\leq$ 0.1 % |
| Insoluble matter C=6.7% IN DILUTE HCL | $\leq$ 0.01 % |
| Chloride Content | $\leq$ 0.001 % |
| Heavy Metals by ICP-OES | $\leq$ 0.001 % |
| Ammonia (NH4) | $\leq$ 0.003 % |
| Sulfate | $\leq$ 0.01 % |
| Flouride | $\leq$ 0.0015 % |
| Meets ACS Requirements | Current ACS Specification |

*Figure 6: Specifications CaCO3*

# 4 Conclusion on first selection criteria for value-added ingredient potential

According to market research, impact-full bio-based value chains were selected within WASEABI based on outcomes in WP3. Since the selection was based on reproducible outcomes from WP3, all selected bio-based value chains were viable and based on existing CAPEX within the industrial partners. This makes easy translation into case studies possible (see tasks 4.2 to 4.6)

In order to select the most promising bio-based value chains, each outcome of WP3 was discussed in detail between the partners and the steering group and the top 5 was retained (see annex 2) and further validated in the next tasks in WP4. For example, when looking at the mussel cooking water and the potential products that could be produced starting with this side-stream, there were 2 possibilities, namely the production of protein by usage of flocculation and centrifugation or the production of a savoury compound via nanofiltration-diafiltration. However, the protein yield in WP3 was only 41% and thus this bio-based value chain was not retained because the low potential in comparison to the potential of the savoury component. As well from a sustainability, and economical standpoint the decisions were examined in WP5 and rejected as bio-based value chain accordingly.

It can also be concluded that the portfolio of the 4 high-added value components (glutamic acid rich savoury ingredient, protein, antioxidative peptides & mineral) not only can be produced from the side-streams within WASEABI but have a higher market potential due to extra beneficial aspects (such as sustainability) beyond the commercially available concepts. This offers beneficial market potential in terms of market share and profit.

Finally, based on the outcomes of WP1, 2, 3 and 5, it is also clear that there is at this point in time no viable added-value bio-based value chain possible for some of the other/additional WASEABI side-streams. Also concepts based on antihypertensive as well as antimicrobial peptides were not retained, due to the negative results.

# 5 Legislation as final driver towards market

Next to economic value and technical feasibility, the legal framework is a very important asset as well. However, from WP5, it is clear that all retained added-value concepts and bio-based value chains fit within the EU legislation, dealing with:

- Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002
- Regulation (EC) No 1831/2003 of the European Parliament and of the Council of 22 September 2003
- Regulation (EC) No. 882/2004 of the European Parliament and of the Council of 29 April 2004
- Regulation (EC) No 183/2005 of the European Parliament and of the Council of 12 January 2005
- Regulation (EC) No 767/2009 of the European Parliament and of the Council of 13 July 2009. This regulation refers to the Community Catalogue of Feed Materials. The Catalogue facilitates the exchange of information on the product properties and list feed materials in a non-exhaustive manner. This Catalogue is updated minimum once a year. In this newer version, the numbering of the feed materials can change. The actual Catalogue is Regulation No 68/2013.
- Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October 2009
- Regulation (EC) No 999/2001 of the European Parliament and of the Council of 22 May 2001
- Directive 2002/32/EC of the European Parliament and of the Council of 7 May 2002
- Novel food legislation

The chosen project outcomes, beside good nutritional and functional quality, have to comply with safety for use and the content of obnoxious substances. This cross-check is classified into following categories and will be monitored during validation of the bio-based value chains in tasks 4.2 – 4.6:

- **<u>Heavy metal.</u>** In this context, it's important to crosscheck the presence of these heavy metals in the project outcomes, and also, in case they are present, the amount of heavy metals transported in the fractions of interest.

- **Agrochemicals.** For agrochemicals, the presence and the potential carry over must be carefully checked. Even more, the presence of pesticides should be carefully checked for the obvious reason.

- **Microplastics.** The microplastics do not have a max value in the fish. The use of microplastics, however, has been banned by the EU.

# 6. Selected Bio-based value chains: validation and tools

## 6.1. Validation

After above selection criteria were defined, a next step is drafting a blue-print of the bio-based value chains (tasks 4.2-4.6) and defining tools to monitor the progress towards successful implementation.

For that, two tools were used to maximise the feasibility: the AHP tool (indicated with  in figure 7) and the use of the ISO Nr 14044 based tool of the process itself (indicated with  in figure 7).

