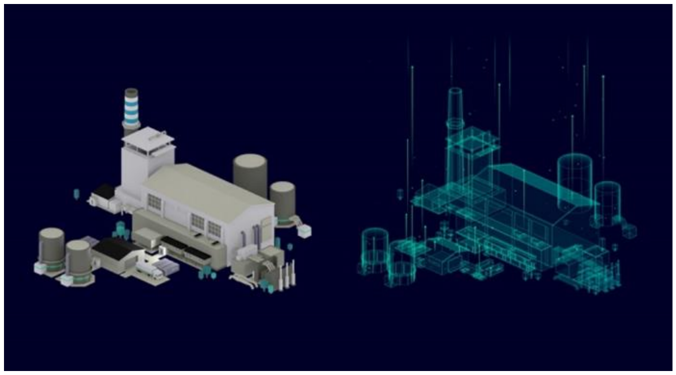

Bilateral Cooperation in the Field of Sustainable Upcycling of By-products in Aquaculture and Fisheries (SAFE)

Guidelines for the design of facilities for the disposal of by-products of the fish industry

European Economic Area Financial Mechanism for the period 2014-2021 and the Norwegian Financial Mechanism for the period 2014-2021

Fund for Bilateral Relations

Realisation of this analysis is co-financed from the *European Economic Area Financial Mechanism for the period 2014-2021 and the Norwegian Financial Mechanism for the period 2014-2021*

Fund for Bilateral Relations

Content of this report is under responsibility of Zadar County and Ministry of Agriculture

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These materials were created in cooperation with the competent administration of the Ministry of Agriculture: Fisheries Administration, Faculty of Agriculture - University of Zagreb

The materials were published by the Zadar County and are used as such for the purpose of initial definition of fishery by-product management in Croatia

The following companies experts participated in the preparation and evaluation of the material:
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European Economic Area Financial Mechanism for the period 2014-2021 and the Norwegian Financial Mechanism for the period 2014-2021

Fund for Bilateral Relations

Content

1 Project Overview - main findings

- **Possible Plant Location:** Poličnik, Zadar County.
- **Land Size:** cca 20,000 m².
- **Layout Planning:** Definition and Design of processing plant for fishery by-product to achieve efficient workflow and minimal cross-contamination between lines, with sufficient place for cold storage and warehouse area- plus distance from other land users
- **Auxilary sourcing structure-** Fishing ports and landing site for trawlers- for collection of discard - "landings"

Raw Material Sourcing and Management

- **Collection:** Establish protocols for collecting discards from ships in fishing ports.
- **Storage in Ports:** Implement a cold chain system for preserving raw materials at fishing ports and landing sites.
- **Transportation:** Arrange logistics for the delivery of raw materials to the processing plant.
- **Raw Materials:** Beside discard to utilize other by-products from sea bass, sea bream, tuna and other marine and freshwater fish processing, and parts of small blue fish (e.g., heads and guts of sardines and anchovies) and other processing by-product like squid etc.. Estimated on cca 15 000 tons- mostly exported
- Alternative Sources: Import of by-products (Italy, Slovenia Albania, Bosnia and Herzegovina, Montenegro, Malta etc…)

Production Line Design & specification- possibilities

- **Fish Meal & Fish Oil Line as a main one:**
- **Design:** Start-up production line unit with a possibility to easy enlarge production capacity
    - **Process Flow:** Raw material reception, cooking, hydrolyse, pressing, drying, oil separation and packaging. Same processing combination required for silage (stabilized) and fishmeal (fresh)
- **Collagen/Gelatine Line:**
    - **Process Flow:** Collagen extraction from fish skins, purification, drying and packaging. Experimental – possible Mobile lab processing unit for collagen and gelatine production plus side products - fish oil ultra and nano filtration - as a separate unit outside or internal processing plan component

- **Silage Line:**
    - **Process Flow:** Raw material preparation, fermentation, stabilization and packaging.
- **Separate Lines:** Design separate production lines to prevent cross-contamination, especially for aquaculture feed purposes.
- **Hydrolysed Fish Protein Line:** Focus on advanced methods to ensure high-quality protein extraction.
- **Fish Oil Production Line:** Implement technologies for efficient oil extraction and purification.
- **Side Products Line:** Explore opportunities for utilizing all by-products in an environmentally friendly and economically beneficial manner.

Equipment Selection for possible capacity building or enlarge

- **Fish Meal & Oil:** Cookers, presses, dryers, centrifuges, etc.
- **Collagen:** Extraction tanks, purifiers, dryers, etc
- **Silage:** Fermentation tanks, stabilizing equipment, etc
- **Common:** Conveyors, packaging machines, storage units, etc

Utility Requirements

- **Power:** Estimate electricity needs for machinery and lighting.
- **Water:** Supply for processing and cleaning.
- **Waste Management:** Effluent treatment and solid waste disposal systems.

Processing Technology

- **High-Quality Output:** The technology should aim at producing high-category products suitable for aquaculture feed, pets, and domestic animals plus human consumptions.
- **Combination and Flexibility:** Ensure the process is versatile and can be combined or adapted based on raw material availability.
- **Competency Requirements:** The technology should require a medium level of competence, implying the need for skilled but not highly specialized personnel.

Storage and Logistics Infrastructure

- **Receiving Containers:** Establish a system for receiving and handling containers at ports.
- **Transport Fleet:** Maintain a fleet of trucks for efficient transportation.

- **Warehouses and Refrigeration:** Build warehouses with refrigeration facilities for both raw materials and finished products.

Quality Control and Laboratory

- **Laboratory Design:** Include a well-equipped laboratory for constant monitoring and quality control.
- **Parameter Testing:** Define the range of parameters to be tested, ensuring product quality and safety.
- **Facility:** A small, efficient lab integrated into the plant.
- **Equipment:** Analytical instruments for quality testing of raw materials and finished products.
- **Standards:** Compliance with food safety and quality standards.

Environmental, safety and Regulatory Compliance

- **Sustainability:** Ensure all processes are environmentally sustainable and minimize waste.
- **Regulatory Standards:** Comply with local, national and international regulations related to food products, especially in aquaculture.
- **Safety Protocols:** Fire, chemical and operational safety measures.
- **Environmental Impact:** Measures to minimize pollution and comply with environmental regulations.

Regulatory Compliance

- **Permits and Licenses:** Acquire necessary approvals from local and national authorities.
- **Industry Standards:** Adherence to food processing and safety standards.

Human Resource Planning

- **Staffing Requirements:** Skilled and unskilled labour, technicians, quality control experts.
- **Training:** Regular training programs for staff.

Financial and Operational Planning

- **Budgeting:** Estimate the capital investment and operational costs.
- **Timeline:** Develop a project timeline from initiation to full operational status.
- **Human Resources:** Plan for staffing requirements across all levels of operation.
- **ROI Analysis:** Projected returns on investment.

Project Timeline and Milestones

- **Phases:** Construction, equipment installation, commissioning, trial runs.
- **Milestones:** Key stages in project development with targeted completion dates.

Marketing and Sales Strategy

- **Market Analysis:** Identify target markets for each product line.
- **Sales Channels:** Distribution and marketing strategies.

Maintenance and Upkeep

- **Maintenance Plan:** Routine and preventive maintenance schedules for equipment.
- **Upgrades:** Plan for future upgrades and expansions

Risk Management

- **Risk Assessment:** Conduct a comprehensive risk assessment, covering supply chain, production and market risks.
- **Mitigation Strategies:** Develop strategies to mitigate identified risks.

Project Documentation and reporting

- **Technical Documentation:** Prepare detailed technical documents for each aspect of the project.
- **Operational Manuals:** Develop operational manuals for staff training and reference.
- **Record-Keeping:** Maintain records of production, quality control and environmental compliance.
- **Reporting:** Regular reports to stakeholders.

After making this preliminary study of technical and technological possibilities and product line option chosen, it is necessary to start tendering equipment and create a complete and targeted technical and technological analysis with all financial elements as well as management models.

1 Basic rules to industry

Establishing a fish by-product processing industry involves adhering to a range of basic rules spanning various domains. These rules are crucial for ensuring the efficiency, safety, sustainability and profitability of the operation. Below is a summary of key rules and needed protocols across different categories:

1. Regulatory Compliance and Licensing

- **Permits:** Obtain necessary permits and licenses from relevant local, national and international authorities.
- **Food Safety Regulations:** Adhere to food safety standards set by official bodies
- **Environmental Regulations:** Comply with environmental regulations regarding waste disposal, emissions and resource usage.

2. Quality Control and Standards

- **Product Quality:** Establish standards for the final product quality, consistent with market expectations and regulatory requirements.
- **Raw Material Inspection:** Implement strict inspection procedures for incoming raw materials.
- **Hygiene and Sanitation:** Maintain high hygiene standards in all processing areas to prevent contamination.

3. Health and Safety

- **Worker Safety:** Follow Occupational Safety and Health Administration guidelines or equivalent for worker safety.
- **Training:** Provide regular training to employees on safety practices and emergency procedures.
- **Equipment Safety:** Ensure all processing equipment is regularly inspected and maintained.

4. Environmental Sustainability

- **Waste Management:** Develop efficient waste management systems to minimize environmental impact.
- **Resource Conservation:** Implement measures for conserving water and energy.
- **Emission Control:** Monitor and control emissions from the processing plant.

5. Operational Efficiency

- **Process Optimization:** Continuously seek ways to improve processing efficiency and reduce costs.
- **Maintenance:** Establish a routine maintenance schedule for all machinery and equipment.
- **Inventory Management:** Implement effective inventory management to ensure a steady supply of raw materials and efficient storage of finished products.

6. Supply Chain Management

- **Reliable Sourcing:** Establish a reliable network of raw material suppliers.
- **Transport and Logistics:** Ensure efficient and safe transportation of raw materials and finished products.
- **Cold Chain Management:** Maintain a consistent cold chain to preserve product quality.

7. Market and Consumer Research

- **Market Trends:** Stay informed about market trends and consumer preferences.
- **Product Development:** Innovate and develop products that meet changing market needs.
- **Competitive Analysis:** Regularly analyse competitors to stay competitive in the market.

8. Financial Management

- **Budgeting:** Develop and adhere to a comprehensive budget for operations.
- **Cost Control:** Monitor and control operational costs.
- **Investment Planning:** Plan for future investments in technology and capacity expansion.

9. Record Keeping and Documentation

- **Documentation:** Maintain accurate records of all operations, including sourcing, production, quality control and sales.
- **Traceability:** Implement a system for tracing products from raw material to final consumer.

10. Stakeholder Engagement

- **Community Relations:** Maintain good relations with the local community and address any concerns related to the plant's operations.
- **Employee Engagement:** Foster a positive work environment and engage employees in decision-making processes.

These rules form the foundational framework for establishing and operating a fish by-product processing industry. It's important to tailor these rules to the specific requirements of operation and continuously update them in line with evolving industry standards and regulations.

2 Introduction

The objective of the SAFE project is define optimal utilisation of unwanted catches provided from landing obligation in Croatia and to combine and optimize utilization of Category 3 by-products from the fish processing industry. The initiative aims to collaborate with Norwegian experts to exchange knowledge, data and best practices for set up Fishery by product processing in Croatia. The overarching goal is to bring about sustainable upcycling processes that would benefit both the environment and the industry.

This study evaluation needs to bring defined technic and technological solution and schematic diagrams for defined efficient production lines together with operation principles and base for related market and economic study for feasibility study and start up process in Croatia.

Idea is to follow up efficient production needs and open a space for learning and progressing in high value product development to be competitive on the market and create a base for training.

After the last round of consultations with the Ministry of Agriculture - Fisheries directorate and the Zadar County, based on presentation of all possible processing capacities presented by SINTEF OCEAN and NOFIMA, the following assumptions are defined:

- It is necessary to implement a pilot scheme for collecting fish discard in ports following principles of selection, cold chain and preservation.

- The focus of care for the pilot project is currently base on five fishing ports and landing sites: Rogoznica, Hvar-Vira, Tribunj, Brižine, Gaženica. The quantities of landings for main 10 ports are given in the tables

- Brižine and Gaženica port are smaller with no defined landing quantity.

- The estimated amount of catch for processing is driven from the value of total catch and represent 20 % of discard – extrapolated from commercial catch.

- ***Representative quantity from discard are not sufficient to make feasible productions so it will need to be combine with other sources of raw materials.***

- It is necessary to define small sorting devices on board, achieving also cold chain on boat and a reception on autonomous cooler in port with temperature control, define preservation methods and chemicals, simplified reception capacity and disposal, which would be transferred by autonomous truck with crane or cooler on the trailer - to the disposal processing centre one or more times per week and returned back in exchange. Each port is supposed to have a two of them. When one full container or bin with discard fish is taken, the other is left. A vehicle definition is required for such disposal via refrigerated containers or as an option on trailers.

Picture 1. Type as cooler in port or similar

Mobile Blast Freezer

MBF 10

Freezing Amount (24h)	**2750 kg/24h**
Compressor Power	**15 HP**
Chassis	**10ft Container**

- The accommodation position will be agreed later with port authority following main needs for energy supply, loading manipulation and safety.

- Through acceptance, it must be possible to weigh and register catch by ship so that it is known which ship delivered which quantity.

- Targeted production of fish meal, fish oil, concentrated hydrolysed fish protein as a raw material basis for food for the aquaculture, pet and fur industries - also possible human consumptions.

- The logistics units that need to be provided through conceptual and implementation design schemes in the waste by-product disposal centre in Poličnik.

- Line in a for the production of high quality fish meal and fish oil from whole fish and crabs - discard - mainly demersal resources combined with cephalopods by species sources.

- Product high quality aquaculture and pet feed

- Parallel line for the disposal of by-products from the processing of the fish industry - fish heads, bones and tails from the production of sardines, anchovy and tuna, seabass, seabream, freshwater fish. Product combination for high quality fish meal and oil for aquaculture/pet/fur/domestic animal feed.

It is important to make rules and techniques to avoid cross-contamination - to avoid mixing of one species with another regarding feed allocation.

- Line for silage capacity - lower quality raw material as a material for aquaculture, pet, fur, domestic animals

- Parallel lines of evaporation

- Lines for filling and stabilizing raw materials in final packaging - antioxidants

- Laboratory with complete instrumentation and devices for product quality monitoring

- Manufacturer's proposal for a possible performance

- Storage capacity for receiving fish in minus, storage capacity for finished products

- Office and other ancillary rooms can be defined as part of the project It is necessary to design equipment with the best possible efficiency in terms of the production of high-quality raw materials and lower consumption of energy and work in addition to the above

- A specific separate part will be necessary to design an experimental mobile sea lab container or a mini mobile line of capacity in which collagen and fish oil for nutraceuticals and pharmaceuticals would be produced from the highest quality raw materials, but which would be outside the scope of Poličnik as a production experimental unit for highest quality products – functional food and to teach operators

The project will focus on five specific areas of expertise:

1. Fish landing obligation - utilisation of discard resources capacity and product definition

2. Define opportunities to convert targeted fishery by-products into valuable products (high quality raw material for aquaculture and pet industry)

3. Proposed short and long-term directions, possible engineering design, definition of product lines and modules according to capacity, by-product structure and legislation rules

4. Definition of scope of Fish by-product management centre and auxiliary solutions for distance by-product handling and logistic

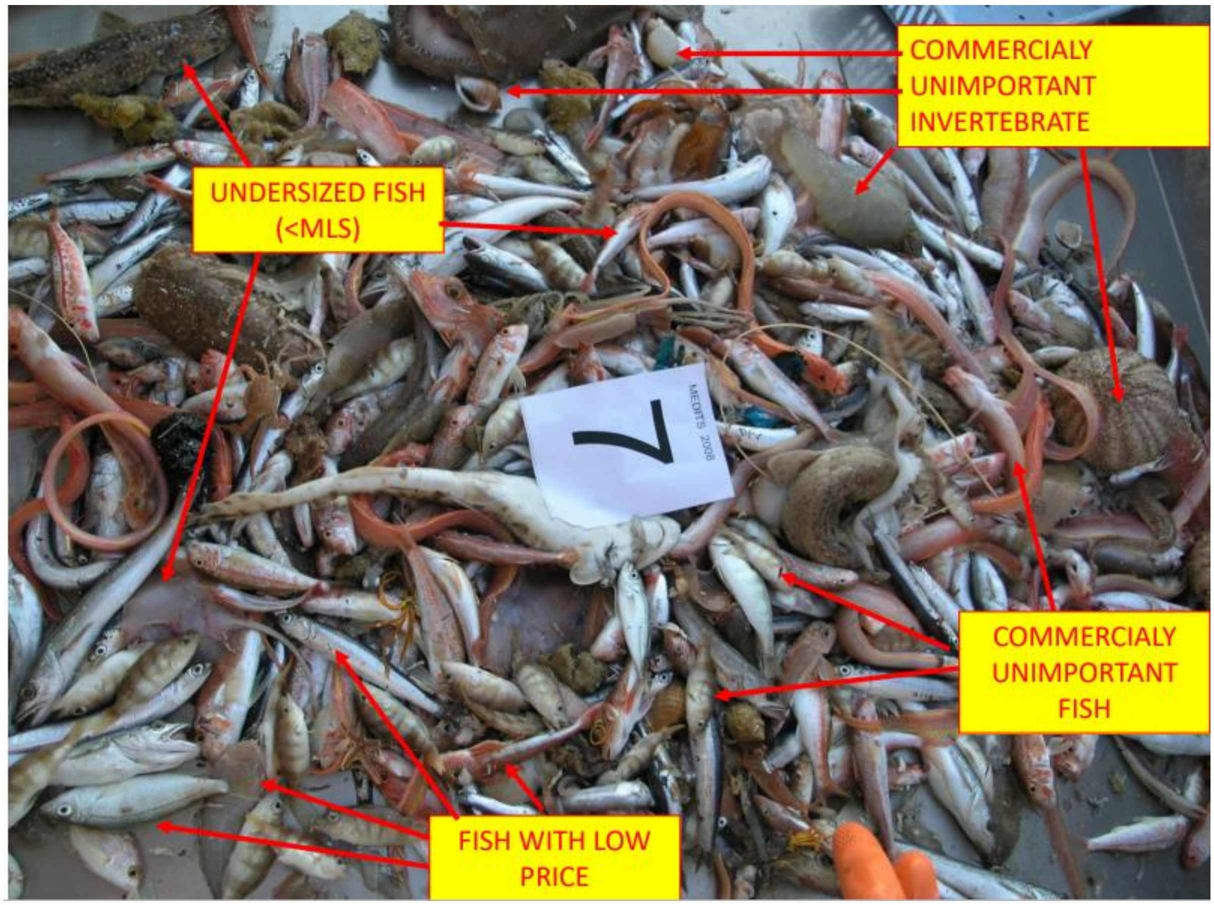
5. Product diversification and market

The outcome of the work on focus areas will be described in the “Report on sustainable management of fisheries and aquaculture by-products“.

3 Species review- Landings -numbers

Main focus - Landing obligation from Trawlers - whole fish and crustaceans highly depending of zone and period.

Picture 2. Trawler catch validation



Picture 3 & 4. Trawler seasonal catch seasonal and area distribution

Overall, discard represented 32.9±15.4% of the total catch. Multiple analysis of variance highlighted the significant effect on discard assemblage only for the factor of depth (p-value <0.05). In general, bony fish were the most discarded organisms (23.5±14.4%). Cartilaginous fish, crustaceans and other invertebrates represented approximately 13% of the total catch. The fraction of discard in the catch presented significant variation regarding the years, depth and fishing ground. Results showed that most of the discards in the deep water rose shrimp (DPS) fisheries are due to species that have a minimum legal size (Hake, DPS, *Trachurus* spp.), and are consequently subjected to the discard ban (art. 15 of the reg. EU 1380/2013). To avoid the landing of discards, specific measures aimed to minimize the unwanted catches of undersized species should be implemented.

MILISENDA, G., VITALE, S., MASSI, D., ENEA, M., GANCITANO, V., GIUSTO, G. B., BADALUCCO, C., GRISTINA, M., GAROFALO, G., & FIORENTINO, F. (2017). Discard composition associated with the deep water rose shrimp fisheries (Parapenaeus longirostris, Lucas 1846) in the south-central Mediterranean Sea. *Mediterranean Marine Science*, *18*(1), 53–63. https://doi.org/10.12681/mms.1787

3.1 Main species in trawl-net fishery

Picture 5. Hake

The energy value of haddock is 88 kcal / 368 kJ per 100 g of fresh food. In 100 grams of fresh haddock, there is 80% water, 0.85 g of fat, 17.2 g of protein, 0 g of carbohydrates, and 0 g of fibre.

Water 79.04%, total nitrogen 2.96%, ash 1.31%, lipid 2.24%, non-protein nitrogen 0.304%. There was a small effect of season on these values. The length/weight relationship, the condition factor, and the yields of various parts of the fish were also determined.

Pérez-Villarreal, Begoña, and Peter Howgate. "Composition of European hake, Merluccius merluccius." *Journal of the Science of Food and Agriculture* 40.4 (1987): 347-356.

Picture 6. Red mullet

The energy value of 100 g of fresh mullet is 117 kcal / 490 kJ, of which it contains 19.4 g of protein and 3.8 g of fat. In terms of minerals, fresh mullet contains potassium (357 mg), phosphorus (221 mg), magnesium (29 mg), selenium (36.5 µg), calcium (41 mg), iron (1 mg), zinc (0.5 mg), copper (0.1 mg), and iodine (65 mg). Fresh mullet also contains B complex vitamins, thiamine (0.1 mg), riboflavin (0.1 mg), niacin (5.2 mg), pantothenic acid (0.8 mg), vitamin B6 (0.4 mg), vitamin B9 (9 µg), vitamin B12 (0.2 µg), vitamin E (1 mg), vitamin A (123 IU), and vitamin C (1.2 mg). Mullet also contains omega-3 fatty acids, with 0.13 g of DHA (docosahexaenoic acid) and 0.26 g of EPA (eicosapentaenoic acid) found in 100 g of fresh mullet.

Picture 7. Deep water rose shrimp

Picture 8. Norway lobster

3.2 Landing ports – evaluation of discard

- pilot 5 fishing and landing ports for trawlers are selected for startup needs
- Tribunj, Rogoznica, Vira-Hvar, Brižine and Gaženica

Table 1. Landing trough 2022 in Port of Tribunj by month and quantity

Year 2022					
Landing site	**Gear**	**Month**	**Commercial landing (kg)**	**Number of vesels**	**Estimated discard kg**
TRIBUNJ	Trawl-net	1	25,980.90	19	10,392.36
TRIBUNJ	Trawl-net	2	28,798.85	20	11,519.54
TRIBUNJ	Trawl-net	3	33,847.90	25	13,539.16
TRIBUNJ	Trawl-net	4	24,360.60	19	9,744.24
TRIBUNJ	Trawl-net	5	68,394.27	25	27,357.71
TRIBUNJ	Trawl-net	6	60,220.85	25	24,088.34
TRIBUNJ	Trawl-net	7	55,956.90	22	22,382.76
TRIBUNJ	Trawl-net	8	59,712.20	21	23,884.88
TRIBUNJ	Trawl-net	9	23,659.60	18	9,463.84
TRIBUNJ	Trawl-net	10	43,938.30	21	17,575.32
TRIBUNJ	Trawl-net	11	43,028.70	18	17,211.48
TRIBUNJ	Trawl-net	12	24,368.30	18	9,747.32

Table 2. Landing trough 2022 in Port of Rogoznica by month and quantity

Year 2022					
Landing site	**Gear**	**Month**	**Commercial landing (kg)**	**Number of vesels**	**Estimated discard kg**
ROGOZNICA	Trawl-net	1	27,017.00	17	10,806.80
ROGOZNICA	Trawl-net	2	26,006.50	19	10,402.60
ROGOZNICA	Trawl-net	3	38,530.20	28	15,412.08
ROGOZNICA	Trawl-net	4	29,440.70	18	11,776.28
ROGOZNICA	Trawl-net	5	46,645.10	22	18,658.04
ROGOZNICA	Trawl-net	6	46,510.20	21	18,604.08
ROGOZNICA	Trawl-net	7	46,900.80	20	18,760.32
ROGOZNICA	Trawl-net	8	36,218.00	18	14,487.20
ROGOZNICA	Trawl-net	9	21,050.80	15	8,420.32
ROGOZNICA	Trawl-net	10	31,042.85	14	12,417.14
ROGOZNICA	Trawl-net	11	37,429.60	15	14,971.84
ROGOZNICA	Trawl-net	12	33,895.30	12	13,558.12
			420,687.05		**168,274.82**

Table 3. Landing trough 2022 in Port of Hvar- Vira by month and quantity

Year 2022					
Landing site	Gear	Month	Commercial landing (kg)	Number of vesels	Estimated discard kg
HVAR - VIRA	Trawl-net	1	28,726.20	13	11,490.48
HVAR - VIRA	Trawl-net	2	23,944.90	13	9,577.96
HVAR - VIRA	Trawl-net	3	32,546.20	13	13,018.48
HVAR - VIRA	Trawl-net	4	8,360.30	7	3,344.12
HVAR - VIRA	Trawl-net	5	24,151.90	12	9,660.76
HVAR - VIRA	Trawl-net	6	29,270.00	14	11,708.00
HVAR - VIRA	Trawl-net	7	25,967.50	13	10,387.00
HVAR - VIRA	Trawl-net	8	32,292.10	13	12,916.84
HVAR - VIRA	Trawl-net	9	16,229.90	13	6,491.96
HVAR - VIRA	Trawl-net	10	12,323.35	9	4,929.34
HVAR - VIRA	Trawl-net	11	41,966.70	14	16,786.68
HVAR - VIRA	Trawl-net	12	40,009.60	13	16,003.84

Table 4. Top 10 landing site for trawlers in 2022 – landing and estimated discard

Top 10 landing site- trawl-net 2022 year	landing commercial (kg)/(% per species)	Estimated landing discard kg
TRIBUNJ	**492,267.37**	**196,906.95**
KOZICA- Parapenaeus longirostris- Deep water rose shrimp	34.36%	
OSLIĆ- Merluccius merluccius- European hake	26.87%	
TRLJA BLATARICA- Mullus barbatus- Red mullet	10.09%	
ŠKAMP-Nephrops norvegicus-Norway lobster	9.15%	
LIGNJUNI- Todarodes sagittatus-European flying squid- similar	4.12%	
OSTALO- Other	15.41%	
ROGOZNICA	**420,687.05**	**168,274.82**
KOZICA- Parapenaeus longirostris- Deep water rose shrimp	35.83%	
OSLIĆ- Merluccius merluccius- European hake	25.47%	
TRLJA BLATARICA- Mullus barbatus- Red mullet	8.60%	
PIŠMOLJ- Merlangius merlangius- Whiting	5.68%	
ŠKAMP-Nephrops norvegicus-Norway lobster	5.51%	
OSTALO- Other	18.91%	
HVAR - VIRA	**315,788.65**	**126,315.46**

TRLJA BLATARICA- Mullus barbatus- Red mullet	45.28%	
OSLIĆ- Merluccius merluccius- European hake	33.37%	
KOZICA- Parapenaeus longirostris- Deep water rose shrimp	8.00%	
ARBUN-Pagellus erythrinus-Pandora	3.69%	
GRDOBINE-Lophius piscatorius-Angler and similar	2.03%	
OSTALO- Other	7.63%	
PRIMOŠTEN	**188,870.30**	**75,548.12**
KOZICA- Parapenaeus longirostris- Deep water rose shrimp	33.53%	
OSLIĆ- Merluccius merluccius- European hake	29.28%	
ŠKAMP-Nephrops norvegicus-Norway lobster	9.10%	
TRLJA BLATARICA- Mullus barbatus- Red mullet	8.98%	
LIGNJUNI- Todarodes sagittatus-European flying squid- similar	3.77%	
OSTALO- Other	15.35%	
VELA LUKA - JUGOZAPADNA STRANA TRAJEKTNOG PRISTANIŠTA	**135,634.00**	**54,253.60**
KOZICA- Parapenaeus longirostris- Deep water rose shrimp	50.59%	
OSLIĆ- Merluccius merluccius- European hake	20.50%	
TRLJA BLATARICA- Mullus barbatus- Red mullet	7.50%	
ŠKAMP-Nephrops norvegicus-Norway lobster	3.78%	
GRDOBINE-Lophius piscatorius-Angler and similar	3.17%	
OSTALO- Other	14.46%	
MURTER	**113,971.81**	**45,588.72**
OSLIĆ- Merluccius merluccius- European hake	45.58%	
TRLJA BLATARICA- Mullus barbatus- Red mullet	17.61%	
KOZICA- Parapenaeus longirostris- Deep water rose shrimp	14.17%	
LIGNJUNI- Todarodes sagittatus-European flying squid- similar	4.13%	
PIŠMOLJ- Merlangius merlangius- Whiting	2.73%	
OSTALO- Other	15.78%	
DUBROVNIK - GRUŽ	**104,331.46**	**41,732.58**
KOZICA- Parapenaeus longirostris- Deep water rose shrimp	39.34%	
OSLIĆ- Merluccius merluccius- European hake	23.33%	
LIGNJUNI- Todarodes sagittatus-European flying squid- similar	6.05%	
TRLJA BLATARICA- Mullus barbatus- Red mullet	5.13%	
GRDOBINE-Lophius piscatorius-Angler and similar	4.67%	
OSTALO- Other	21.47%	

KOMIŽA	**92,230.30**	**36,892.12**
KOZICA- Parapenaeus longirostris- Deep water rose shrimp	37.83%	
OSLIĆ- Merluccius merluccius- European hake	21.09%	
ŠKAMP-Nephrops norvegicus-Norway lobster	13.75%	
TRLJA BLATARICA- Mullus barbatus- Red mullet	5.87%	
PATARAČE-Citharus linguatula-Spotted flounder	3.98%	
OSTALO- Other	17.48%	
OREBIĆ - OPERATIVNA OBALA UZ RAMPU ZA TRAJEKTNI PROMET	**89,462.36**	**35,784.94**
KOZICA- Parapenaeus longirostris- Deep water rose shrimp	25.85%	
OSLIĆ- Merluccius merluccius- European hake	23.87%	
TRLJA BLATARICA- Mullus barbatus- Red mullet	12.11%	
RAŽE- Rajidae- Skate- family	10.38%	
GRDOBINE-Lophius piscatorius-Angler and similar	4.75%	
OSTALO- Other	23.03%	
MALI LOŠINJ - DIO UZ TRAJEKTNU RAMPU	**79,397.55**	**31,759.02**
TRLJA BLATARICA- Mullus barbatus- Red mullet	28.86%	
MUZGAVAC- Eledone moschata-Musky octopus	10.86%	
LIGNJA- Loligo vulgaris-European squid	9.46%	
OSLIĆ- Merluccius merluccius- European hake	8.61%	
TRLJA KAMENJARKA- Mullus surmuletus-Surmullet	5.16%	
OSTALO- Other	37.05%	

Estimated quantity for discard in top 10 ports are cca 813 t

Some other important by product from trawl nets-

Skin, head, viscera of Cartilaginous fish which cleaning and gutting is obligation to make on shore

Estimated quantity 50 t

This can be a nice source for specific collagen-gelatine production

Picture 9 & 10 Peeled cartilaginous fish-skin resource

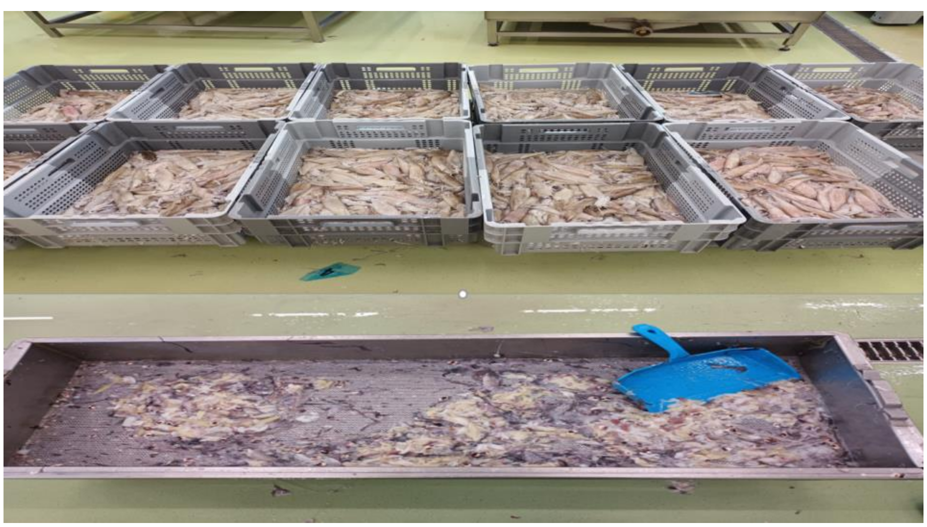

4 Other sources for byproducts

-Important sources from other processing industry- squid and cuttlefish – mostly import

Estimated quantity 1 000 t

11.European squid  12.Common cuttlefish 

Picture 13. Cleaning of squid



Other major sources of byproduct which can be used in combination with discard or separate

-Picture 14. By-product from farming seabass/seabream/meagre/freshwater species-

Estimated quantity 2000 tons

Picture 15. Whole or head, tails and scales from small pelagic-

Estimated quantity 10 000 t

Picture 16, Bluefin tuna processing

Estimated quantity 1 000 t

Total estimation of landing plus other by-products are together 14 863, 00 t, as a category 3.

It is an evident from the rough figures that processing of only discard is not feasible and need to be in combination with other sources of raw materials. Especially because some bycatch product already found niche market and it will be very important to attract those category for Poličnik pilot plant-

5 Chemical composition of different rat raw materials collected in Croatia

5.1 Intro - Fisheries discards

- Trawl-net discards (mix - red mullet, commnon pandora, ..)
- Trawl-net discards (squids, musky octopuses)
- Trawl-net discards (shark skin & viscera)
- „**discard**" – includes many fish species or by-catch products

1) little or no commercial value,

2) undersized or damaged commercial species

3) species that have commercial value but are caught in non-sufficient quantities for sale

Picture 17,18,19,20- Raw material for processing

5.2 Intro - Aquaculture side-streams

Samples – divided on the basis of its orgin

- Side-streams - A. bluefin tuna (head, fins)

- Side-streams – A. bluefin tuna (viscera)
- Side-streams – A. E. seabass, gilthead seabream) (viscera & filet trimmings)

Picture 21,22,23,24,25- Raw material for processing





5.3 Intro - Rest raw material of processing

- Rest raw material of small pelagic fish processing (sardine heads, tails)
- Purse seine discard („tuna bait”; Atlantic chub mackerel, sardine, ..)
- **SS, RRM** - low-grade whole fish, fish skeletons (heads and tails, viscera, skin and filet trimmings, shell material)

Picture 26,27,28,29,30- Byproducts ready for processing

5.4 Value of the byproduct

All samples material provided were stored (freezed) at -20 deegrees and prior the analysis were homogenized.

Picture 31 & 32. Homogenized sample of byproducts

The proximate composition of the different fish by-product samples was determined using the following Association of Official Analytical Chemists (AOAC) and International Organization for Standardization (ISO) methods.

Measuring chemical value (Table A), shows that raw materials contain approx. 20-50% dry matter. Amount of protein is quite stable: it varies form 13-20 %, while lipids vary from 2 till 20%. Ash makes up a smaller part of the rest raw materials, but can be measured up till 6% in rest raw material, probably containing significant part of bones. Chemical composition is one of the important factor setting the basis for choosing technological solutions for the preservation, processing and fractionation of rest raw materials to obtain valuable marine lipids, proteins and/or minerals (rich in calcium and phosphorus and other minerals).

Increased amounts of lipids in raw material gives an increased amount of oil fraction after fractionation. Some calculations made with cod rest raw materials indicated that raw material must contain more than approximately 6 g lipids/100 g of wet weight in order to obtain lipid as a separate lipid fraction. However, this number should be checked and validated for each rest raw materials. Based on this statement and data provided by Croation partners it can be indicated that only rest raw materials from tuna (head, fins) and seabass, seabream obtained from aquaculture and shark skin & entrails from fisheries sector can be used for extraction of oil by technological processing.

Table 5. Chemical composition of by-products/rest raw materials collected in Croatia. Data provided by creation project partners on 22 December 2023.

Rest raw materials	Crude Proteins	Crude Lipids	Ash	Moisture	Ca	P
By-product aquaculture – tuna (head, fins)	180,33±24,92	150,00±9,90	28,75±1,71	627,33±13,63	7,85±0,81	8,80±0,92
By-product aquaculture – tuna (entrails)	195,75±5,80	52,00±2,58	21,25±0,96	708,50±1,05	0,95±0,19	2,50±0,08
By-product aquaculture – (seabass, seabream)	133,70±16,94	286,75±51,33	25,25±1,50	565,33±25,13	10,73±0,98	2,95±0,19
By-product fisheries (sardine, heads)	154,63±15,01	26,75±4,65	56,00±1,41	771,00±3,22	15,45±0,48	7,85±0,69
By-product fisheries (mix – Red mullet, Common pandora, ..)	195,25±11,60	33,00±2,94	48,75±1,50	744,50±6,75	12,03±1,53	7,28±0,62
By-product fisheries (squids, musky octopuses)	146,33±13,07	30,25±0,96	19,00±0,82	801,17±1,17	1,40±0,32	1,65±0,10
By-product fisheries (shark skin & entrails)	187,55±43,15	212,75±77,66	14,00±1,83	551,67±19,37	1,08±0,17	1,60±0,12
By-product fisheries (bait; Atlantic chub mackerel, sardine, ..)	198,05±14,26	65,00±1,00	38,00±4,08	717,33±4,63	6,63±2,13	7,13±2,99

Table 6-Chemical composition- second analyse

Materials	Parameter (g/kg of wet weight)					
	CP	CF	Ash	Moisture	Ca	P
Side-streams - A. bluefin tuna (head, fins)	183,10 ±19,78	154,50 ±10,60	28,17 ±1,72	627,33 ±13,63	7,93 ±0,81	8,67 ±0,74
Side-streams – A. bluefin tuna (viscera)	199,55 ±8,02	53,00 ±2,61	20,50 ±1,38	708,50 ±1,05	1,07 ±0,19	2,50 ±0,06
Side-streams – A. E. seabass, gilthead seabream) (viscera & filet trimmings)	142,72 ±19,97	326,00 ±73,69	24,50 ±1,76	565,33 ±25,13	7,60 ±4,34	2,90 ±0,18
Rest raw material of small pelagic fish processing (sardine heads, tails)	156,63 ±12,29	29,67 ±5,99	55,00 ±2,00	771,00 ±3,22	15,40 ±0,48	7,93 ±0,60
Trawl-net discards (mix - red mullet, commnon pandora, ..)	192,87 ±11,56	33,83 ±2,64	50,00 ±2,28	744,50 ±6,75	12,13 ±1,53	7,48 ±0,58
Trawl-net discards (squids, musky octopuses)	149,63 ±11,47	31,67 ±3,20	19,00 ±0,63	801,17 ±1,17	1,53 ±0,32	1,70 ±0,11
Trawl-net discards (shark skin & viscera)	178,52 ±36,32	177,17 ±81,94	14,00 ±1,55	551,67 ±19,37	1,17 ±0,17	1,63 ±0,10
Purse seine discard („tuna bait"; Atlantic chub mackerel, sardine, ..)	198,98 ±14,61	61,60 ±4,83	37,00 ±3,74	717,33 ±4,63	7,25 ±2,13	6,35 ±2,61

*S-S = Side-streams; RRM = Rest raw material

- CF – S-S aquaculture of E. sea bass and gilthead seabream
- CP - more consistent - RRM of fisheries (Atlantic chub mackerel, sardines), (with red mullet and common pandora), entrails from the aquaculture of tuna