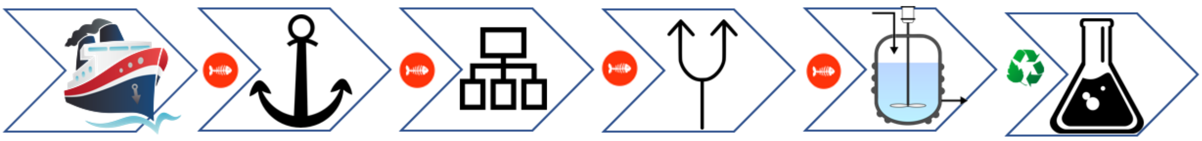

*Figure 7: Template value-chain, indicating the different processing units, as well the tools and ISO norms used.*

The AHP tool as developed in WP2 will be used to determine the legal, technical, economic and environmental viability of each step of the bio-based value chain except for the last step, which will be assessed by the sustainability tool created in WP5.

AHP stands for Analytic Hierarchy Process. The AHP tool will need parameters to determine the feasibility. Some examples for the validation of the technical aspect: Geographical dispersion, store capacity, initial protein content and so forth. When one of these viabilities are not fulfilled, there will have to be optimization of the process in order that the process is viable.

The environmental viability will give as output 3 indicators based on the added-value concept created in the bio-based value chain. These indicators (carbon footprint, eutrophication and water footprint) will help to see what can be done to further optimize the process towards more sustainability. When the carbon footprint is too high, the decision can be made to reduce or increase the efficiency of the transport for example.

When looking at the last steps of the process (conversion to final product), there is also a need for a final validation by an external party to test the conformity of the concept, in order to capture the potential market value beyond the one of existing commercial concepts. For example, product certification can be included to guarantee the quality of the product, but that is out-of-scope of the WASEABI project. Within WASEABI, the technical sheet of competing products will be used as a first measure for market compatibility. This will be a minimum quality that must be reached in order to be profitable in comparison to the benchmark.

## 6.2. Tools to monitor bio-based value chain design towards success

For each process unit within the bio-based value chain, there is a need to monitor some indicators that secure the production of added-value concepts. These indicators are important to reach successful validation of the bio-based value chain.

In order to get the final added-value concept, different steps need to be taken, as described in the bio-based value chain elements. These different steps will have their customised 'checklist' of criteria which will need to be fulfilled in order to be allowed to proceed to the next step in the bio-based value chain.

The different cross-checks and their criteria are listed below in addition to complying to the legislation of the aforementioned section. Next criteria are important:

### Legal (generic)

- Feed/food legislation in terms of contaminants, …
- Labour law
- Valid permits (e.g., import permit/ fish permit)

These criteria are in line with the regulation of the aforementioned paragraph about the legal aspect.

### Economic (generic)

- OPEX
    - Operation Expenses are the variable costs for example the use of water in a production process.
- CAPEX
    - Capital expenditures are major purchases for example a fermenter, it can be used for multiple years and will thus be an investment.
- Taxes
    - For example, the import tax when wanting to import fish from the international sea to land.
- Interest/funds
    - This is the cost of a loan which can be taken to pay for the equipment, or the funds which are provided by the government for example.
- Raw material must be process compatible.
- Product must have an added value in comparison to the raw material in current market (supply/demand).
    - It is important that when the product is made, there is an actual market interested in the product.
- Socially acceptable fishing practices (good fishing practices/governance).
    - This criterion is based on the handling of the fish for example, there must be compliance with the regulation on the processing of the fish. From an ethical standpoint, this is also an important criterion.

## Technological

- Seasonal technicality
  - This will refer to whether the number of fish to be supplied is dependent on the seasons or not.
- Storing capability
  - The storage capacity is important to provide the best quality of raw material as possible.
- Geographical dispersion
  - The distance between the collecting site of the raw material and the process facility will be important for the storage on one hand and environmental impact on the other.
- Minimum content in raw material in order to be economically feasible.
  - The raw material which is supplied will need to have a minimum of, for example, protein content in order to be useful when wanting to make a protein isolate from it.
- Public perception of technology must be positive.
  - This criterion refers to the public perception of either the technology/process used or the product in itself. When the product is obtained by using environmentally polluting reagent or use of illegal means of producing the product can have a negative public perception and will thus not be bought. This is also the case for the product itself. If the product gets a negative connotation in the media for example, chances are that the product will no longer be desired by the public.

## Environmental

- Minimal environmental impact at each step.
  - Excessive/overfishing
  - Carbon footprint
  - Water footprint
  - Ozone Layer depletion
  - Human toxicity
  - Acidification
  - Eutrophication
  - These steps will be dependent on which process step it is determined. When looking at the water footprint, this will be higher in the actual production process and less so on the transportation and so forth.
- Waste
- Packaging
- Consumables (raw material/energy)

# 7. Value Chain Navigator

Within WASEABI, the Value Chain Navigator is constructed to systematically analyse the bio-based value chains within tasks 4.2 – 4.6. All criteria per level are grouped and need to be analysed in all case studies. In case one of the criteria fail, the bio-based value chain is not viable. In case all defined criteria are met, the bio-based value chain is viable (when also the market conform specifications are met).