Graph 1. Crude protein and crude fat driven from samples

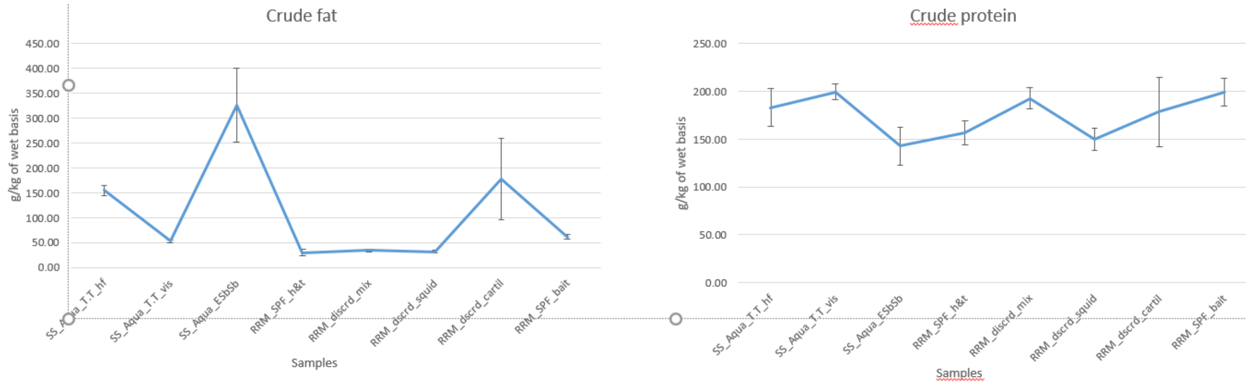


Table 7. Overall values range (all samples), regarding the analized parameter

	Overall range			
Parameter	**min**	**max**	**avg**	**SD**
Crude protein	142,72	199,55	171,13	27,40
Crude fat	29,67	326,00	109,43	106,54
Ash	14,00	55,00	31,02	14,27
Moisture	551,67	801,17	685,85	89,33
Ca	1,07	15,40	6,76	5,24
P	1,63	8,67	4,90	2,98

Table 8. Overall values range of certain fishes

Species	Byproduct	Protein (%)	Fat (%)	Humidity (%)	Ash (%)	References
Argentine hake (*Merluccius hubbsi*)	Gonad	21.95	10.92	68.72	11.61	(21)
	Liver	16.38	29.71	55.79	1.61	
Tilapia (*Oreochromis nilotica*)	Skeletons	50.6	30.6	65.3	15.3	(22)
Cape hake (*Merluccius capensis*)	Byproducts	18.0	1.1	78.5	1.9	(23)
Atlantic salmon (*Salmo salar*)	Viscera	8 ± 2	44 ± 9	60 ± 8	1 ± 0	(16)
	Heads	13 ± 1	22 ± 2	39 ± 4	4 ± 1	
	Skeletons	15 ± 1	27 ± 1	42 ± 2	4 ± 1	
Black Sea anchovy (*Engraulis encrasicholus*)	Head	13.39 ± 0.17	10.02 ± 2.38	70.94 ± 1.23	5.00 ± 0.35	(24)
	Frame	16.47 ± 0.38	15.50 ± 0.78	59.72 ± 1.16	7.60 ± 0.55	
	Viscera	12.05 ± 1.44	23.90 ± 4.36	61.50 ± 3.59	2.09 ± 0.22	
Mackerel (*Trachurus mediterraneus*)	Muscle	21.4	1.0	77.5	1.5	(25)
Sardine (*Sardina pilchardus*)	Muscle	18.8	1.2	78.1	1.5	
Cuttlefish (*Sepia officinalis*)	Viscera	17.45 ± 0.25	4.78 ± 0.7	74.99 ± 0.1	1.95 ± 0.0	(26)
Yellowfin tuna (*Thunnus albacares*)	Skin	32.38	3.22	0.67	62.57	(27)
Blue shark (*Prionace glauca*)		22.79	0.24	76.03	4.24	
Greenland halibut (*Reinhardtius hippoglossoides*)		15.95	10.62	55.44	17.63	

Lopera et al., 2018

Table 9. Proximate composition of the protein for certain fishes

TABLE 1. ***Proximate composition (g/100 g dry weight) of the protein feedstuffs evaluated in this study.***

Feedstuff	Dry Matter	Organic matter	Crude protein	Lipid	Ash	Gross energy (kcal/g)
Anchovy fish meal	93.2	84.4	71.6	10.0	15.6	5037
Shrimp by-catch meal	96.8	75.5	70.9	5.2	24.2	4639
Shrimp processing waste meal	92.1	73.2	54.1	7.3	26.8	4443
Pacific whiting meal	89.3	93.5	80.0	12.3	6.5	5720
Pacific whiting meal with solubles	86.3	93.2	77.3	15.8	6.8	5629

Means of two replicate analyses.

Hardy and Gatlin, 2005

Table 10. Proximate composition of the seabream byproduct

	(g/100 g) *	Head				Gills				Intestines				Trimmings				Bones				Head			
		Large		Small		Large		Small		Large		Small		Large		Small		Large		Small		Large		Small	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Gilthead Sea Bream	Moisture	57.3	0.7	62.4	0.2	66.6	0.3	62.9	0.8	67.1	1.0	57.15	0.5	48.6	0.1	53.1	0.2	53.3	0.7	74.5	0.8	53.0	0.5	61.2	0.1
	Ash	18.11	1.24	21.39	1.33	16.60	0.40	17.49	0.30	3.57	0.06	2.62	0.07	45.76	2.29	47.26	0.73	26.62	0.10	27.70	0.58	6.02	0.17	4.36	0.17
	Protein	32.40	0.45	37.19	0.67	31.49	0.42	38.50	1.47	37.23	0.75	26.87	0.35	41.85	1.00	45.10	2.30	34.02	0.98	40.74	1.57	43.16	0.89	49.67	0.11
	Fat	37.08	4.19	28.76	0.47	37.46	1.16	26.69	0.23	43.19	0.35	55.12	0.98	5.45	0.09	4.09	0.33	30.56	0.11	21.47	0.54	46.39	3.45	45.94	0.54
	Carbohydrates	12.41	4.39	12.66	1.56	14.45	1.30	17.32	1.52	16.01	0.83	15.39	1.04	6.94	2.50	3.55	2.44	8.80	0.99	10.09	1.75	4.43	3.56	0.03	0.02

Kandyliari et al., 2020

6 Project assignment

Project task for building a processing plant with 2 or three product lines requires a comprehensive approach, considering various aspects like process design, equipment selection, layout planning, and integration of a laboratory for quality control. Here's an outline to guide you through the process:

1. Project Overview

- **Objective:** Develop a processing plant (possible Poličnik area) with three distinct production lines for fish meal & fish oil, concentrated hydrolysed fish protein, and silage. It is a need to also plan Mobile processing unit for collagen production as an experimental station for high value product.
- **Capacity:** Each line to process 400-1000 kg/hour. **Total estimation of landing plus other by-products together are 14 863,00 t, as a category 3. In recent period those by-product started to be a commercial goods so it`s necessary to implement price for it, while landing obligations need to be obligatory for dedicated plant due to fishing regulatory obligations of controlling.**
- Heterogeneous composition possibility that more than one material or compound is present from production
- High level biosecurity-inactivate pathogenic microorganisms and endogenous enzymes to ensure food safety and modify the texture, composition, and colour of foods to make them acceptable for consumers, including an increase in digestibility and shelf life. Today, traditional heat treatments have been partially replaced by advanced processing methods such as microwave treatment ,ohmic heating and infrared heating

2. Site Selection and Plant Layout

- **Location:** Selected site considering logistics - Poličnik - Zadar County, In the existing production zone, cca **2 ha are possible for project of fishery by-product**

Picture 33 & 34. Poličnik- Grabi Comercial zone

7 Raw Material Sourcing and Management

- **Collection:** Establish protocols for collecting discards from ships.
- **Storage in Ports:** Implement a cold chain system for preserving raw materials at ports.

Basic (minimum) quality criteria for rest raw material is defined on the basis of quality regulations, hygiene regulations and regulations for food and feed additives. It is desirable to apply a preservation/conservation method that give the lowest possible rate of quality degradation processes. Based on these evaluations, chemical composition of raw material and available equipment the following stabilisation and preservation methods can be applied for storage and transportation:

1. Freezing,
2. Preservation with low pH (silaging),
3. Salting.

Freezing is one of the most usual technologies to stabilise raw material for storage and transportation. However, freezing of rest raw materials form fish, containing significant amount of water, can be energy consuming and expensive method.

Event freezing is defined as one of the best conservation methods to stabilise raw materials it is important to remember that storage temperature can be a key factor for chemical changes as it is known that even and minus temperatures several chemical reactions take place and they can influence the quality of raw material and out-coming products.

Stabilization by low pH (ensiling) of rest raw materials is a simple, well-established and profitable technology. Preservation of rest raw materials by adding acids has been known for centuries. Different (for example lactic, acetic, propionic, citric, formic, benzoic) acids added to raw materials and conservation principle is based on dissociation of acid after diffusion through the microbial cell wall. This reduces the cytoplasmic pH, and in combination with accumulation of acid anions, inhibits cellular functions. It is important to mention that ensiling can not only preserve raw materials, but also affect the quality of silage products and produces more degraded protein hydrolyzate and oxidized oil (Meidell, 2023). Formic acid is commonly used in fish processing and to reach microbiological stabile silage pH should be below 4.0. At this pH several endogenous enzymes are active and rate of autolysis is determined by the composition of raw materials, activity of digestive enzymes, achieved pH and storage temperature. In order to preserve high quality in rest raw material and output products, technology should be optimised with respect of type of acid added, silaging time and temperature addition of antioxidants.

Conservation by salting is achieved by addition of salt to fish of fish rest raw materials. Fish sauce production isa a popular product in many countries of. South-East Asia. The mixture is stored for several months at elevated temperatures, until a clear, amber water solution, rich in hydrolyzed protein and salt, can be recovered. Very few microorganisms can survive and grow at such high salt concentration. Fish sauce contain protein and free amino acids, together with short-chain fatty acids and aldehydes, adding cheesy and meaty aromas to the dominant sharp, salty taste. Lean raw materials are more suitable than fat raw materials, since the oil fraction does not contribute significantly to the volume of sauce recovered. To obtain good product stability, the amount of salt added to the fresh raw material must be in the range of 1:3–1:2 by weight. Fish sauce mostly is uses as a salting and flavouring condiment for vegetable dishes. It is also proved that rest raw materials like skins can be preserved by salting, which did not significantly influnce quality and yield of following gelatine extraction.

- **Transportation:** Arrange logistics for the delivery of raw materials to the Poličnik plant.

7.1 Summing up collecting, landing, conservation and storage of marine raw and rest raw materials

The following points should be taken into account while establish protocols for collecting, landing, conservation and storage of marine raw and rest raw materials:

- Temperature control: temperature need to be reduced right after harvesting and must be lowest possible while transporting/storage: preferably on ice,
- Fish should be fractionated if possible: each fraction should be stored/transporter separately;
- Preservation methods/technology should be chosen based on intended use of final products/ingredients: to ensure what human grade raw materials will not be allowed to use for human consumption due to improper choice of equipment and preservation means,

7.2 Raw Materials utilisation:

- Utilize discards, by-products from sea bass, sea bream, tuna and other freshwater fish processing, and parts of small blue fish (e.g., heads and guts of sardines and anchovies).

- In recent decades, the interest to decrease the environmental impact of by-products and rest raw materials from fishing and fish processing activities has increased in the Nordic Countries [a]. Approximately 29% of the total landings can be considered as under-utilized, unexploited or as by-catch. More than 1 000 000 tons of rest raw material is generated in Norway each year [b]. Most of Norwegian aquaculture industry and pelagic fisheries regards rest raw materials as valuable products, utilizing 91% and 100% of the available resources respectively, while whitefish industry still needs to increase the utilization of their underutilized rest raw material resources, which todays counts 56 % of resource utilization. The biggest part of utilised rest raw materials is used for silage production, followed by production of fish feed, fish oil and protein hydrolysates (16%), the latter two intended mostly for feed. Only a relatively small proportion (10%) is processed for human consumption (b). The current fish ensiling process was developed to handle mixed rest- and by-products of varying age and quality from the traditional fish industry. The proper slaughtering and processing of the fish generate fresh, high-quality rest-materials and by-products that may be separated into different fractions. These characteristics allow their use in high quality feed across important life stages of several animals and fish especially because of the highly digestible essential amino- and fatty acids (c). These raw materials therefore have great potential to be used for products to more demanding, but also better paying markets such as ingredients, e.g. protein hydrolysates, for use in functional stage specific diets for poultry, pet food including nutritional supplements for human consumption. This requires hygienic handling of the by-products to ensure food safety as well as methods to generate storage-stable products. A large industrial segment deals with extraction and purification of marine lipids from various fish material. Marine proteins, on the other hand, have received much less attention, despite their high nutritional value.

- Higher fishing efficiency, increased quotas and technical regulations has led to downscaled attention to increased value creation from whitefish rest raw material. Higher percentages of available resources are utilized by the coastal fleet since it delivers fresh raw material (often round fish) to the land-based industry, while sea going vessels produces headed and gutted (HG) frozen products, generating rest raw materials-fractions on-board. Due to economic and technical issues such as limited storage space and freezing capacities, the vessels are not able to store and treat the rest raw material properly resulting in low quality materials with limited applications.
- The quality of ingredients (eq. oils and proteins) produced from rest raw materials depend upon sorting, storage and handling practices of the rest raw materials. Marine rest raw materials are especially vulnerable when it comes to spoilage and degradation, and prolonged storage of these materials gives increased concentration of free fatty acids (FFA) (d), increased oxidation (e), reduction in the molecular weight of proteins (f) and formation of biogenic amines (g) leading to

the degradation and quality loss. To utilize a higher amount of the rest raw material generated by the fishing vessels, the rest raw materials need to be preserved by thermal and/or chemical methods in order to increase their shelf life or be processed into semi-manufactures or ingredients on board. The catches are today preserved mainly by cooling or freezing, but new methods are needed to delay the breakdown and increase the value of the biomass. However, application of these technological solutions is costly and, as long as there are no obvious economic incentives to increase the use of rest raw materials, it is difficult to encourage value creation. In the Norwegian coastal- and pelagic fleet most of the rest raw materials are processed onshore. Other coastal countries such as Iceland have introduced new regulations that force the seagoing vessels to take care of the rest raw materials and bring it onshore Icelandic regulations also specify that heads and cut-offs from trawlers producing frozen fillets or HG-fish should be landed. It is likely that Norway will enforce similar regulations in the future, thus it is important to investigate the possibilities for cost-effective utilization of rest raw materials before that occurs. Studies have shown that use of chemical preservation agents as acetic acid and sodium sulphite prolongs the shelf-life of rest raw materials and reduces oxidation and the formation of FFA However, the preservation effect varies depending on the origin of the rest raw materials (eq. pelagic species, whitefish or salmon) and need to be optimized in each case. Developing and optimisation of solutions for optimal on-board handling, preservation and storage of rest raw materials by using a combination of chemical preservation agents and thermal solutions (e.g. freezing, post combustion drying) is a key factor leading to better utilisation of valuable marine rest raw materials. It is showed that synergy of several traditional methods for processing of rest raw materials could give several high-quality ingredients.

- In Norway, international guidelines about reuse of rest raw materials from discard and bycatch of fish entered into force in March 2011 (j). Inefficient use of rest raw materials in whitefish supply chains not only contributes to an adverse environmental impact on living resources, but also on the environment due to dumping of rest raw materials. The logistic solutions should secure the volumes needed for industry scale systems in a way that secures the quality of the rest raw materials and the profitability. In addition, the environmental impacts from transport should not outplay the benefits from improved resource utilization. New, optimised and improved logistic solutions to design and operate rest raw materials value chains calls for the use of quantitative methods from operations research. By increasing utilization of rest raw materials will carry a much lower environmental footprint

- The raw material's chemical composition, physical properties and quality are decisive, dimensioning factors for the development and selection of the right preservation and process technologies. Rest raw materials from fish as well as fish are perishable commodities, and when the fish dies, a series of decomposition and degradation processes starts at once. Marine raw materials (included rest raw materials) represent a rich supply of easily available nutrients.

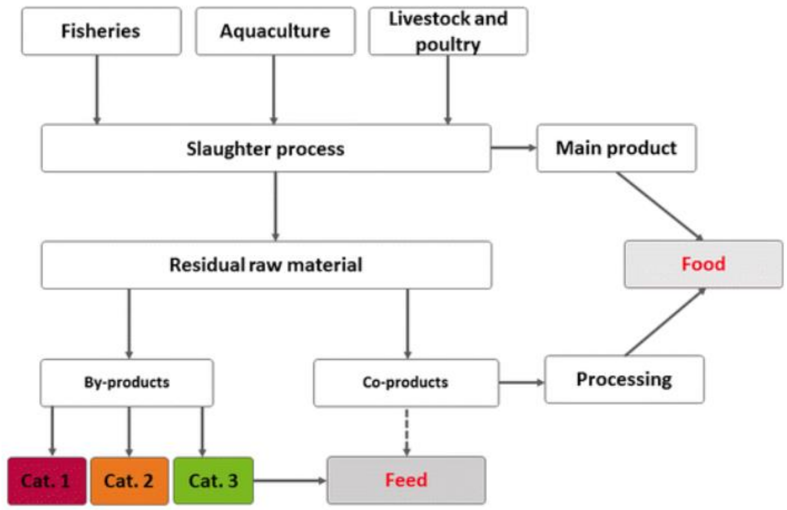
However, they have high moisture content and can therefore be easily spoilt by different microorganisms, which are naturally appear in water and other natural environment. Fish and fish rest raw materials van be contaminated with microorganisms via the fish themselves, e.g. from the gastrointestinal tract. Contamination can also come from the handling, processing environment, e.g. due to poor employee hygiene or process facility cleansing routines. Different endogenous lipases and phospholipases will lead to the formation of free fatty acids and reduce the quality and stability of the lipids (Falch et al, 2007; Jacobsen et al, 2009). In addition, poly-unsaturation patterns of marine oil makes then very perishable for oxidation and all accessible oxygen will cause oxidation of oil leading to undesirable quality changes and lost of valuable polyunsaturated fatty acids. At the same time, proteolytic enzymes will start hydrolysis and degradation of proteins and will cause a reduction in the quality, molecular weight of the proteins and thus reduce their functional properties (Rustad et al, 2014).

- Fishing, slaughtering, fractionating and filleting of very fresh fish not only produces superior quality fillets (and other main products), but also a variety of very fresh residual/rest raw materials. An initially high quality of the raw material is a key factor for producing different products and ingredients of superior quality. In the ideal world generated rest raw material need to be processed at once and this would ensure the best possible quality of outcoming products and ingredients. The EU legislation framework governs the use of rest raw materials from fisheries and aquaculture indicating that raw materials that do not meet the general rules for food hygiene or are classified as not suitable for human consumption are regulated by the rules of animal by-products regulations and derived products cannot be used for human consumption. Animal by-products are divided into three categories; 1, 2 and 3 based on their origin and potential risk to public and animal health and the environment. No ABPs can be used for human consumption, and only low-risk, category 3 by-products can be used for feed production.

Picture 35. Overview of animal by-product categories regulated by the EU regulation with examples of some approved uses of animal by-products in each category.

- Source: Aspevik et al., 2017.

Picture 36. Overview over processes in fisheries and aquaculture of fish and livestock to generate co- and by-products.



- Co-products are defined herein as rest raw materials from the slaughter process that have food-grade quality and can be further utilised for human consumption. By-products are materials, which due to quality, safety or/and regulatory issues are not suitable for human consumption. By-products can be divided into three categories based on their origin (Figure O) and potentially used in feed applications. Source: Aspevik et al., 2017.

- Aquaculture sector, as it is located on land or very closed to land has a bigger potential to handle and process super fresh fish as transportation time to processing plants can take only hours. In these cases, proper storage and transportation temperature is a key factor. Raw materials should be kept and transported on ice, in chilling systems based on circulation of refrigerated sea water or in combination with refrigerated fresh or at the cold room temperatures. It is also advisable to separate and fractionate different parts of the as some fraction like viscera contains more active endogenous enzymes which will influence the quicky enzymatic degradation of raw materials. However, not always it is possible to handle and process raw material right after catch (in the case of fisheries) and mapping of the value chains with emphasis on temperature monitoring during storage and transportation of the raw material should be done in order to identify the critical points connected to possible quality loss and deterioration. The quality of raw material will be reflected on quality of rest raw materials and can be the important factor determined the scope of usage of obtained fractions and ingredients.

- **Alternative Sources:** Plan for sourcing from freshwater fish to supplement raw material during low availability periods.

8 Processing technologies - overview

Mainly, there are three different technological solutions used for processing/fractionation of rest raw materials:

- Ensiling,
- Enzymatic hydrolysis and
- Thermal separation (often called the Fishmeal and oil process).

Figure A and Table B gives the overview over main technological steps and parameters used for the mentioned technological processing. There are also other methods at the research stage, such as pH shifts, but these are currently not relevant for commercial use on rest raw material from fish.

Picture 37. Methods for processing marine rest raw materials: A – ensiling, B – enzymatic hydrolysis, C – thermal/fishmeal production. From Falch et al., 2007.

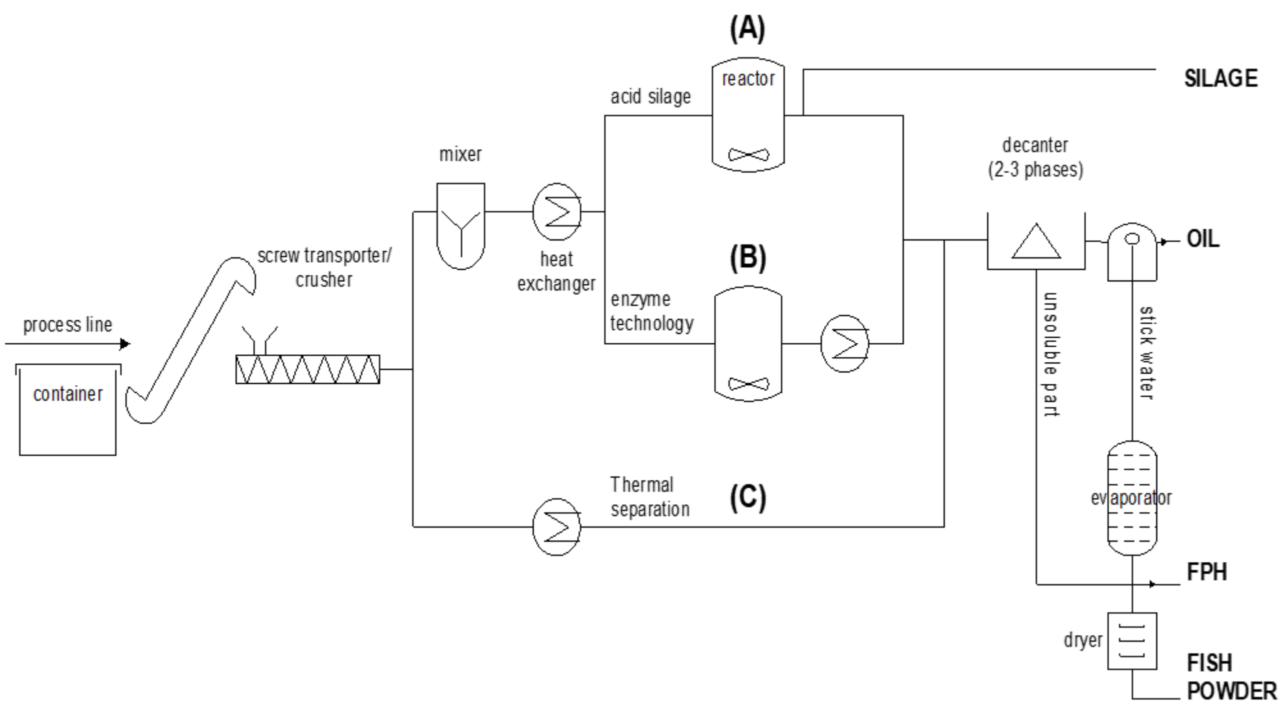


Table 11. Methods for processing marine rest raw materials, with selected process parameters, main and secondary products.

Metode	Temperature	pH	Time	Main products	Secondary products
Ensiling	10 ºC, 40ºC + >90ºC	2.9-3.8	24-48 hours + 10 min	Silage	
Hydrolysis	50ºC + >90ºC	Natural	60 min + 10 min	Protein hydrolysate	Oil, sediments
Thermal separation/fishmeal production	>90ºC	Natural	15 -30 min	Oil, fishmeal	

9 Processing technologies for fish-based products

When selecting the most suitable process for each specific situation, a trade-off is possible. Established processes, with relatively easy production and low investment cost, represent a somewhat restricted product segment. On the other hand, more complex technology often requires higher investment cost, but allows for wider end markets and possibly higher market price for some products. The available volume, its quality and nutritional properties, together with current legislation, regulate the potential use and processing demands for residual raw materials. In addition, market demand, consumer acceptance, feasibility, technology awareness, the required level of process control, and the available infrastructure influence the choice of the most beneficial and cost-effective process.

To facilitate and strengthen the Nordic cooperation and bioeconomy, a Nordic Centre of Excellence in Fishmeal and Fish oil was established in 2018 with support from the Nordic Council of Ministers. The expert group included members from Mátis (Iceland), DTU (Denmark), EUfishmeal, Nofima (Norway), FF Skagen (Denmark) Havsbrún (Faroe Islands) and TripleNine Group (Norway). Their report (Einarsson, Jokumsen et al 2019) contains a detailed review of the current knowledge on raw material quality and seasonal variation, processing methods and the nutritional properties and characteristics of fishmeal and –oils. Processing methods, both traditional and new were discussed along with applied analytical methods. The effect of fish species and seasonal variation on the nutritional and technical properties of fishmeal and –oils, were explored. Preservation methods throughout the value chain were also been discussed as well as food grade production regulations and end use.

A. MAIN LINES

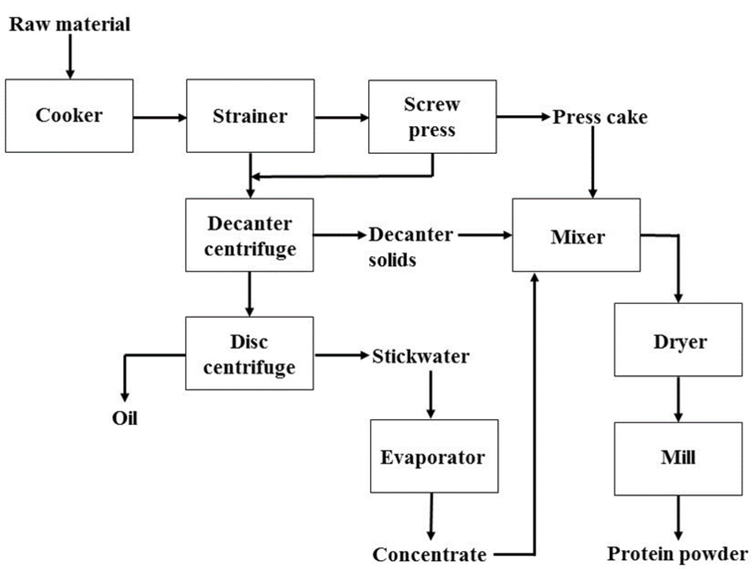
9.1 Fishmeal and oil production

Fishmeal & oil production, fishmeal process or thermal separation/extraction - several terminology can be used to dfine traditional production of fish oil and fishmeal. The method(s) uses heating (to 90 – 95 °C) to denature and coagulate proteins and destroy oil deposits, thus releasing oil and water so that the fractions can be separated from each other. In terms of equipment, the line layout can vary somewhat for both the heating stage and the separation stage. Typically, this takes far less time than ensiling, and the products can in principle be used for human consumption, although fodder production and/or pet food is far more common (FAO, 1986).

9.2 Fish meal process

By a combination of thermal and mechanical treatment, the fish based raw material is separated into a water-phase (press liquid) and solid phase (press cake), illustrated in Figure 1. Briefly, the raw material is heated to T > 80 °C to coagulate proteins, inactivate microorganisms, disrupt fat deposits, and release oil and water. After the heat treatment, the raw material run over a strainer to remove free water before mechanically pressed in a continuous doble-screw press to reduce water and oil content. The press cake is rich in non-water-soluble proteins, bones, and minerals. The liquid phase is separated into a stickwater and oil phase. The stickwater contains proteins, amino acids and other water-soluble compounds and is concentrated by evaporation before combined with the presscake and decanter solids and dried to a fish meal. Finally, the fish meal is milled to obtain the final protein powder.

Picture 38 Flow diagram showing the main unit operations applied in thermal processing of fish raw materials (Aspevik, Oterhals et al., 2017)

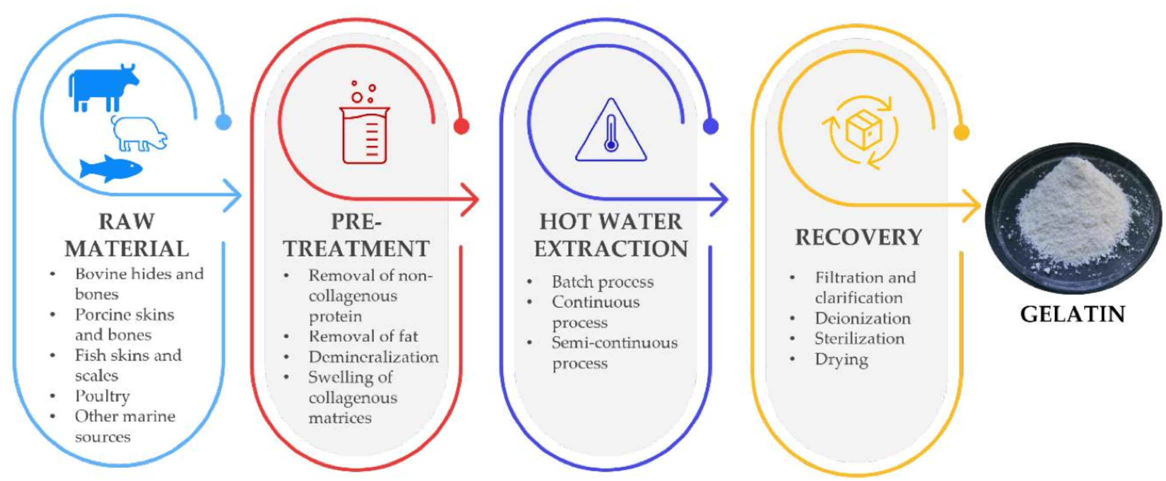


9.3 Collagen & Gelatine Line:

Recently the demand and use of collagen and gelatine have expanded in foods, pharmaceuticals and cosmetics. Traditionally, the industrial use of collagen was limited to porcine and bovine skin and bones. However, due to some disease (bovine spongiform encephalitis, foot and mouth diseases) as well as religious and social issues, and ecological impact of wasting fish rest raw materials are the driving force for the increasing commercial use of fish gelatine/collagen (Shahidi et al., 2019). Fish skin, scales, bones and fins can be used as alternative source of collagen/gelatine (Bae et al., 2008; Taheri et al., 2009; Karim and Bhat, 2009). Gelatine properties depends on the characteristic of the raw material source and the method of extraction used. Due to higher amount of hydroxyproline, mammalian gelatine has higher boiling and gelling points compared to marine gelatine. However, thickness for single fish gelatine films from various sources has been reported in the same range as the thickness for single mammalian gelatine films. Gelatine is derived from the fibrous protein collagen and is a mixture of water-soluble proteins of high molecular weight. The general collagen/gelatine extraction technology cover the following steps

- Raw materials preparation.
- Pre-treatment:
- Hot water extraction.
- Recovery.

Picture 39. Overview over gelatine extraction procedure. Source: Noor et al, 2021.



Complexity, pre-treatment and extraction steps can vary significantly and depend on raw materials and desirable yield, purity and composition of final gelatine. Generally, gelatine is generated from partially hydrolyzed collagen. Conversion of collagen into soluble gelatine can be achieved by heating the collagen in either acid, alkali or enzymatic hydrolysis The hydrogen bonds and some of the covalent bonds are cleaved at temperatures above 40°C, and this leads to destabilisation of triple helix structure of collagen leading to the formation of soluble gelatine. Extracted gelatine properties and yields depend on the pre-treatment method. Initially acid and alkaline pre-treatment are used for swelling of collagen and removal of non-collagenous protein. Type A gelatine usually is derived by acid hydrolysis and type B is derived by alkaline treatment. The differences between these two gelatines is that type A has its isoelectric point at pH 6-9, while for type B it is at pH 4.7- 5.4 (Siburian et al., 2020). Fish bones are rich in calcium, demineralization prior to gelatine extraction is crucial to improve the yield, purity and gel strength of the gelatine. Fish gelatine from cold water fish (cod, salmon) usually have poor gelling ability and their gelling temperature is usually below 8-10°C (Norland, 1990). The main constrain related to fish collagen is the establishment of a sound pre-treatment and extraction process for their commercial exploitation. Processing and extraction conditions, including time and temperature combinations and chemical nature of raw materials can affect the yield ad techno-functional properties of extracted gelatine.

9.4 Silage Line:

Ensiling, also known as acid preservation, hydrolysis or autolysis, is the process where fish or parts of fish (rest raw materials) is processed and hydrolysed using enzymes found in the raw material (called endogenous enzymes), at the right pH and the right temperature. As a preservative, an acid is usually used which brings the pH (acidity) of the mixture down to a level where bacterial growth in the fish mixture stops. There are different acids that can be used for this purpose, but the most common is formic acid. The products cannot then be used for human consumption. When the conditions are right, i.e. with a temperature above 5 °C and a pH of 3.5 to 4.0, the fish mass will begin to break down. This happens faster at higher temperatures (up to 40 °C), but the process usually takes 24-48 hours or more. The enzymes break down the muscle tissue and the acid dissolves the bones, so that the result is a liquid mass. In order to protect oil from oxidation several antioxidant can be added into initial silage mixture. Oil and protein are then easier to separate from each other. The mixture is heated and processed into oil and protein concentrate (designated as FPC – Fish Protein Concentrate) (RUBIN, 1993, Toppe et al, 2018).

Fish silage is a liquid product made from whole fish or fish side streams that are grinded and stabilized by the addition of formic acid to a pH<4.0. During long-tern storage (several months) at acidic pH, the digestive enzymes break down the fish proteins into smaller soluble peptides and free amino acids. The process is inexpensive and does not require high investment-costs and is regarded as especially useful when only small amounts of fishery side streams are available.

The final liquified fish can be heat treated, separated to remove oil, and concentrated to a fish protein concentrate (FPC). For preparation of fish silage, the raw material must be ground, and the mixture stirred to ensure good contact between the raw material and added acid. At pH <4, enzymes naturally present in fish viscera degrade and liquefy the fish tissue without risk of bacterial spoilage. Antioxidants should be added to prevent oxidation of the fish oil. Production of fish silage is a relatively simple and low-cost technology but requires strict process control to avoid growth of spoilage bacteria. The rate of liquefaction depends on the type of raw material, its freshness, and the temperature of the process. Fatty fish liquefy more quickly than lean fish and the fish should be as fresh as possible. Fish silage of the correct acidity keeps at room temperature for at least two years without putrefaction. The final product is not suitable for human consumption, and silage technology should preferably be based on fish and residuals found unfit for food production.

- **Process Flow:** Raw material preparation, fermentation, stabilization, and packaging.

- Raw material reception, cooking, hydrolyse, pressing, drying, oil separation, and packaging. Same processing required for silage (stabilized) and fishmeal (fresh)

B. SEPARATE LINES

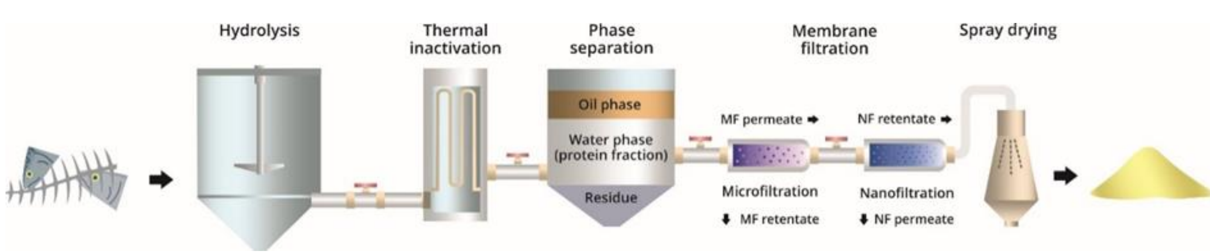
9.5 Enzymatic protein hydrolysis:

Enzymatic protein hydrolysis is a method commonly used to extract proteins from fish side stream products. The main purpose of a hydrolysis process is to degrade and solubilize high molecular weight proteins to increase the yield of soluble proteins. Protein hydrolysis can be achieved chemically or enzymatically, where the latter is a preferred product for human consumption. The hydrolysis process will yield a water-phase (the protein hydrolysate), a sludge phase (non-soluble solids) and oil phase (if based on a fatty raw material). The fish protein hydrolysate (FPH) can be concentrated by evaporation and optionally dried to a protein powder with potential applications within a variety of food and petfood products.

The production of FPH includes the following steps:

- Preparation of raw material (mincing and dilution with water)
- Adjustment of reaction temperature (typically 60-70 °C)
- Addition of enzyme
- Hydrolysis reaction for a predefined time
- Inactivation of enzyme by heating to >85 °C
- Separation of the water, oil, and solid phases
- Membrane filtration to remove suspended particles and fat (microfiltration) and/or nanofiltration to remove salt and small metabolites (optional steps)
- Concentration and drying to a powder

Picture 40 Enzymatic protein hydrolysis ©Nofima



Proper dilution with water, usually 1:1, can prevent product inhibition and maximize product yield, but added water is also a factor influencing processing costs. In industrial operations, final products are often dried and a compromise between desired product yield and water that needs to be removed is imperative. The hydrolysis process and enzyme performance depend on reaction temperature and pH. Several commercial proteases working well under the substrate natural pH are available, avoiding the need for pH-adjustment. At the end of the reaction, the enzyme activity is terminated by irreversible denaturation of the enzyme by heating the slurry to temperatures above 85 °C for at least 10 minutes. Finally, the slurry is separated into three phases: an oil phase, a water phase, and a sludge phase.

Enzymatic hydrolysis with the use of commercial (or endogenous) enzymes is a more advanced process that can be controlled by the type and amount of added enzyme, hydrolysis time and hydrolysis temperature, as well as the amount of added water. To hydrolyze means "to make water soluble", and the difference between autolysis/acid hydrolysis with endogenous enzymes and hydrolysis with exogenous enzymes (added enzymes) is that the process is faster and more controlled. Hydrolysis normally performed at 45-60ºC for 1 or several hours. After enzymatic hydrolyses enzyme are inactivated by high temperature (>90ºC) or addition of acids and different fractions are separate by centrifugation or/and decanting. The main fractions that can be separated out after enzymatic hydrolysis are fish protein hydrolyzate (FPH, water-soluble components), sediments (insoluble proteins, lipids, possibly bones) and fish oil (Kristinsson & Rasco, 2000).

9.6 Fish Oil Production Line:

Omega-3 fatty acids are polyunsaturated fatty acids (PUFAs) characterized by the presence of a double bond three atoms away from the terminal methyl group in their chemical structure. Fish is especially rich in the important omega -3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). EPA and DHA play a key role in many biological processes in the human body and are thus essential for human well-being. An Omega-3 process begins with high-quality, human-grade crude oil.

The quality of the oil depends on handling of the residual raw material received. The challenges associated with pelagic raw materials are that the quality changes happen quickly, and that the raw materials must be processed as quickly as possible after filleting in order to minimize oxidation during production. The rest raw materials contain high levels of blood and intestinal fractions of endogenous enzymes which may lead to enzymatic degradation and acceleration of oxidation. This in turn may lead to the formation of free fatty acids (FFA) and reduction in quality and stability of the oil.

The refining process includes following steps (Oterhals and Vogt, 2013):

1) Alkali refining to remove free fatty acids.
2) Winterization is performed to make the oil clear at refrigerator temperature. This process removes wax and high melting point triacylglycerols, like stearin.
3) Bleaching is done to remove oxidation products and reduce the level of heavy metals and environmental toxins.
4) Molecular distillation (stripping) at high temperatures to remove environmental toxins as well as FFA.

5) Deodorization and addition of antioxidant is carried out to remove odour and prevent oxidation of the oil.