In a further step this Value Chain Navigator can be digitalised in a dashboard front-end based on the tools in the back-end, but this is out of scope of WASEABI. The Value Chain Navigator is illustrated in figure 8.

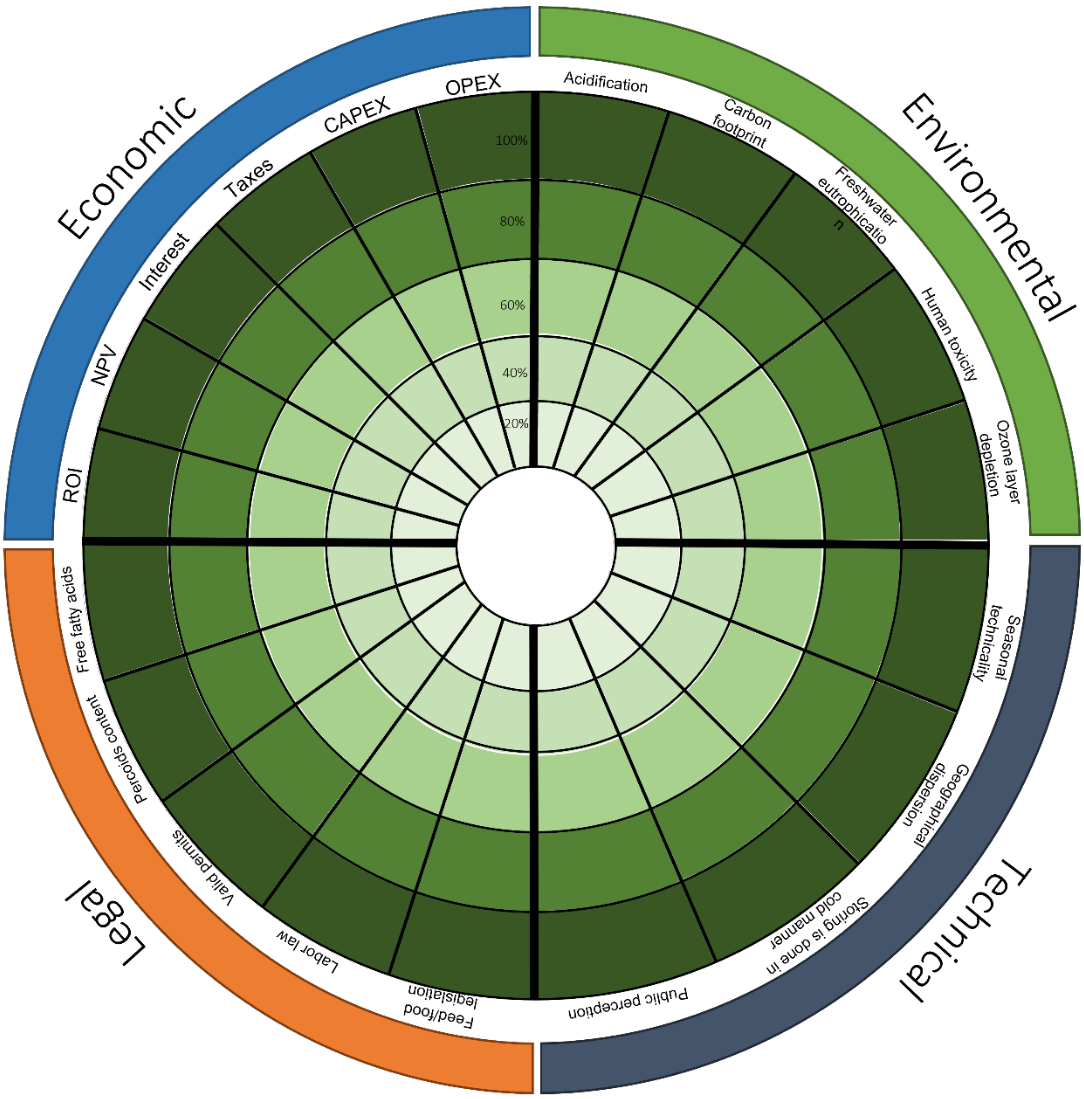


*Figure 8. Example of Value Chain Navigator*

# 8. Example: Savoury ingredient rich in free glutamic acid, Royal Greenland

The Value Chain Navigator will be applied in the different case studies in tasks 4.2- 4.6. However, to illustrate the *modus operandus* of the Value chain Navigator, the case for Royal Greenland is highlighted in this deliverable 4.1.