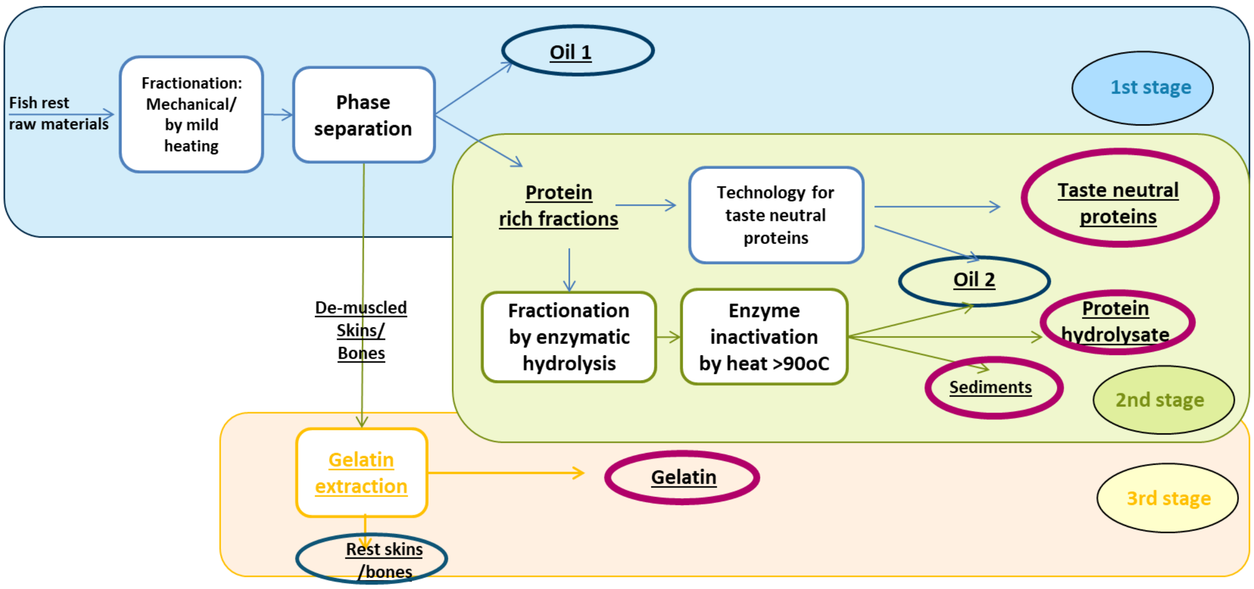
Oils from North Atlantic pelagic species (herring and mackerel) contain a high proportion of monounsaturated long chain fatty acids (LC-MUFA) which is challenging for the traditional process steps used by Pelagia-EPAX. There is a need to reduce the amounts of MUFA, which is a modified processing step. One of the biggest challenges when concentrating on selected fatty acids is to separate the LC-MUFA and omega-3 fatty acids EPA and DHA. Crude oil produced from Norwegian pelagic raw material has unwanted fish smell and taste. So, an effective deodorization technology must be applied to reduce this sensory attribute.

10 Optimal combination of traditional processing

Within traditional processing technologies for marine by-products and rest raw materials, the focus is often placed on processing a main product which can be oil or proteins. The process is designed and optimized to obtain either high amounts of oil or maximized solubilization of proteins (Table B above). Due to lower yield and/or insufficient quality, the proteins or oil are then considered secondary products.

SINTEF has proposed a three-stage concept (Figure B) that combines traditional (previously mentioned) methods that are optimized to process fatty marine rest raw materials to achieve maximum yield with the highest possible quality of bot marine oil and proteins. First, gentle thermal treatment lead to easier separation of muscle form skins or bones. Separated muscle fractions is used to extract oil, and then further processing of the remaining, protein-rich fraction. In the first step, mild thermal treatment (approx. 40 °C) of fresh rest raw material, up to 85% of the lipids in the raw material can be separated into high-quality oil. Early separation of a significant part of the oil results in reduced mass flow into the next process step, which then requires less equipment capacity, and results in reduced enzyme and energy consumption (Slizyte et al, 2018).

Picture 41. Three-stage processing/fractionation for the utilization of salmon skin or bones.

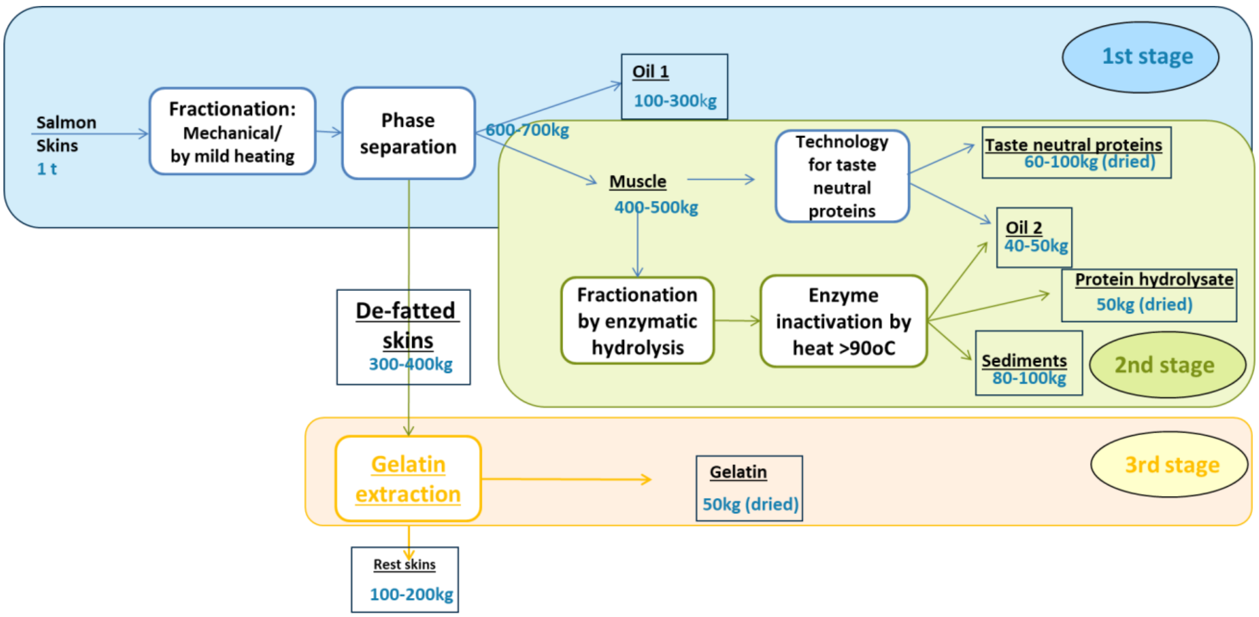


The second step covers the processing of the protein-rich fraction, which, after separating out a significant part of the oil, can be used for enzymatic hydrolysis. Then three products can be obtained: fish protein hydrolyzate (FPH, water-soluble components), sediments (insoluble proteins, lipids, possibly bones) and fish oil. Protein-rich fraction can also be used for the production of taste-neutral proteins. The technology covers several washing steps to wash out taste components to give protein fraction without taste (Mozuraityte et al., 2012).

In cases where skin and bones are further processed after separation of oil and muscle, you can obtain almost clean skin and bones, which can be a good raw material for collagen and gelatine extraction. This is step 3. Both fish bones and fish skin are rich in collagen and can be a raw material for the extraction of both marine collagen and gelatine. Different extraction technologies are used for the extraction of collagen and gelatine, and the optimal technology can be chosen based on the desired yield, chemical composition, quality and characteristics of the final products. Both marine collagen and gelatine are ingredients in high demand for many markets: the food industry, dietary supplements, medicine and cosmetics are just some of the sectors that have a growing need for marine ingredients such as collagen and gelatine.

Based on the average chemical composition of collagen and oil rich rest raw materials such as salmon skin and bone, the following products can be obtained using three-stage processing: High-quality oil, secondary oil, taste-neutral proteins, protein hydrolyzate and gelatine.

Picture 42. Three-stage processing/fractionation and possible products/ingredients when salmon skin is used as raw material



Picture 43. Three-stage processing/fractionation and possible products/ingredients when salmon bones are used as raw material.

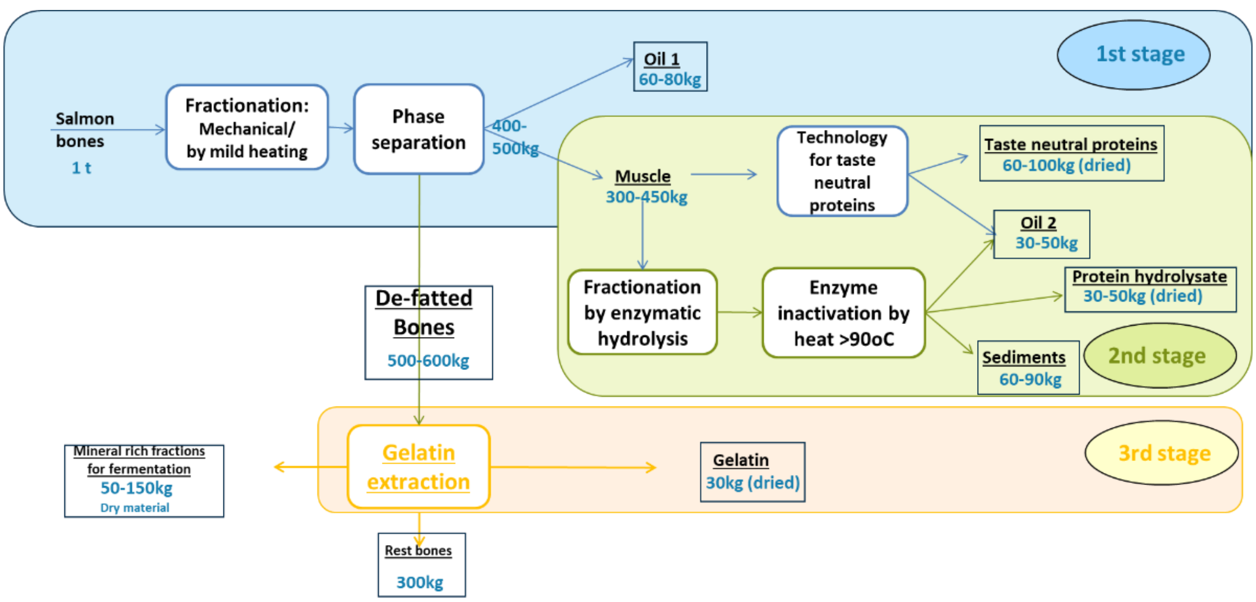


Table 12. Main products (and quantities, kg) that can be produced using three-stage processing from 1 tonne (1000kg) of rest raw material when salmon skin or salmon bones are used as raw material.

Raw materiall	High quality oil, kg	Secondary oil, kg	Taste-neutral proteins*, kg dry	Protein hydrolysate*, kg dry	Sediment/fish meal*, kg dry	Gelatin, kg dryr
Salmon skin	100-300	40-50	60-100	50	80-100	50
Salmon bones	60-80	30-50	60-100	30-50	60-90	30

* - Choice of technology in step 2 determines which products are produced: taste-neutral proteins or protein hydrolyzate and sediments.

10.1 Choice of preservation and processing technology

Preservation and storage methods/technology must be chosen based on quality, quality and availability of technological equipment (like access to freezers).

While processing technology must primarily be chosen based on chemical composition of raw material. Quality must also be evaluated. Raw materials based on chemical composition can be divided in several groups:

- Fatty fish and rest raw materials from them
- Lean fish and rest raw materials from them
- Collagen/gelatine rich raw materials.

It is important to notice that by processing fatty fish res raw materials (seabass, seabream) approx. 400-450 kg dry material (oil proteins, collagen, C/P rich fraction) from 1 tonne (1000kg) of raw material can be obtained, while more than 500 kg water need to be evaporated/removed. By processing lean fish res raw materials (sardines, heads) approx. 200-250 kg dry material (oil proteins, collagen, C/P rich fraction) from 1 tonne (1000kg) of raw material can be obtained, while more than 750 kg water need to be evaporated/removed. The overview of possible products and ingredients from these 3 groups are presented in the following tables:

Table 13. Main products (and coarse quantities, kg) that can be produced from 1 tonne (1000kg) of fatty fish and rest raw materials: Seabass and seabream are taken as example.

Raw material	Marine oil, kg	Taste-neutral proteins*, kg dry	Protein hydrolysate*, kg dry	Sediment/fishmeal*, kg dry	Gelatin, kg dry
By-products from seabass/seabream	120-240	20-80	20-80	300-400	5-25

* - Choice of technology determines which products are produced: taste-neutral proteins or protein hydrolyzate and sediments.

Table 14. Main products (and coarse quantities, kg) that can be produced from 1 tonne (1000kg) of lean fish and rest raw materials: sardines (heads) are taken as example.

Raw material	Marine oil, kg	Taste-neutral proteins*, kg dry	Protein hydrolysate*, kg dry	Sediment/fishmeal*, kg dry	Gelatin, kg dry
By-products from sardines: heads	0-20		50-100	100-150	20-50

* - Choice of technology determines which products are produced: taste-neutral proteins or protein hydrolyzate and sediments.

Table 15. Main products (and coarse quantities, kg) that can be produced from 1 tonne (1000kg) of Collagen/gelatine rich raw materials and rest raw materials: shark skin is taken as example.

Raw material	Marine oil, kg	Taste-neutral proteins*, kg dry	Protein hydrolysate*, kg dry	Sediment/fishmeal*, kg dry	Gelatin*, kg dry
By-products from shark; skin	0-20		50-100	100-150	150-250

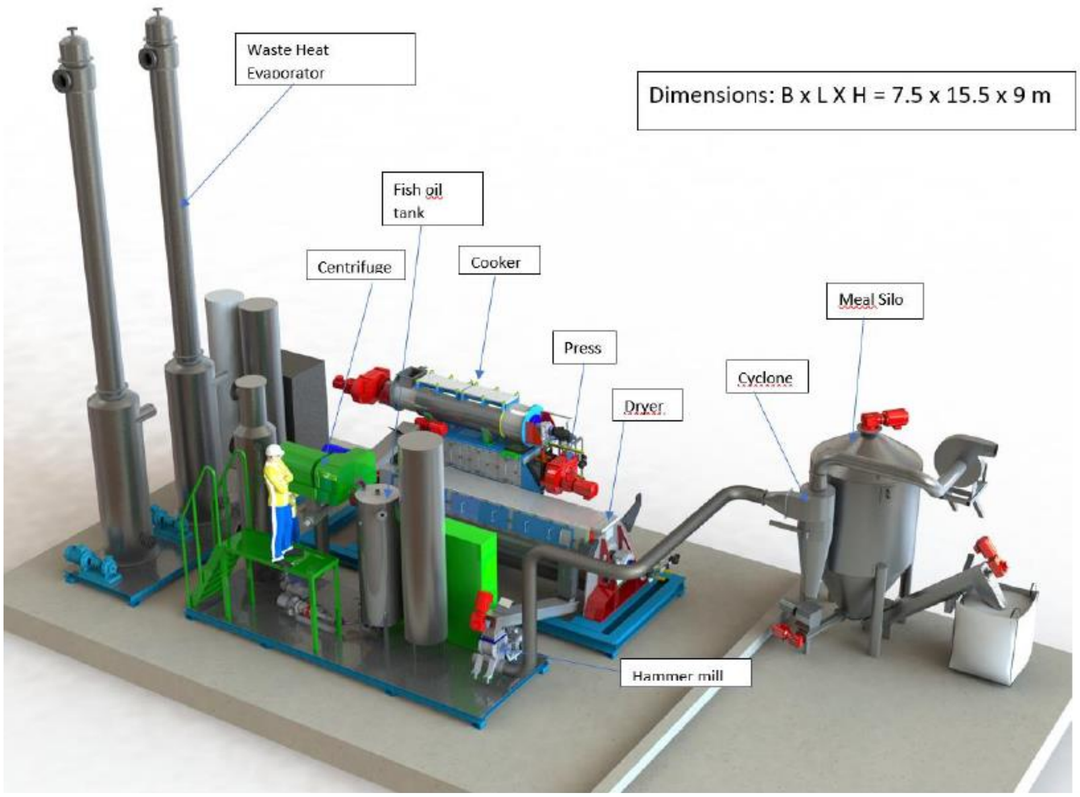
* - Choice of technology determines which products are produced: taste-neutral proteins or protein hydrolysate and sediments, or gelatin extraction.

11 Production Line Design & specification

11.1 Fixed line Equipment Selection

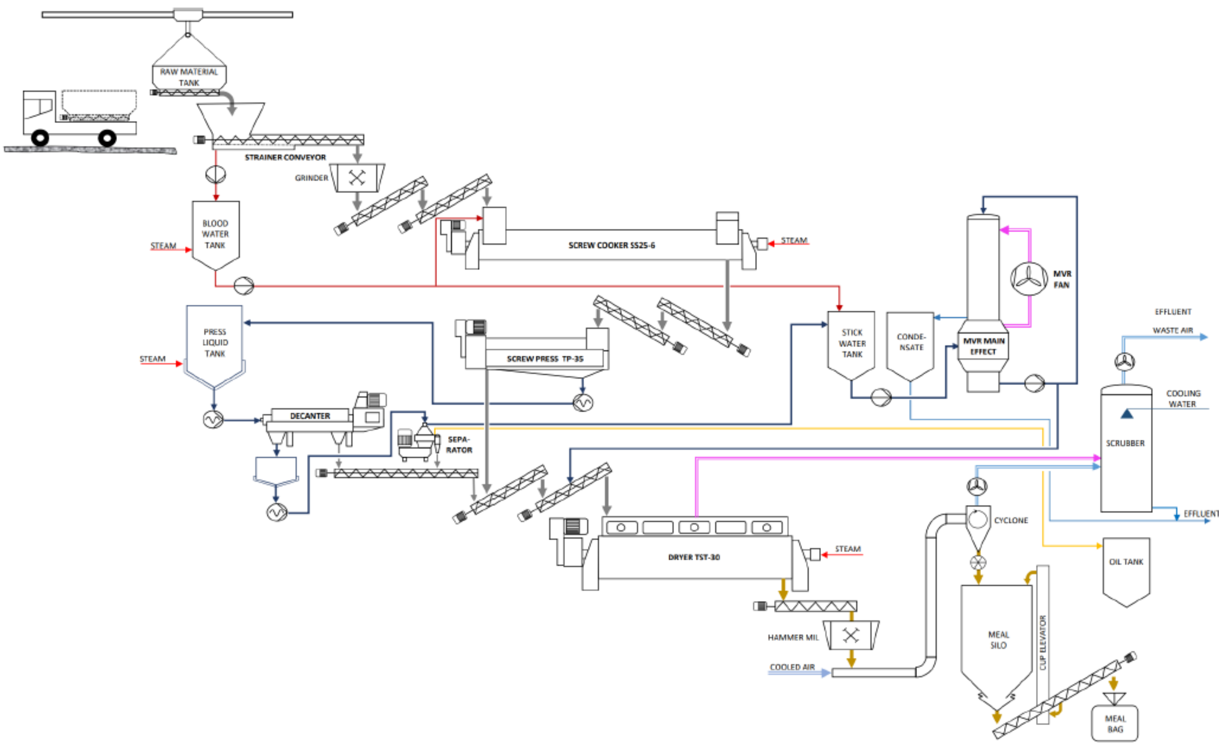
The Norwegian supplier Fjell Technology has proposed the following offer for a 50 Ton Per day fish meal/oil plant:

Picture 44. 3D Drawing of a 50 TPD fish meal/oil plant



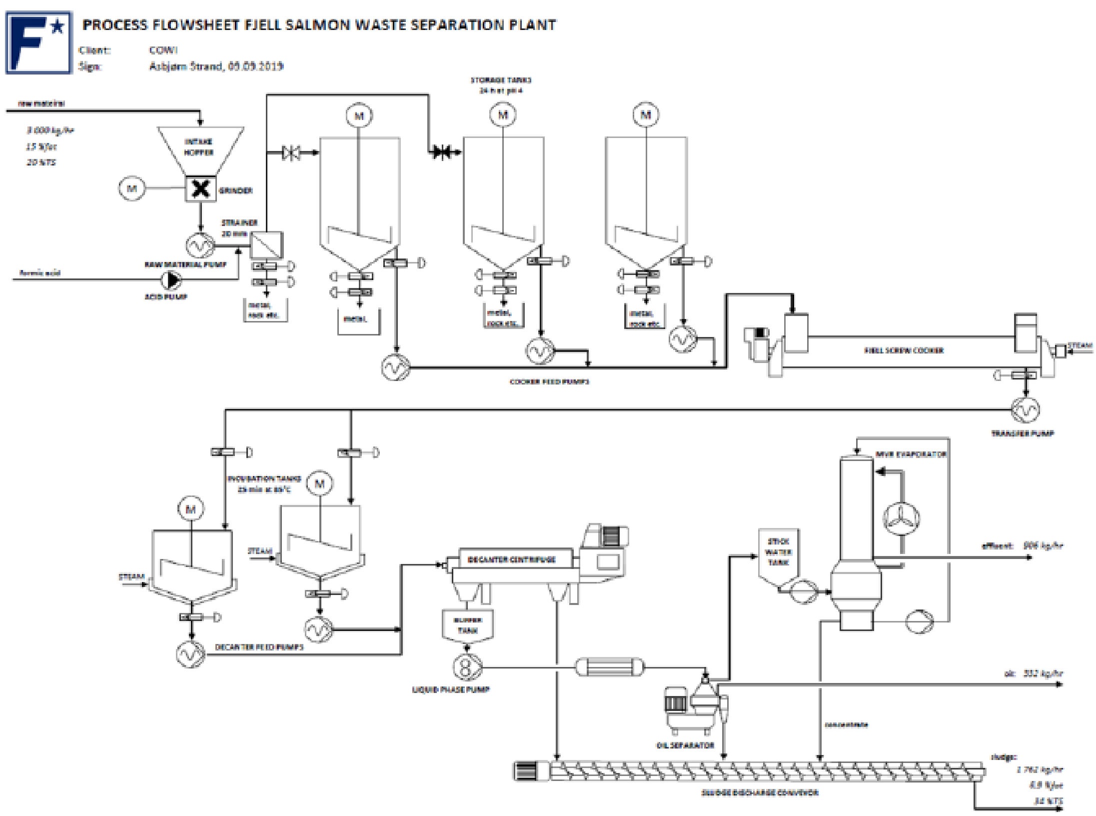
The main processing steps are 1) Raw material treatment/strainer, 2) cooking and blood water treatment, 3) cooking to 95 °C, 4) pressing to 35 % dry solids, 5) separation and oil polish, 6) drying to 92 % dry solids, 7) evaporation for protein collection, 8) meal storage and bagging, 9) scrubbing and odor treatment. Picture below shows a flowsheet of a typical fish meal and oil plant.

Picture 45 Fish meal plant



The silage concentrate process consists of 6 processing steps: 1) raw material storage and transportation, 2) cooking (heating to 95 °C), 3) incubation at 85°C for 20 minutes, 4) separation of dry solids/fat and stickwater, 5) evaporation. 6) cooling and storage. Picture below shows a typical fish silage plant.

Picture 46 Typical fish silage process plant



12 Choice of processing technology and factory design

Choice of processing technology and factory design should be made based on:

- Amount of rest raw materials/by-products
- Quality of rest raw materials/by-products
- Physical and chemical composition of rest raw materials/by-products
- Logistical and storage possibilities
- Available infrastructure
- Access to water, electricity

Both mobile and stationary technological facilities can be design for processing and utilisation of marine of rest raw materials/by-products.

12.1 Mobile processing plants

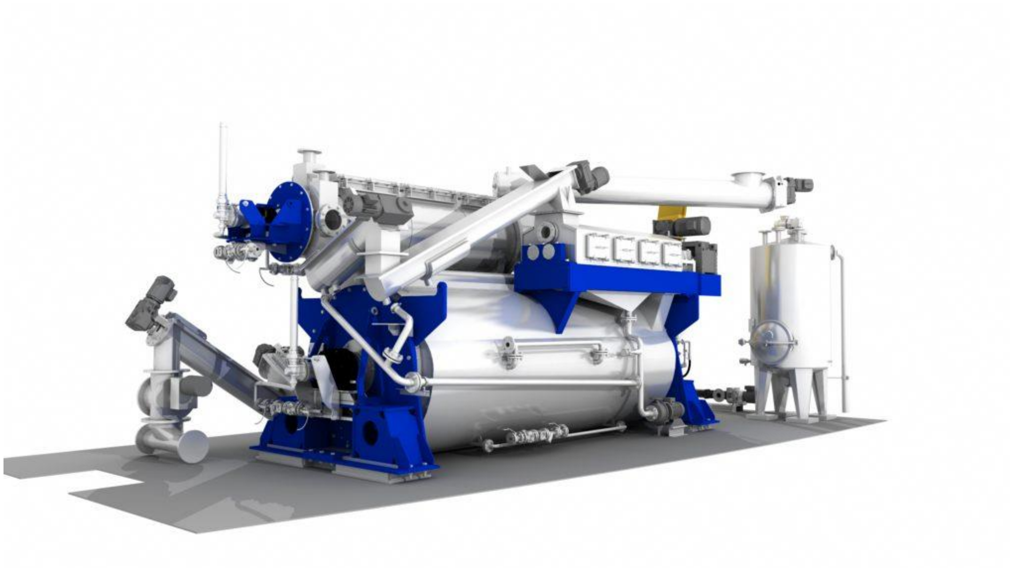
SINTEF Ocean have a mobile processing plant built for research and flexibility. It has been in operation since 2009 and has processed a wide range of (rest) raw materials. However, it is not designed with energy optimization and profitable production in mind, and should not be used for commercial production as it is.

https://www.sintef.no/en/all-laboratories/mobile-sealab/
Picture 47. SINTEF Ocean's "Mobile Sealab" (Photo: SINTEF.)

Amof-Fjell deliver compact fishmeal plants designed for fishmeal production onboard ships. These are so far not designed for hydrolysis processing, but standard fishmeal processing.
https://www.amof-fjell.com/no/plant-design/compact-fishmeal-plant/

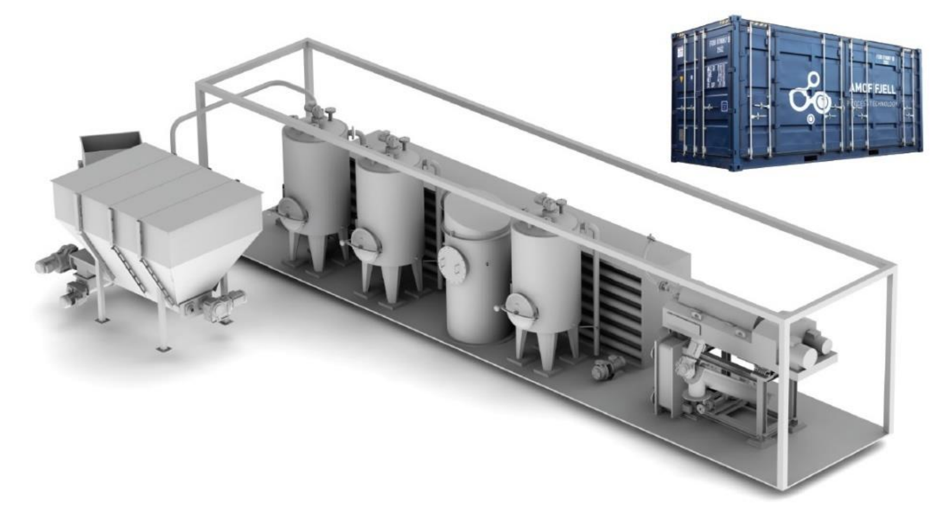
Capacity can range from 15-700 tonnes per day. They have delivered a lot of similar processing lines for both Norwegian and Russian fishing boats. They could possibly be placed in containers and utilized on land.

Picture 48. AMOF Fjell's compact fishmeal plant (Photo: AMOF Fjell)



AMOF Fjell have also designed a container-based fish oil factory. We are not aware that this has been manufactured, sold and/or tested.

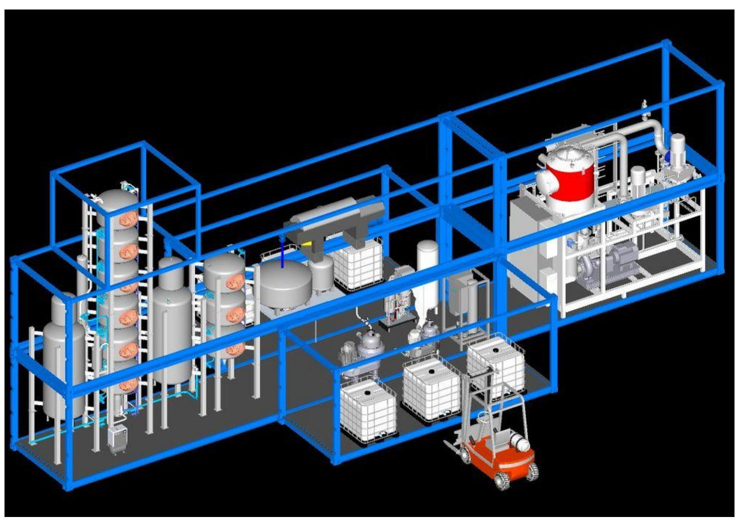
Picture 49. AMOF Fjell's mobile fish oil plant. (Photo: AMOF Fjell.)



Skala have designed a mobile processing plant for the first part of the hydrolysis processing to raw oil, protein water and sludge. This can be expanded with an evaporator and a drier and utilized as a complete mobile plant (in one large and two small containers). However, this solution has so far never been not been manufactured and tested. Processing capacity is said to be 300 kg/hour or more. Skala do not have

a dedicated home page for mobile solutions, but can be contacted for inquiries from their main home page https://www.skala.no/.
Picture 50. Skala's mobile processing plant. (Photo: Skala)

NUAS AS have designed a mobile hydrolysis plant for a variety of possible species, including the world's first mobile and inline (continuous) hydrolysis unit (not using a batch reactor). It is based on the same patent as the stationary factory at Nutrimar AS at Kverva. NUAS currently have a ongoing project where they will build the first full-scale prototype plant and test it on whitefish RRM (cod milt).
https://www.brukfisken.no/en/use-the-fish-technology/
Picture 51. NUAS' mobile hydrolysis factory (Photo: NUAS.)



GEA Westfalia also had a mobile container solution, but it was unfortunately decommissioned after a fire, and has not been restored. They have to our knowledge not pursued this nieche further, but focus on separation equipment. Worth mentioning is their CF 7000 "Fishmaster" decanter, said to be designed especially for separation rest raw material from fish (as the only such separator in the world so far; all others are redesigned from sludge handling machines. (This has quite a few implications for hygienic design and cleanability vs human consumption.)

As exemplified here, there are several process/equipment suppliers with different mobile/compact plants in various stages of TRL (technology readiness level). Note that none can be said to be fully tested and optimized technology that can simply be purchased off-the-shelf. Also, all perform the first process stages to the separation of oil, stick water/protein water and sludge (after tricanter), but that is not the complete line. Evaporation and drying and oil polishing/further refining should also be included in a commercial plant producing stabilized end products.

12.2 Logistics and process economy

Capacity in such mobile plants is lower both in terms of a) throughput per hour AND b) in operational time. This is because of a) more compact facilities and b) the need to transport the facility to the rest raw material where it is produced in adequate amounts. Not all small streams of rest raw material are sufficient to justify the deployment of the factory; a sizeable portion of the rest raw materials will still have to be stabilized and transported. Even with good and practical design of the mobile facility and its infrastructure/connections, there is still a lot of work involved in rigging down and up and transporting everything around.

If we consider ca. 240 working days available in a year (minus weekends and holidays), and well-planned logistics with suitable amounts of rest raw material available within a relatively short distance, we estimate that at least a third of the available time will be spent rigging up/down the line and transporting it to other locations. Thus only 160 days per year are actual operational time.

12.3 Processing capacity

Most mobile plants of this kind will have a processing capacity between 300 and 1000 kg/hour raw material input *for thermal separation* (or the first parts of standard fishmeal processing). Some may be said to achieve bigger numbers, but that requires larger equipment or more lines, and thus several containers more. In reality this will mean that higher capacity than 1 ton/hour is no longer an actually mobile plant. A larger plant can also be based in a series of containers and said to be possible to relocate, but in practice it should not be done with any hope of good production economy.

Plants based on batch hydrolysis suffer even worse in capacity, because of the simple volumetric physics in using a 1000 liters batch hydrolysis reactor in a container. In the largest 40 feet long standard shipping container it is possible to fit grinders, pumps, heat exchanger, tricanter and oil polisher, but not more than one (or possibly two) batch reactors. More batch reactors will require more containers. Further, the grinding/heating/infeeding to the batch reactor takes time, and also the ca. 1 hour holding time/hydrolysis reaction time. Thereafter comes the time required for inactivation of the enzymes and pumping time through the separation step (such as tricanter). Actual capacity therefore is significantly lower than for an

inline/continuous process, when there is no room for a series of batch reactors than can be run in sequence. The result is that possibly only two or three batches of 500 kg rest raw material can be run per working day, which gives an actual capacity for batch hydrolysis lower than 150 kg/hour.
Table 16- some typical production of compact fish plants AMOF-FJELL

Compact Fishmeal Plants (typical)

Type	*CFP-24**	*CFP-48**	*CFP-60*	*CFP-80*
Raw material capacity**	24 ton/24 hr	48 ton/24 hr	60 ton/24 hr	80 ton/24 hr
Meal output**	3,7 ton/24 hr	7,4 ton/24 hr	9,2 ton/24 hr	12,3 ton/24 hr
Oil output**	0,7 ton/24 hr	1,4 ton/24 hr	1,8 ton/24 hr	2,4 ton/24 hr
Steam consumption**	400 kg/hr	800 kg/hr	1 000 kg/hr	1 320 kg/hr
Cooker	TC1-2.5	TC2-3	TC3-5	TC3-5+
Press	TP21-2	TP23-2	TP24-2	TP-24-2
3 phase decanter	Included	Included	Included	Included
Dryer	AF TD-30+	AF TD-50+	AF TD-60+	AF TD-90+
Space requirement (LxWxH)***	8000x4000x3000	9000x5000x3000	13000x5000x3000	15000x5500x3500
Dry weight***	10 ton	16 ton	30 ton	35 ton
Electric installation (consuption is smaller)	70 kW	130 kW	150 kW	170 kW

* Skid based arrangement
** Nominal values given based on white fish offal (total solid 17,5%, fat 4%). Meal output is increased by 25-30 % with evaporator included
*** Area for meal handling system not included

13 Solution for Croatia

As discussed with researchers as well as government and industrial representatives during the visit to Croatia, the Norwegian researchers believe the solution most applicable here is NOT a mobile line for human consumption. Instead, we propose a stationary, combined line for both silage and standard fishmeal production. This can also include a separate line for hydrolysis processing to human consumption products from particularly suited parts of the available rest raw material.
The proposal is thus a factory comprised of (at least) three (somewhat separate) processing lines:
-fishmeal line for the average amount of available rest raw material
-silage line for small/insignificant side streams of rest raw material, and for seasonal tops that cannot be handled in the fishmeal line
-human consumption line for particularly interesting/valuable materials

Another issue that has to be incorporated in the planning/calculation of dimensioning capacity is farmed fish. RRM from these species cannot be processed in the same line as their intended feed, because of cross-contamination. Products from a farmed species cannot be fed to the same species. This can be solved by not producing feed for the local seabass/seabream market, but for export as feed for other species of farmed fish, such as salmon, trout etc. Or, the solution can be two separate fishmeal lines; one for farmed fish and one for wildcaught fish. There is, however, a question whether the amounts of wildcaught fish and farmed fish each on their own in Croatia are sufficient to warrant a separate line.

13.1 Dimensioning capacity

The most important basis for the projecting of any new processing plant is the dimensioning capacity; how many tonnes/hour (of what material) shall the calculations be based on? In this case there are many small streams of different rest raw materials, and all cannot be processed in the same way or in the same line.

Pelagic fish/high fat materials
Whitefish/low fat materials
Seasonality

To achieve an estimated dimensioning capacity, it is here necessary to obtain an overview of the amounts of available materials and when they are available. (Sample table over RRM and months.)
Table 17. Evaluation of dimensioning capacity for Croatia raw material

Dimensioning capacity Croatia rest raw working draft version- to check and adapt table

catch/farming evaluation 2025-worst scenario	Main species	JAN-ban	FEB	MAR	APR	MAY-ban	JUN	JUL	AUG	SEP	OKT	NOV	DEC	Calc TOTAL	TOTAL (overview)	Proposal for line to avoid croscontamination-to have a several products and achive higher value products	Product	Quantity achived	Price	Value
30000	Sardine head viscera		200	300	300		400	300	300	300	1000	1000	1000	5100	**5100**	Main line- fish meal/oil/FPC				
7500	Anchovy head viscera		40	80	80		80	80	80	80	300	300	300	1420	**1420**	Main line- fish meal/oil/FPC				
1500	Other small pelagic		10	17	17		17	17	17	17	60	60	60	292	**292**	Main line- fish meal/oil/FPC				
3000	Discard-fro Landing	50	50	50	50	150	150	150	150	50	50	100	100	1100	**1100**	Main line- fish meal/oil/FPC				
	TOTAL /month	**50**	**300**	**447**	**447**	**150**	**647**	**547**	**547**	**447**	**1410**	**1460**	**1460**	**7912**	**7912**	**Total for main line**				
	below also head/viscera																			
3000	Tuna	400	400	200										1000	**1000**	Special product line				
10000	Seabass	30	30	150	30	30	150	150	150	100	50	30	150	1050	**1050**	Special product line				
7000	Seabream	20	20	100	20	20	120	120	120	80	30	20	120	790	**790**	Special product line				
1000	Meager	2	2	2	2	2	10	10	10	8	2	2	10	62	**62**	Special product line				
	Squid	50	50	100	50	50	150	150	150	100	30	30	90	1000	**1000**	Special product line				
3000	Carp-other fresh	5	5	10	5	10	10	10	10	5	5	5	10	90	**90**	Special product line				
	TOTAL /month	**507**	**507**	**562**	**107**	**112**	**440**	**440**	**440**	**293**	**117**	**87**	**380**	**3992**	**3992**	**Total Special product line**				
														0						
														0						
														0						
66000	**TOTAL all per mon**	**557**	**807**	**1009**	**554**	**262**	**1087**	**987**	**987**	**740**	**1527**	**1547**	**1840**	**11904**	**11904**	**Total capacity**				
2025																				

2022=86013 **NOTES:**

Table without possible small pelagic bycatch
Considered fresh input-
Considering 80 not working days- possible cleaning
24 hours when working-285 days in three shift
to calculate storing capacity-frigo , defreezing chamber, warehouse
Main line raw material f fish meal, fish oil ,FPC
To consider from special line -Possible products for ornamental/juvenile fish- small packages
and farmaceitics, nutraceutics....
To define packaging of main product and define marked
Fix plant in favour to mobile
To define laboratory
etc....
like management- public/private, economics......

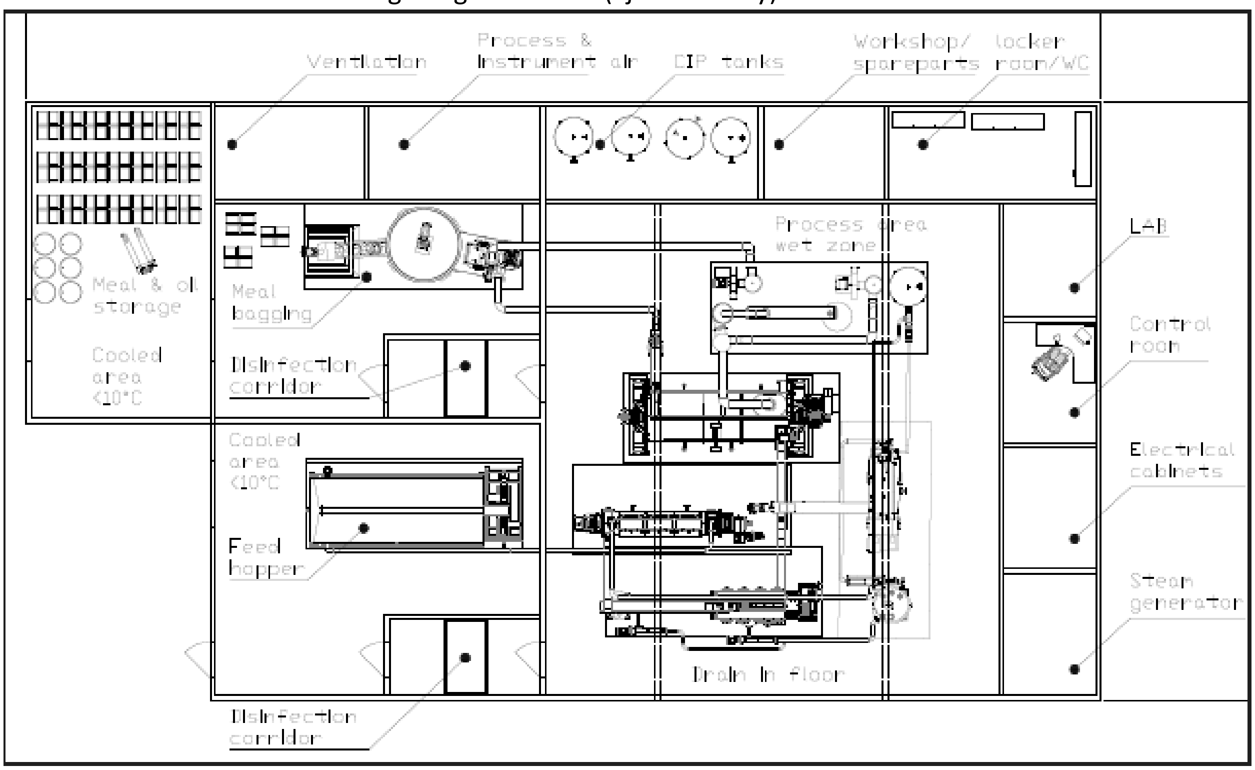
Silage- auxilary suport- for tops/small catches- when reach quantity pass main line
Fishmeal line to feed for main catches/general quality
Special products line for better valued parts/species

Capacity of lines to calculate" from -to" what gives oportunity to double capacity within same equipment

Any plant running a drying process should ideally never stop, because of the challenges involved in cleaning a drying line. Therefor the fishmeal line should be run 24/7 for as long as possible, and only stop for planned maintenance and longer periods of seasonal downs when not enough material is available. It is also essential for any processing line to achieve as stable production as possible, both because of the risk for clogs/stops in the process and energy use considertions. (Starting up and stopping a line requires significant amounts of power, whereas keeping the equipment running is relatively cheap.)