Royal Greenland is located at Greenland. The global presence of Royal Greenland has its origins in the vast areas of the North Atlantic and the Arctic Ocean. They fish in the rich fishing grounds between Greenland and Eastern Canada, east of Greenland and as far to the Northeast as the Barents Sea (figure 9).


*Figure 9: Picture of Royal Greenland boat*

WP3 showed that the side-catch of Royal Greenland can be easily processed into added-value glutamic acid rich flavour ingredient. See the bio-based value chain in figure 10.

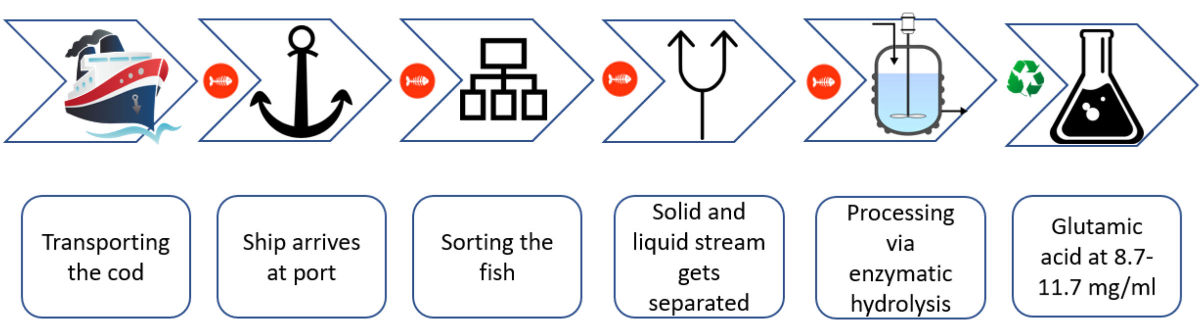


*Figure 10: Value-chain of cod solid stream*

Glutamic acid can be processed out of the solid side side-stream of cod. This is done via enzymatic hydrolysis. More specifically, a customised enzyme cocktail will be applied under very defined conditions (details will be published soon but are now still confidential). This side-stream can also be used for producing antioxidants, but the production of glutamic acid was favoured from a technical point of view (see selection methodology in section 1).The sorting of the side-stream is already done at Royal Greenland in order to avoid blending of different grades of side-streams , and securing the value of the final concept (glutamic acid). The storage is done in a food grade manner with retained cold chain, and that side streams are pre-dipped in antioxidants (e.g. Duralox-MANC or rosemary extract alone) to limit the risk of oxidation. The pre-biorefinery logistics are pre-dipping in antioxidants to limit risk of oxidation. There is a risk of autolysis and microbial spoilage. This can be mitigated by keeping the raw material cold.

High temperature and pH can stimulate bacterial growth and the high temperature can also induce oxidation which have an impact on the key specifications. Bacterial growth must be further addressed as there is so far worked with avoiding lipid oxidation. Low levels of oxidation of the side-stream does not have any negative on the savoury properties of the final ingredient.

The process was tuned as described above by application of the easy-accessible and straightforward Value Chain Navigator that showed all weak and working points towards a successful bio-based value chain. When all needed criteria are matched, a green light will be given towards successful implementation of the bio-based value chain. This approach creates credit for customers of Royal Greenland, what is translated into Business-2-business sales and innovative new concepts in the market. In case one crucial criterium is not met in the value chain navigator, a risk is detected and a mitigation has to be provided. In the case of Royal Greenland, one of the crucial elements is the sorting of the side-streams, what led to successful investment in that respect to secure the innovation.

Other important criteria to consider for Royal Greenland are (besides the generic ones):

### Economic

- CAPEX
  - Hydrolysis tank with stirrer and temperature control, centrifugation equipment and heat exchanger, transportation unit (truck/boat) and other.
- OPEX
  - Enzymes, water and other chemicals/reagent
- Product must have an added value in comparison to the raw material in current market (supply/demand).
  - WASEABI produces a flavour ingredient enriched in free glutamic acid (best benchmark available is MSG). This includes also an evaluation of the savoury effect of the savoury ingredient. This could for example be evaluated by a flavour house.

### Technological

- Storing capability
  - Storing in a cold matter, pre-dipped in antioxidant and no mixing of fractions

### Environmental

- Consumables (raw material/energy)
  - Electricity, natural gas, chemical for cleaning, enzymes and process water.

Once, all the abovementioned issues have been addressed, it will be clear whether the Value Chain Navigator gave rise to further red lights that must be further dealt with before the company can move on with implementation of the process in large scale and marketing of the products.

# 9. The Value Chain Navigator … Some final reflections …

The Value Chain Navigator is further validated in tasks 4.2 – 4.6 by collection of relevant data within flagship partners and enables the transformation of selected value chains into viable ones. These final bio-based value chains are summarized into deliverables 4.2 till 4.6 and the outcome of the use of the Value Chain Navigator on these value chains will be discussed in the final report of WASEABI. Once criteria (for example in legislation, …) changes in time, new data can be collected and the Value Chain Navigator can be used for scenario analysis to re-empower the bio-based value chains into viable ones, making the side-catch opportunities and their challenges manageable. Ultimately, this can become a standard operation procedure within the respective industries.

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## Annex 1: Illustration of selection process bio-based value chains (based on extensive database created in WASEABI)

➔ **<u>Step 1:</u>** Starting point is the potential of minimal viable concept (picture below shows an <u>extract</u> of the database)

| Task | Lead | Person in charge | Raw material Side Stream | Class Targeted Product | Best Minimal Viable Concept (Best MVC) Process | Process Condition that corresponds to the Current Best Value | Specification Differentiator in market Driver / Value concept | Value parameter | Current Best Value (and unit) | KPI bio-refinery / quality check (DO) | KPI bio-refinery / quality check (DONT) | Ben mar |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.1 | CHA | Bita Forghani Targhi | Mussel cooking water | Protein | Flocculation with centrifugatio | flocculation with 0.025% v/v Silica (levasil RD442) at native pH or pH 4 | Interesting Sensory profile/protein ingredient from sustainable | Protein content/quality | 41% | Sensory attributes/ Gel strength/ Whiteness/ WHC/ Protein content/Amino | Minimise the mineral content | No S |
| 3.1 | CHA | Bita Forghani Targhi | Herring process water | Protein and lipids | Flocculation with centrifugatio | Flocculation of 10% pre-salting brine with 1.8% $CaCl_2$ at native pH and 3h incubation at cold temperature resulted in protein sedimentation of 64% | Protein ingredient from sustainable sources | Protein recovery yield | 64% | Sensory attributes/ Gel strength/ Whiteness/ WHC/ Protein content/Amino Acid profile | | No S |
| 3.1 | CHA | Bita Forghani Targhi | Cod brine | Protein | Flocculation with centrifugatio | Recently got the samples - No data yet | Protein ingredient from sustainable sources | | | Sensory attributes/ Gel strength/ Whiteness/ WHC/ Protein content/Amino | | No S |
| 3.1 | AZTI | Monica Gutierrez | Mussel cooking water | Savoury compounds | Concentration technologies | NF-DF- 25 ºC | Natural seafood savoury sauce | Glutamic acid content | XX=mg/ml | Glutamic acid content | Reduce Salt Content | |
| 3.2 | CHA | Mehdi Abdollahi | Cod brine | Protein isolates | pH-shift technology | Recently got the samples - No data yet | Protein ingredient from sustainable sources | Very difficult; lets discuss | Very difficult; lets discuss | Sensory attributes/ Gel strength/ Whiteness/ WHC/ Protein content/Amino | Avoid the presence of anions | No S |
| 3.2 | CHA | Mehdi Abdollahi | Liquid herring side-strean | Protein isolates | pH-shift technology | 10% pre-salting brine: more than 90% of protein sedimented at pH 4 | Protein ingredient from sustainable sources | Protein recovery yield | 90% | Sensory attributes/ Gel strength/ Whiteness/ WHC/ Protein content/Amino Acid profile | Avoid the presence of anions | No S |