With this continuous operation in mind and from the monthly overview can be calculated an average, dimensioning capacity for the whole plant, which again will have to be divided into the separate lines: Tops and insignificantly small streams for silage, the main part for fishmeal, and particularly interesting/valuable materials for the human consumption line.

Picture 52. Possible dimensioning are given below (Fjell courtesy)



13.2 Infrastructure- to consider

CIP-line with evaporate, lye and acid

Electricity for equipment and facilities – typically 100 kWh/tonne in the 1-3 ton/hour range

Power for heating (el, fuel oil or gas) – typically 1000 kWh/tonne (but here several lines/more?)

Water for processing and washing – addition for hydrolysis 1:1 water/RRM, standard numbers for washing water (including reuse of evaporate/condensate)

Water purification and reuse

Sewage

Storage and Logistics Infrastructure

- Receiving Containers: Establish a system for receiving and handling containers at ports.
- Transport Fleet: Maintain a fleet of trucks for efficient transportation.
- Warehouses and Refrigeration: Build warehouses with refrigeration facilities for both raw materials and finished products.

Handling non-utilized materials ("rest-rest raw materials") – freezing chambers - bins

Packaging

Additional details requested regarding the project.

- Firstly, the estimated cost for constructing the factory is approximately 2.1 million Euros, rather than the 3.6 million Euros initially mentioned. This estimate encompasses the entire factory setup, including transportation and installation costs without building, infrastructure and land.
- Regarding the factory's infrastructure, it will necessitate a dedicated building. While we cannot specify the exact dimensions at this stage, a preliminary base case suggests a structure approximately 30 meters in length, 16 meters in width, and 6 meters in height.
- In terms of energy requirements, the factory is expected to consume around 100 kW/h of electrical energy and 300 kW/h of thermal energy. It's worth noting that the thermal energy can be sourced from alternatives to electricity.
- Operational staffing needs are modest, with the factory requiring the presence of one to two personnel on-site during its operational hours.

Additionally, it's important to note that our estimates for fishmeal and fish oil yields are based on preliminary assumptions and will need to be adjusted once we have precise data on the fish composition.

We have aimed to be conservative in our projections, in line with your preference for cautious estimations.

14 Quality Control and Laboratory

There are a multitude of commercial analytical laboratories available, including Nofima Biolab and Eurofins. However, as a minimum, we suggest that the proposed Croatian fish meal processing facility establishes the following analysis:

- Protein
- Ash
- Moisture
- Salt
- Fat
- Free fatty acids
- Anisidin value
- Peroxide value

Moreover In order to ensure safety of final products both raw materials and final products must be analysed and evaluated. The main points should be covered by analysing safety, composition and quality of raw materials and final products:

- **Chemical composition**
  - **Proteins**
  - **Lipids**
  - **Minerals/ash**
  - **Moisture/dry matter**
- Characterisation of proteins
- Characterisation of lipids
- Quality and stability
- Sensory quality
- Functional and bioactivity properties
- Microbiological quality
- Organic pollutants, heavy metals

The overview over analytical methods used by SINTEF Ocean are presented in the following table:

Table 18. Proteins/peptides definition analyse

	Objective	Method	Source	Sample quantity
Proteins, peptides				
Composition	Amount of C and N in sample. Protein amount = 6.25 × N	CN analysis		5 mg
	Amino acids composition	HPLC	(Lindroth and Mopper, 1979) modified by (Flynn, 1988)	mg
	Hydroxyprolin	Spectroscopy		mg
	Content of water and salt soluble proteins	Spectroscopy	Folin phenol method (Lowry *et al.*, 1951)	20 g
Characterization	Quantitative and qualitative evaluation - traceability - enzymatic activity-degradation - composition	Electrophoresis 2D electrophoresis	(Laemmli, 1970; Lodemel and Olsen, 2003)	mg
	Molecular weight distribution of proteins and peptides	FPLC		mg
	Degree of hydrolysis	Formol titration	(Taylor, 1957)	2 g
	Free amino acids	HPLC	(Lindroth and Mopper, 1979) modified by (Flynn, 1988)	mg
	Oxidation of proteins	Carbonyls and SH groups analysis		g
	Sensory analysis	Colour, taste		3 – 5 g
Functional properties	Emulsification properties			g
	Water holding capacity	Gravimetric	(Eide *et al.*, 1982)	g
	Fat absorption	Gravimetric	(Eide *et al.*, 1982)	g
	Antioxidative properties	Oxygen uptake: Oxygraph	Slizye et al. (2009) + instrument manual (Hansatech)	g

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Table 18. Marine lipids definition analyse

SINTEF	Objective	Method	Source	Sample quantity
Lipids				
Isolation/extraction	Total fat/oil	Accelerated solvent extraction (ASE) Bligh and Dyer Soxhlet extraction	Bligh & Dyer (1959)	10 – 100 g 10 – 20g 20 g
	Lipid classes Phospholipid classes	Solid phase extraction	Dybvik et al. (2008)	10 g
	Phospholipids	Acetone precipitation	Kates (2010)	10 g
Composition	Lipid/fat content	Bligh and Dyer	Bligh & Dyer (1959)	10 – 20 g
	Fat, salt and water distribution Structure	Low field NMR, MR Imaging		20 g
	Fatty acid composition	GC-FID		mg
	Lipid classes	TLC: Iatroscan	Rainuzzo et. al (1992)	mg
	Lipid classes Phospholipids classes	HPTLC: Camag		mg
	Lipid classes Phospholipid classes	HPLC-CAD	ESA application note: 70-8335 Rev A ESA application note: 70-6506 IA-1	1 g
	Profile of phospholipids and fatty acids	LC-MS, LC-TOF-MS		mg
	Fatty acid composition Lipid classes Phospholipids classes Positioning: sn1,sn2,sn3	High field NMR H1, C13, P31		200 mg

Table 19. Quality and stability definition analyse

	Objective	Method	Source	Sample quantity
Quality and stability	Primary oxidation products	Peroxide value – iodometric titration	AOCS official method: Cd 8b-90 combined with Radiometer Analytical application (TTIP02-01AFD/2002-06A)	15 g
		Peroxide value – spectroscopy (micro method)	IDF Standard 74A	200 mg
		Conjugated dienes/trienes – spectroscopy	AOCS official method: Ti 1a-64	200 mg
	Secondary oxidation products	*p*-Anisidine value – spectroscopy	AOCS official method: Cd 18-19	2 g
		TBARS in oil – spectroscopy	Ke & Woyewoda (1979)	200 mg
		TBARS in emulsions – spectroscopy	McDonald & Hultin (1987)	10 g
	Free fatty acids	Titration	AOCS official method: Ca 5a-40	20 g
		Spectroscopy	Bernardez et al. (2005)	1 g
	Water content	Karl-Fisher titration	AOCS official method: Ca 2e-84 combined with Radiometer Analytical application (T550VKF041)	5 g
	Carrotenoids	Spectroscopy	Sachindra et al. (2005)	1 g
	Phenolic antioxidants (BHT, PG, BHA)	HPLC-DAD	IUPAC-AOAC official method: 983:15	0.5 – 1 g
	Oxidation in oil and emulsion Resistance for iron and hemoglobin induced oxidation in o/w systems	Oxygen uptake: Oxygraph	Mozuraityte et al. (2006) + instrument manual (Hansatech)	20 g
	Susceptibility to oxidation	Oil Stability Index (OSI) – for oil/fat	AOCS official method: Cd 12b-92	20 g
		Shaal's oven test – for fat containing samples	Wanasundara & Shahidi (1994)	20 g
	Lipid polymerization	HPLC-CAD with size exclusion column		
	Tocoferol/Tocotrienol	HPLC-DAD	IUPAC-AOAC official method: 983:15	0.5 – 1 g
	Trans fatty acids	GC – RI		
	Lipid-protein interaction – Schiff bases	Fluorescence		g
Antioxidative activity	H donating ability, radical scavenging capacity	DPPH assay	Nenadis et al. (2007)	g
		ABTS assay	Re et al. (1999)	g
	Reducing capacity	FRAP assay	Nenadis et al. (2007)	g
		FC test	Singleton et al. (1999)	g
	Iron scavenging ability			g

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15 Financial and Operational Planning

Environmental and Economic Impact-benefits" of this project will cover:

Environmental Protection

Biodiversity Preservation: Sustainable management practices help preserve marine biodiversity by reducing pollution and habitat destruction.

Reduced Pollution: Proper processing and disposal of by-products minimize pollution in marine and coastal environments.

Sustainable Ecosystems: Recycling and reusing by-products contribute to the health of marine ecosystems by reducing waste and promoting circular economy principles.

Climate Change Mitigation: Efficient operations and waste management can lower greenhouse gas emissions, contributing to global efforts against climate change.

Economic Growth

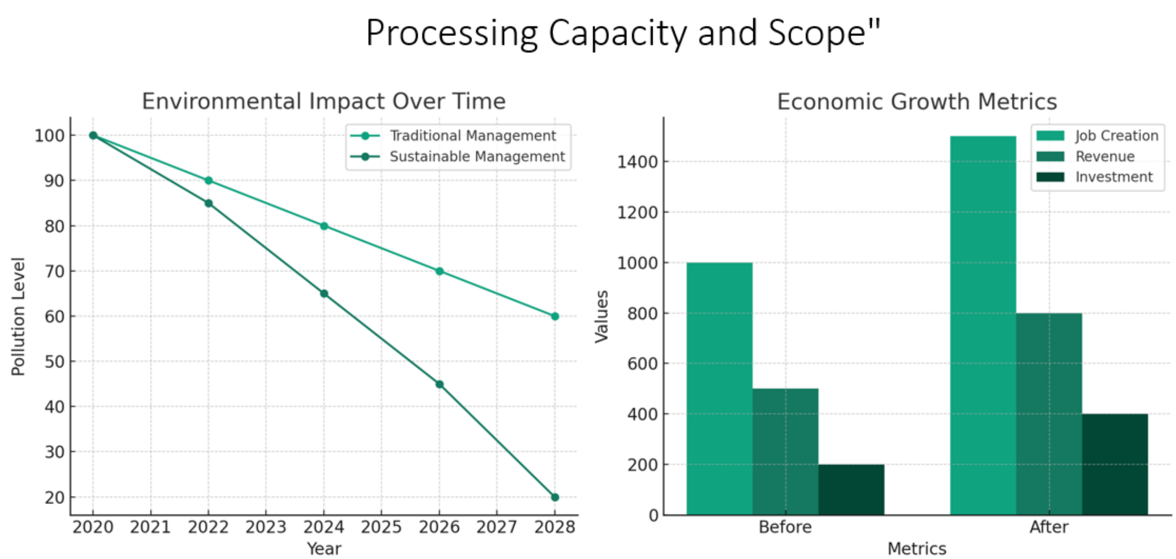
Job Creation: Establishing and operating disposal and processing facilities generate employment opportunities in both the direct (processing, management) and indirect (service providers, equipment suppliers) sectors.

Innovation and Investment: Investment in new technologies and processes for by-product management spurs innovation and attracts further investments.

Resource Optimization: By converting by-products into marketable goods (like fish meal, cosmetics, pharmaceuticals), the industry can tap into new revenue streams.

Community Upliftment: Economic growth from these initiatives can have a positive trickle-down effect on local communities, improving livelihoods and community welfare.

Graph 2. Processing capacity and Scope of production for byproduct material



15.1 **Budgeting:** Estimation of the capital investment and operational costs.

- Three different budget offers have been proposed, based on 30, 50 or 80 ton per day of raw material processing, and finaly for small 7 000 tons.

Table 20. Budget price for a 50 TPD combination fish meal, oil and silage plant

Scope of supply and CAPEX – 50 TPD plant
Combination Meal/Oil/Silage

UNIT
Raw material intake tank
Waste Water Treatment + scrubbersystem
Intake Solution and rest raw material storage incl lamella pump
Cooking and separation treatment
Oil treatment and Storage
Evaporation
Drying and Meal treatment
Process Control, software and electrical cabinets
Auxciliary Equipment, pumps , conveyors, valves,pumps
Steam Boiler included pipes
Silage process system
Freight
Mechanical and electrical Assembly
Engineering and Project management
Contingency
Commissioning, start up and traing of personnel

CAPEX: € 7 000 000,-

Building is not included in scope of supply

Picture 21. Budget price for a 80 TPD combination fish meal, oil and silage plant

Scope of supply and CAPEX – 80 TPD plant
Combination Meal/Oil/Silage

UNIT
Raw material intake tank
Waste Water Treatment + scrubbersystem
Intake Solution and rest raw material storage incl lamella pump
Cooking and separation treatment
Oil treatment and Storage
Evaporation
Drying and Meal treatment
Process Control, software and electrical cabinets
Auxciliary Equipment, pumps , conveyors, valves,pumps
Steam Boiler included pipes
Silage process system
Freight
Mechanical and electrical Assembly
Engineering and Project management
Contingency
Commissioning, start up and traing of personnel

CAPEX: € 8 000 000,-

Building is not included in scope of supply

Tentative operational budget:

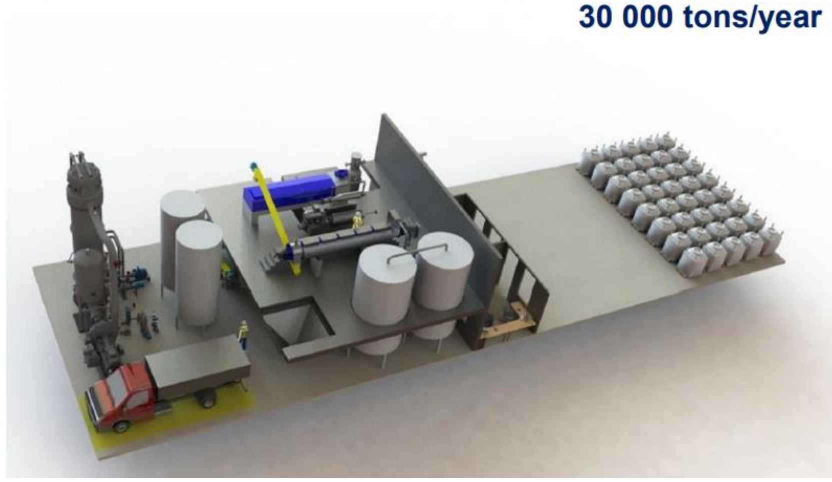
Investment Meal & Oil Plant:
€ 9 000 000 excluded VAT

Net profit:
15,000 tons/year: **€** 3.5 mill.
20,000 tons/year; **€** 3.7 mill.
30,000 tons/year: **€** 6.2 mill.

Silage Concentrate Plant:
3 TPH
€ 7 000 000 excluded VAT

Combined production Plant:
€ 10 000 000 excluded VAT

3D Drawing of a Fishmeal and Oil Plant. Capacity 120 TPD
30 000 tons/year



15.2 Timeline & Milestones: Implementation project timeline from initiation to full operational status- Plan-Road map.

- **Timeline: 2024 - 2028**

15.2.1 Phase 1: Planning and Approval (2024 Q1 - Q2)

- Initial proposal and feasibility study
- Securing approvals from local authorities
- Environmental impact assessment

15.2.2 Phase 2: Design and Funding (2024 Q3 - 2025 Q1)

- Finalizing design and layout of the facility
- Arranging funding and partnerships
- Community engagement and feedback

15.2.3 Phase 3: Construction (2025 Q2 - 2026 Q2)

- Groundbreaking and commencement of construction
- Infrastructure development (roads, utilities)
- Regular progress reviews and community updates

15.2.4 Phase 4: Installation and Testing (2026 Q3 - 2027 Q1)

- Installation of processing machinery and technology
- Staff recruitment and training
- Testing of processes and equipment

15.2.5 Phase 5: Operational Launch (2027 Q2)

- Official opening of the disposal center
- Commencement of full-scale operations
- Initial performance and impact assessment

15.2.6 Phase 6: Optimization and Expansion (2027 Q3 - 2028)

- Monitoring and optimizing operational processes
- Assessing potential for expansion or additional services

- Continuous improvement based on feedback and performance data

15.3 Challenges and Solutions

"Anticipated Challenges and Mitigation Strategies"

Challenge 1: Regulatory Compliance

Hurdle: Navigating complex environmental regulations and obtaining necessary permits.

Solution: Engage with regulatory bodies early in the planning process, ensure thorough understanding and adherence to regulations, and hire experienced legal advisors.

Challenge 2: Environmental Concerns

Hurdle: Minimizing the environmental impact during construction and operation.

Solution: Implement eco-friendly construction practices, use sustainable technologies, and conduct regular environmental impact assessments.

Challenge 3: Financial Constraints

Hurdle: Securing sufficient funding for project implementation and sustainability.

Solution: Explore diverse funding sources including government grants, private investments, and partnerships; prepare a robust financial plan.

Challenge 4: Technological Challenges

Hurdle: Ensuring the availability of advanced technology for efficient processing.

Solution: Collaborate with technology providers, invest in research and development, and stay updated with industry advancements.

Challenge 5: Community Acceptance

Hurdle: Gaining support and acceptance from the local community and stakeholders.

Solution: Conduct community outreach programs, provide transparent information, involve local stakeholders in planning, and demonstrate the project's benefits.

Challenge 6: Skilled Workforce

Hurdle: Recruiting and retaining a skilled workforce for the center's operations.

Solution: Offer competitive wages, invest in employee training programs, and collaborate with educational institutions for talent development.

Challenge 7: Operational Efficiency

Hurdle: Maintaining high efficiency and productivity in waste processing.

Solution: Implement best practices in operational management, conduct regular performance evaluations, and adopt continuous improvement methodologies.

Challenge 8: Market for By-Products

Hurdle: Developing a stable market for products derived from fishery by-products.

Solution: Conduct market research, develop quality products, establish strong distribution channels, and engage in effective marketing strategies.

15.4 ROI Analysis: Projected returns on investment.

ROI, or Return on Investment, analysis in the fishery by-product industry involves evaluating the profitability and efficiency of investments made into processing and utilizing by-products of fisheries. This can include various aspects such as the production of fish meal, fish oil, pharmaceuticals, nutraceuticals, and other value-added products derived from parts of the fish that are not consumed directly as food.

The fishery by-product industry has gained significant attention due to the increasing awareness of sustainable practices and the desire to minimize waste in the seafood sector. By-products, which traditionally were discarded or underutilized, are now recognized for their potential in generating additional revenue streams, contributing to the circular economy, and reducing environmental impact.

An ROI analysis in this context would typically involve:

1. **Cost Analysis**: Identifying all costs associated with the processing and marketing of fishery by-products. This includes capital investment in processing equipment, operating costs (such as labor, utilities, and maintenance), and any costs related to certification, marketing, and distribution.
2. **Revenue Generation**: Estimating the potential revenue from selling fishery by-products. This could vary significantly depending on the products' market demand, pricing strategies, and the effectiveness of marketing efforts.
3. **Profitability Assessment**: Calculating the net profit from by-product utilization by subtracting the total costs from the total revenues. This assessment helps in understanding the direct financial benefits of investing in by-product processing.
4. **Investment Efficiency**: Evaluating the efficiency of the investment by calculating the ROI metric, which is typically expressed as a percentage. The ROI is calculated by dividing the net profit by the total investment cost and then multiplying by 100. A higher ROI indicates a more efficient investment.