| 3.2 | CHA | Mehdi Abdollahi | Mussel cooking water | Protein isolates | pH-shift technology | The pH shift technique does not enhance protein sedimentaion when used with mussel cooking water thus no product. | Interesting Sensory profile/protein ingredient from sustainable sources | Very difficult; lets discuss | Very difficult; lets discuss | Sensory attributes/ Gel strength/ Whiteness/ WHC/ Protein content/Amino Acid profile | Avoid the presence of anions | No S |
| 3.2 | CHA | Mehdi Abdollahi | Solid cod side-streams | Protein isolates | pH-shift technology | | Gelation capacity/protein purity/sustainable sources | ¿Gelation capacity? | | Sensory attributes/ Gel strength/ Whiteness/ WHC/ Protein content/Amino | Avoid the presence of anions | Suri |
| 3.2 | CHA | Mehdi Abdollahi | Solid herring side-stream | Protein isolates | pH-shift technology | | Gelation capacity/protein purity/sustaiable sources | ¿Gelation capacity? | | Whiteness/ WHC/ Protein content/Amino Acid profile | Avoid the presence of anions | Suri |
| 3.3 | AZTI | Bruno Iñarra | Discards (Undersized Hak | Bioactive peptides | Enzymatic hydrolysis | Not identidfied yet | Bioactive peptide | Anti-microbial effect | MIC = XX mg/ml | | Ensure enzyme inactivation + ... | |
| 3.3 | AZTI | Bruno Iñarra | Discards (Undersized Hak | Bioactive peptides | Enzymatic hydrolysis | NZ28 1 %; 70 ºC pH 6 3h | Bioactive peptide | antioxidant effect | 135 mg TEAC / g | Trolox equivalents by ABTS method | Ensure enzyme inactivation | |
| 3.3 | AZTI | Carlos Bald | Salmon solid side stream | Bioactive peptides | Enzymatic hydrolysis | NZ28 1 %; 70 ºC pH 6 3h | Bioactive peptide | Anti-microbial effect | MIC > 200 mg/ml | Minimun Inhibition Concentratio for Bacillus cereus and Bacillus subtilis. | Ensure enzyme inactivation | |
| 3.3 | AZTI | Carlos Bald | Salmon solid side stream | Bioactive peptides | Enzymatic hydrolysis | Protamex 1 %+ NZ 18 1%; 50 ºC; pH 6; 3 | Bioactive peptide | Antihipertiensive activity | IC50= 5 mg/mL | ACE inhibitory effect | Ensure enzyme inactivation | |
| 3.3 | AZTI | Carlos Bald | Salmon solid side stream | Bioactive peptides | Enzymatic hydrolysis | Alcalase 1% + Flavourzyme 1 %, 50 ºC, | Bioactive peptide | antioxidant effect | 125 mg TEAC/g | Trolox equivalents by ABTS method | Ensure enzyme inactivation | |
| 3.3 | AZTI | Carlos Bald | Mussel shells | Bioactive peptides | Enzymatic hydrolysis | Not identidfied yet | Bioactive peptide | Anti-microbial effect | MIC = XX mg/ml | | Ensure enzyme inactivation | |
| 3.3 | AZTI | Carlos Bald | Mussel shells | Bioactive peptides | Enzymatic hydrolysis | Not identidfied yet | Bioactive peptide | antioxidant effect | XX mg TEAC/g | | Ensure enzyme inactivation | |
| 3.3 | DTU | Ann-Dorit Moltke Sørensen | Cod solid side streams Fr | Bioactive peptides | Enzymatic hydrolysis | Not identidfied yet | Bioactive peptide | Anti-microbial effect | IC50= XX mg/ml | | Ensure enzyme inactivation | |
| 3.3 | DTU | Ann-Dorit Moltke Sørensen | Cod solid side streams Fr | Bioactive peptides | Enzymatic hydrolysis | Diluted 50:50 with water, pH 6.5, 1% protamex, 50C, 6h (Supernatant: 71.4 g) | Bioactive peptide | antioxidant effect, Radical | IC50= 2.14 mg powder / mL (1.75 mg protein / mL) | AO assay - DPPH radical scavenging, protein content | Ensure enzyme inactivation | |
| | | | | | | 1) 30 min control (no enzyme); no pH | | | 1) 1.76 mg powder / | | | |

Target Best MVC | Sidestreams | Sorting and storage | Sheet1

➔ **<u>Step 2:</u>** Further ranking of the retained potentials from step 1 on processing, sorting and storage feasibility as well as on offering a sustainable solution compared to existing benchmarks in terms of differentiating aspects (pictures below show an <u>extract</u> of the database)

| Raw material Side Stream | Class Targeted Product | Best Minimal Viable Concept (Best MVC) Process | Current Best Value (and unit) | Conditions to be met (WP1) | Mitigation | QC check | Priority rank to move to sorting&storage | Dissemination proof |
|---|---|---|---|---|---|---|---|---|
| Mussel cooking water | Protein | Flocculation with centrifugatior | 41% | Technical AND/OR onsumer conditions | | OK/NOK | | YES |
| Herring process water | Protein and lipids | Flocculation with centrifugatior | 64% | Technical AND/OR onsumer conditions | | OK/NOK | | YES |
| Cod brine | Protein | Flocculation with centrifugation | | Technical AND/OR onsumer conditions | | OK/NOK | | YES |
| Mussel cooking water | Savoury compounds | Concentration technologies | XX=mg/ml | Technical AND/OR onsumer conditions | | OK/NOK | | YES |
| Cod brine | Protein isolates | pH-shift technology | Very difficult; lets discuss | Technical AND/OR onsumer conditions | | OK/NOK | | YES |
| Liquid herring side-strean | Protein isolates | pH-shift technology | 90% | Technical AND/OR onsumer conditions | | OK/NOK | | YES |
| Mussel cooking water | Protein isolates | pH-shift technology | Very difficult; lets discuss | Technical AND/OR onsumer conditions | | OK/NOK | | YES |
| Solid cod side-streams | Protein isolates | pH-shift technology | | Technical AND/OR onsumer conditions | | OK/NOK | | YES |
| Solid herring side-streams | Protein isolates | pH-shift technology | | Technical AND/OR onsumer conditions | | OK/NOK | | YES |
| Discards (Undersized Hak | Bioactive peptides | Enzymatic hydrolysis | MIC = XX mg/ml | Technical AND/OR onsumer conditions | | OK/NOK | | YES |
| Discards (Undersized Hak | Bioactive peptides | Enzymatic hydrolysis | 135 mg TEAC / g | Technical AND/OR onsumer conditions | | OK/NOK | | YES |
| Salmon solid side stream | Bioactive peptides | Enzymatic hydrolysis | MIC > 200 mg/ml | Technical AND/OR onsumer conditions | | OK/NOK | | YES |
| Salmon solid side stream | Bioactive peptides | Enzymatic hydrolysis | IC50= 5 mg/mL | Technical AND/OR onsumer conditions | | OK/NOK | | YES |
| Salmon solid side stream | Bioactive peptides | Enzymatic hydrolysis | 125 mg TEAC/g | Technical AND/OR onsumer conditions | | OK/NOK | | YES |
| Mussel shells | Bioactive peptides | Enzymatic hydrolysis | MIC = XX mg/ml | Technical AND/OR onsumer conditions | | OK/NOK | | YES |
| Mussel shells | Bioactive peptides | Enzymatic hydrolysis | XX mg TEAC/g | Technical AND/OR onsumer conditions | | OK/NOK | | YES |
| Cod solid side streams Fra | Bioactive peptides | Enzymatic hydrolysis | IC50= XX mg/ml | Technical AND/OR onsumer conditions | | OK/NOK | | YES |
| Cod solid side streams Fra | Bioactive peptides | Enzymatic hydrolysis | IC50= 2.14 mg powder / mL (1.75 mg protein / mL) | Technical AND/OR onsumer conditions | | OK/NOK | | YES |
| | | | 1) 1.76 mg powder / mL (1.36 mg protein / mL) and 2) 1.48 mg | | | | | |

Target Best MVC | **Sidestreams** | Sorting and storage | Sheet1

| Task | | Lead | Person in charge | Raw material Side Stream | Class Targeted Product | Best Minimal Viable Concept (Best MVC) Process | Process Condition that corresponds to the Current Best Value | Specification Differentiator in market Driver / Value concept | Value parameter | Current Best Value (and unit) | KPI bio-refinery / quality check (DO) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.1 | Scandic p 32 | CHA | Bita Forghani Targhi | Herring process water | Protein and lipids | Flocculation with centrifugation | Flocculation of 10% pre-salting brine with 1.8% $CaCl_2$ at native pH and 3h incubation at cold temperature resulted in protein sedimentation of 64% | Protein ingredient from sustainable sources | Protein recovery yield | 64% | Sensory attributes/ Gel strangth/ Whiteness/ WHC/ Protein content/A Acid profile |
| 3.1 | Scandic | AZTI | Monica Gutierrez | Mussel cooking water | Savoury compounds | Concentration technologies | NF-DF- 25 ºC | Natural seafood savoury sauce | Glutamic acid content | XX=mg/ml | Glutamic acid content |
| 3.2 | Jeka Fish p38 | CHA | Mehdi Abdollahi | Liquid herring side-streams | Protein isolates | pH-shift technology | 10% pre-salting brine: more than 90% of protein sedimented at pH 4 | Protein ingredient from sustainable sources | Protein recovery yield | 90% | Sensory attributes/ Gel strangth/ Whiteness/ WHC/ Protein content/A Acid profile |
| 3.3 | Barna p42 | AZTI | Carlos Bald | Salmon solid side stream | Bioactive peptides | Enzymatic hydrolysis | Alcalase 1% + Flavourzyme 1 %, 50 ºC, pH6, 3 h | Bioactive peptide | antioxidant effect | 125 mg TEAC/g | Trolox equivalents by ABTS method antioxidant > antimicrobieel |
| 3.4 | Pescados p45 | DTU | Ann-Dorit Moltke Sørense | Cod solid side-streams Frame | Flavouring agents | Enzymatic hydrolysis | 1% alcalase, 1% exomixture, 1% glutaminase; 6 h at 55C; No pH adjustment (higher content with 2% (instead of 1%) or 18 h (instead of 6h) however not significant - This is in process to be confirmed) | Flavouring capacity / Tasty fish sauce | Glutamic acid content | 8.7-11.7 mg GLU / mL supernatant (52 -56 mg GLU / g powder) | Content of glutamic acid / Sensory attributes: Umami flavour |

## Annex 2: Final selection of bio-based value chains

| | Scalable at location | Raw material Side Stream | Class Targeted Product | Best Minimal Viable Concept Process | Process Condition that corresponds to the Current Best Value | Differentiator in market Driver / Value | Value parameter | Current Best Value (and unit) |
|---|---|---|---|---|---|---|---|---|
| T4.2 | Pescados Marcelino | Mussel cooking water | Savoury compour | Concentration technolog | NF (5x Concentrate) +DF (Water:Co | Natural seafood savoury sauce | Free Glutamic acid content | 70% protein yield / 2,6 mg/g in concentrate / 32,5 mg/g in dry powder- |
| | Pescados Marcelino | Mussel cooking water | Protein | Flocculation with centrifu | flocculation with 0.025% v/v Silica (levasil RD442) at native pH or pH 4 | Interesting Sensory profile/protein ingredient from sustainable | Protein content/quality | 41% |
| T4.3 | AZTI (Only 2nd PLACE fc | Salmon solid side strea | Bioactive peptides | Enzymatic hydrolysis | Alcalase 1% + Flavourzyme 1%, 50 °C | Bioactive peptide | antioxidant effect | 65 % protein yield // 550 ug TEAC/g // ACE IC50 1,5 mg/ml // MIC ~300 mg/ml |
| | AZTI (Only 2nd PLACE fc | Undersized hake | Bioactive peptides | Enzymatic hydrolysis | Alcalase 1% + Flavourzyme 1%, 50 °C | Bioactive peptide | antioxidant effect | 65 % protein yield // 550 ug TEAC/g // ACE IC50 1,5 mg/ml |
| | AZTI (Only 2nd PLACE fc | Bones linked to peptide | Mineral ingredient | Hydrolysis-> Drying-> Milin | Any hydrolysis condition, no diferen | High Bioavailable Mineral from Fish Bones | Bioavailable Ca (or other mineral) | 20-28% Ca; 9% P (Ca/P=2,6) Bioaccesibility |
| T4.4 | BARNA | Salmon solid side-strea | Flavouring agents | Enzymatic hydrolysis | Alcalase 1% + PP 1% + PB 1%, 50 °C, | Glutamic acid content | Glutamic acid content | 20 mg GLU/g |
| | BARNA | Bones linked to savoury/aroma | | Hydrolysis-> Drying-> Milin | Any hydrolysis condition, no diferences noticed. | | Bioavailable Ca (or other mineral) | 20-28% Ca; 9% P (Ca/P=2,6) Bioaccesibility |
| T4.5 | Sweden Pelagic | Herring process water | Protein and lipids | Flocculation with centrifu | Flocculation of 10% pre-salting brine with 1.8% $CaCl_2$ at native pH and 3h incubation at cold temperature resulted in protein | Protein ingredient from sustainable sources | Protein recovery yield | 64% |
| | Sweden Pelagic | Solid herring side-strear | Protein isolates | pH-shift technology | Solubilization at pH 11.5 and precipita | Gelation capacity/protein purity/sustaiable sources | Protein content/Gelation capacity | >85% protein (w/w dry weight), Gel Hardness: 2.48 N |
| | Sweden Pelagic | Liquid herring side-strea | Protein isolates | pH-shift technology | 10% pre-salting brine: more than 90% of protein sedimented at pH 4 | Protein ingredient from sustainable sources | Protein recovery yield | 90% |
| T4.6 | Jeka Fish | Cod brines | Proteins + phosph | Concentration and floccu | lactate 0.048% or Levasil RD442 0.25% native pH: 46% protein sedimentation; ID 21: Levasil RD442 0.5% native pH: 55% protein sedimentation, acidification to pH 3 84% protein; ID 3 and 20 no clear conclusion yet(work ongoing) sedimentation | % protein sedimentation and % phosphours | Phosphorus and protein content | Refer to column I |
| ESAIBILITY | Royal Greenland | Cod solid side-streams | Flavouring agents | Enzymatic hydrolysis | 1% alcalase, 1% exomixture, 1% glutaminase; 6 h at 55C; No pH adjustment | Flavouring capacity / Umami flavored fish boullion | Glutamic acid content | 4 mg GLU / g raw material used for production (40 mg GLU / g powder) |