5. **Risk and Sensitivity Analysis**: Analyzing the risks associated with the by-product industry, such as fluctuations in market demand, changes in raw material availability, and regulatory changes. Sensitivity analysis can help understand how changes in these factors could impact ROI.

6. **Comparative Analysis**: Comparing the ROI of by-product investments with other investment opportunities within the fishery sector or in other sectors to make informed decisions.

ROI analyses help stakeholders in the fishery by-product industry make informed decisions about where and how to invest resources for maximizing profitability and sustainability. This approach supports the development of innovative products and technologies, promotes waste reduction, and contributes to the overall economic and environmental sustainability of the fisheries sector.

We used 2 model scenario based on 0,2 and 0,4 Eur /kg of raw material for hypothetical factory of cca 7 000 t/year- in price not included DED, land, infrastructure, building, environment…

Table 22. Scenario -Sample-0,2 Eur/kg raw material

	Data input client
	Data input AMOF
	Data output

Per year		
Gross Income	€	1 997 280
Opex	€	856 785
Net Income	€	**1 140 495**
Return of Investment		1,91 Years

Capex		
Estimated price processing plant	€	2 000 000
Finance cost (interest)	€	-
Estimated transport cost	€	80 000
Estimated installation cost	€	80 000
Estimated infrastructure on site	€	20 000
Total capex	€	**2 180 000,00**

Net supervising % of operation time	100 %
Number of of operators	1
1950 workhours/year	

Income per year		
Raw material		6 840 000 kg
Output fish oil		410 400 kg
Output fish meal		1 333 800 kg
Cost raw material	€	1 368 000
Income fish oil	€	1 231 200
Income fish meal	€	2 134 080
Gross income	€	**1 997 280**

Opex per year		
Maintenance cost	€	100 000
Operator cost	€	175 385
Energy cost electricity	€	171 000
Energy cost fuel	€	410 400
Total opex	€	**856 785**

Financial data from client		
Income pr kg fish oil	€	3,00
Income pr kg fishmeal 65% protein	€	1,60
Cost raw material	€	0,20
Finance need	€	-
Mortgage time		5 Years
Depreciaton time		10 Years
Interest rate		5 %

Operational data from client		
Raw material pr day		24 tons
Operation days pr year		285
Operation hours pr day		24
Operator cost pr year (1950 worhours)	€	50 000
Fuel cost pr liter	€	1,50
Electricity cost pr kW/h	€	0,25

Capacity and yields	
Oil yield	6,0 %
Fish meal	19,5 %
Raw material	1 000 kg/h
Output fish oil	60 kg/h
Output fish meal	195 kg/h
Operational hours/year	6840

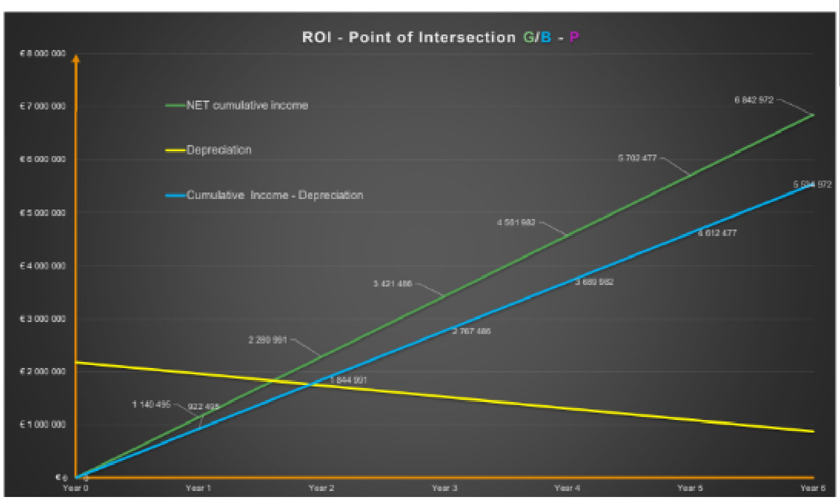


Table 23. Scenario-Sample-0,4 Eur/kg raw material

	Data input client
	Data input AMOF
	Data output

Per year		
Gross Income	€	629 280
Opex	€	856 785
Net Income	-€	227 505
Return of Investment		-

Capex		
Estimated price processing plant	€	2 000 000
Finance cost (interest)	€	-
Estimated transport cost	€	80 000
Estimated installation cost	€	80 000
Estimated infrastructure on site	€	20 000
Total capex	€	2 180 000,00

Net supervising % of operation time	100 %
Number of of operators	1
1950 workhours/year	

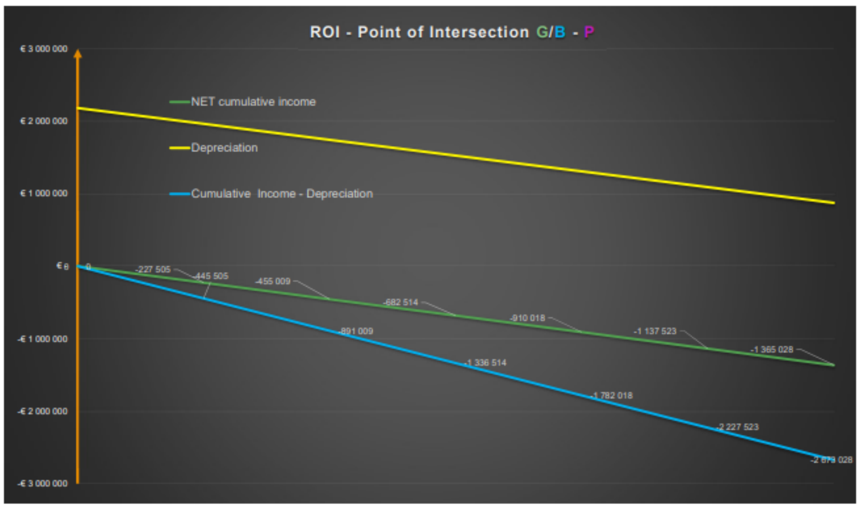
Income per year		
Raw material		6 840 000 kg
Output fish oil		410 400 kg
Output fish meal		1 333 800 kg
Cost raw material	€	2 736 000
Income fish oil	€	1 231 200
Income fish meal	€	2 134 080
Gross income	€	629 280

Opex per year		
Maintenance cost	€	100 000
Operator cost	€	175 385
Energy cost electricity	€	171 000
Energy cost fuel	€	410 400
Total opex	€	856 785

Financial data from client		
Income pr kg fish oil	€	3,00
Income pr kg fishmeal 65% protein	€	1,60
Cost raw material	€	0,40
Finance need	€	-
Mortgage time		5 Years
Depreciaton time		10 Years
Interest rate		5 %

Operational data from client		
Raw material pr day		24 tons
Operation days pr year		285
Operation hours pr day		24
Operator cost pr year (1950 worhours)	€	50 000
Fuel cost pr liter	€	1,50
Electricity cost pr kW/h	€	0,25

Capacity and yields	
Oil yield	6,0 %
Fish meal	19,5 %
Raw material	1 000 kg/h
Output fish oil	60 kg/h
Output fish meal	195 kg/h
Operational hours/year	6840



13. Marketing and Sales Strategy

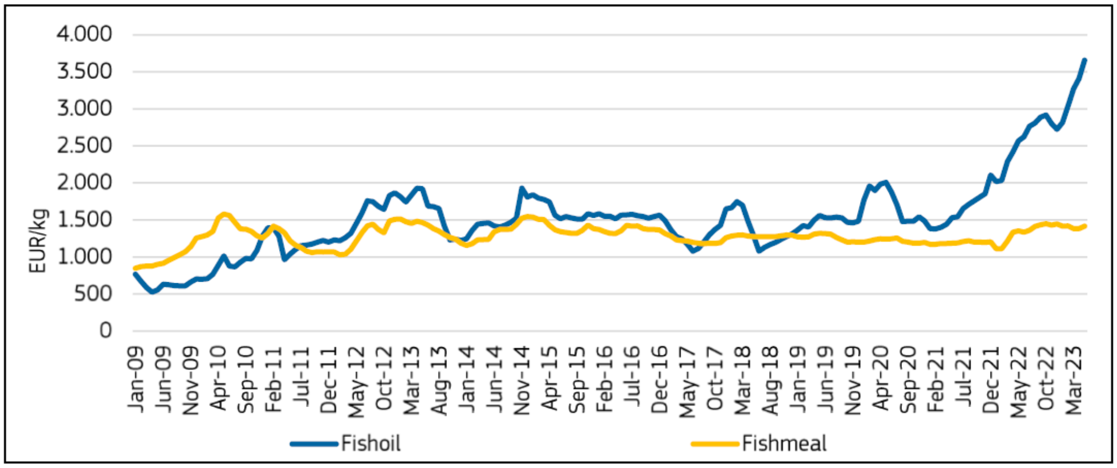
Bases on the chemical composition, the fish raw material have potential as fish meal and fish oil. The assessments are based on 6% moisture and 8 % fat on the final fish meals.

Table 24 Estimation of fish meal and fish oil volumes from different rest raw materials

	Parameter (g/kg)				**Fish meal (kg/ton raw material) ***	**Fish oil (kg/ton raw material) ***
Rest raw materials	*Protein*	*Fat*	*Ash*	*Moisture*		
By-product aquaculture - tuna (head, fins)	*180,3*	*150*	*28,8*	*627,3*	**259**	**129**
By-product aquaculture - tuna (entrails)	*195,8*	*52*	*21,3*	*708,5*	**278**	**30**
By-product aquaculture - (seabass, seabream)	*133,7*	*286,7*	*25,3*	*565,3*	**172**	**273**
By-product fisheries (sardine heads)	*154,6*	*26,8*	*56*	*771,0*	**235**	**8**
By-product fisheries (mix - red mullet, common pandora, ..)	*195,3*	*33,0*	*48,8*	*744,5*	**259**	**12**
By-product fisheries (squids, musky octopuses)	*146,3*	*30,2*	*19*	*801,2*	**196**	**15**
By-product fisheries (shark skin & entrails)	*187,5*	*212,8*	*14*	*551,7*	**274**	**191**
By-product fisheries (bait; Atlantic chub mackerel, sardine, ..)	*198,1*	*65*	*38*	*717,3*	**253**	**45**

At present the fishmeal and fish oil prices are at around 1,5 € and 3,5 €, respectively.

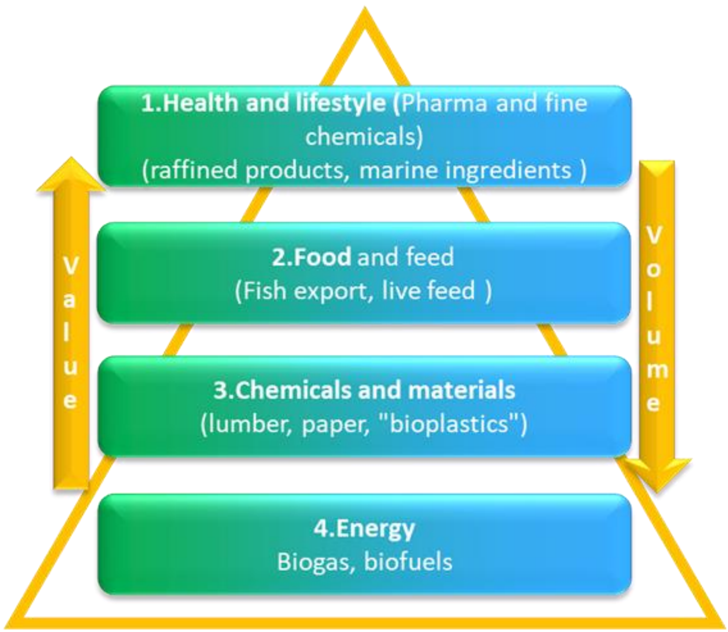
Picture 53. Current prices for fish oil and fishmeal.



Source: Oilworld. Values are deflated by using the GDP deflator (base=2015).

- In order to succeed in investing in a new plant, or processing unit one must start from what products the market/markets are demanding and paying for, as well as what requirements the market has for products and processes. This is a necessary exercise BEFORE detailing the process method, process line and calculating facilities. It can therefore be argued that this preliminary project starts at the wrong end, but as a feasibility study based on cases for the most suitable process methods and experience with local and neighbouring markets, it will still be possible to highlight directions for processing.
- In general, markets, volumes and expected product prices can be set up in the following value pyramid figure:

Picture 54. Markets, volumes and values for products from residual raw materials



There are many different versions of such value pyramids where other applications such as biogas, fertiliser/soil improvement, disposal, composting and more are also included. In this report, the focus is on protein and oil as ingredients for feed and food.

15.5 Basic rules to industry

Establishing a fish by-product processing industry involves adhering to a range of basic rules spanning various domains. These rules are crucial for ensuring the efficiency, safety, sustainability, and profitability of the operation. Below is a summary of key rules and needed protocols across different categories:

16 Regulatory Compliance and Licensing- repetition

- **Permits:** Obtain necessary permits and licenses from relevant local, national, and international authorities.
- **Food Safety Regulations:** Adhere to food safety standards set by official bodies

The laws and regulations governing collection, transport, storage, handling, processing, use and disposal of residual raw materials are often-overlooked factors that severely influence the number of applications available for processing of this material. When material is found to be unfit for food but suitable for feed, it is classified as an animal by-product (ABP) and must be processed at appropriate byproduct plants, according to EU regulations. After the material has reached such a facility, it can no longer be upgraded for food use. It is therefore imperative that as much as possible of residual raw materials is handled according to food hygiene regulations if the intended use is processing for human consumption. The EU has developed an elaborate legislation framework governing the use of residual raw materials from fisheries, aquaculture, livestock, and poultry industries. The type and quality of each residual material are of utmost importance for its further processing possibilities and define its use for food or feed applications, according to the hygiene rules for food of animal origin[1]. Raw materials that do not meet the general rules for food hygiene or are classified as not suitable for human consumption are regulated by the rules of ABP regulations[2] and implementation of health rules for animal by-products and derived products not intended for human consumption[3] . ABPs can be divided into three categories (1–3;) based on their origin and potential risk to public and animal health and the environment. No ABPs can be used for human consumption, and only low-risk, category 3 by-products can be used for feed production. Some animal parts are not eligible for either food or feed use and are classified as category 1, specified risk materials. These include bone marrow, spinal cords and brains from cattle, sheep and goats, and sick and dead animals. Category 3 by-products are further classified according to their origin,i.e. ruminants or non-ruminants, due to the risk of transmissible spongiform encephalopathy (TSE).

A compilation of regulations for use of different category 3 ABPs in feed is presented in Table below. ABP together with TSE regulations[4] are major components of the EU's strategy to eradicate feed-borne crises such as BSE in cattle, foot and mouth disease and dioxin contamination. The main objective of these regulations is to protect the population and farmed animals from any health risks related to contamination by infectious microorganisms or heat-stable bacteria-derived toxins (e.g. histamine and enterotoxins).

[1] EU (2004) European Union Regulation (EC) No. 853/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules for food of animal origin. Off. J. L 139, 30/4/2004

[2] EU (2009) European Union Regulation (EC) No. 1069/2009 of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No. 1774/2002 (Animal by-products Regulation). Off. J. L300,14/11/2009

[3] EU (2011) European Union Regulation (EC) No. 142/2011 of 25 February 2011 implementing Regulation (EC) No. 1069/2009 of the European Parliament and of the Council laying down health rules as regards animal by-products and derived products not intended for human consumption and implementing Council Directive 97/78/EC as regards certain samples and items exempt from veterinary checks at the border under that Directive. Off. J. L54, 26/02/2011

[4] EU (2001) European Union Regulation (EC) No. 999/2001 of the European Parliament and of the Council of 22 May 2001 laying down rules for the prevention, control and eradication of certain transmissible spongiform encephalopathies. Off. J. L147, 31/05/2001

Picture 55 Brief summary of by-products included in each of three animal by-product (ABP) categories regulated in the EU, and examples of some approved uses of ABPs in each category.

Table 25 Overview of category 3 animal by-product material from different animals suitable for feed use according to TSE regulation

	Ruminants	Non-ruminants	Fish	Pets and fur animals
Processed protein from ruminants	✘	✘	✘	✔
Processed protein from non-ruminants	✘	✘	✔	✔
Blood from ruminants	✘	✘	✘	✔
Blood from non-ruminants	✘	✔	✔	✔
Hydrolyzed protein from ruminants	✘	✘	✘	✔
Hydrolyzed protein from non-ruminants	✔	✔	✔	✔
Collagen and gelatin from ruminants	✘	✘	✘	✔
Collagen and gelatin from non-ruminants	✔	✔	✔	✔
Fishmeal	✘	✔	✔	✔

Production plants that process category 3 by-products must comply with the general hygiene requirements provided in ABP regulations and have a documented pest control program. Materials that have not received specific heat treatment during start-up or leakage must be either recirculated through the applied heat treatment step, collected and reprocessed, or discarded.

The health rules regarding ABPs describe several processing methods approved for heat treatment of category 3 by-products, based on methods 1–5 and 7 for material originating from domestic animals and methods 1–7 for aquatic animals. The different heat treatment operation conditions are based on the following critical control parameters: (1) raw material particle size, (2) achieved core particle temperature level, (3) pressure, (4) duration of heat treatment and (5) in case of chemical treatment, the achieved pH level. In the case of fish processing, the material rapidly becomes tender as muscle proteins coagulate and

disintegrate when exposed to mechanical forces in a cooker, strainer, screw-press or screw conveyor. Based on experience, reduction of particle size prior to the heat treatment step is not required to achieve uniform temperature throughout fish material. Moreover, high shear forces during grinding might cause fat separation problems due to formation of emulsions and should be avoided if not needed.
Table 26 Approved alternative methods for heat treatment of category 3 animal by-products

Method	Particle size (mm)	Core temperature (°C)	Time (min)	Pressure (bar)	pH	Batch	Continuous
1	50	>133	20	3		×	×
2	150	>100	125	NS		×	
	150	>110	120	NS		×	
	150	>120	50	NS		×	
3	30	>100	95	NS		×	×
	30	>110	55	NS		×	×
	30	>120	13	NS		×	×
4[a]	30	>100	16	NS		×	×
	30	>110	13	NS		×	×
	30	>120	8	NS		×	×
	30	>130	3	NS		×	×
5[b]	20	>80	120	NS		×	×
	20	>100	60	NS		×	×
6[c]	50	>90	60	NS	<4.0	×	×
	30	>70	30	NS	<4.0	×	×
7[d]	NS	>76	20	NS		×	×
	NS	>70	20	NS		×	×

NS not stated

[a] Carver–Greenfield process, i.e. heating in a vessel with added oil

[b] The by-products must be heat coagulated and mechanically pressed to remove water and fat before final heat treatment

[c] Animal by-products originating from aquatic animals or aquatic invertebrates only

[d] Method approved by Norwegian authorities (wild fish >70 °C, aquaculture fish >76 °C; Nygård [16]), or any method authorized by the competent authorities complying with the following microbiological standards: *Clostridium perfringens* absent in 1 g product after heat treatment, *Salmonella* absent in final product ($n = 5$; $c = 0$; $m = 0$; $M = 0$), *Enterobacteriaceae* ($n = 5$; $c = 2$; $m = 10$; $M = 300$ in 1 g)

- **Environmental Regulations:** Comply with environmental regulations regarding waste disposal, emissions, and resource usage.

17 Quality Control and Standards

Fish meal and fish oil quality criteria are discussed in Einarsson, Jokumsen et al. 2019, but in brief the freshness of the raw material is crucial for the produced fishmeal and oil and the total volatile nitrogen content (TVN) should not exceed 60 mg TVB-N/ 100 g. The mean levels of biogenic amines should not exceed 10 mg/100 g. The recommended quantity of biogenic amines for high-quality fishmeal should be less than 1000 ppm for histamine, and the total sum of all four of the main biogenic amines (cadaverine, putrescine, tyramine, and histamine) should be less than 2000 ppm. The maximum levels of dioxins and dioxine-like PCBs are given in Table 3.

Table 27 Maximum levels of dioxins and dioxine-like PCBs in fish meal

Maximum levels[1]	**Sum**	**Dioxins & Furans**	**Dioxin-like PCBs**
Fish	8 pg/g	4 pg/g	4 pg/g
Marine oil, incl. fish body oil and liver oil	10 pg/g	2 pg/g	8 pg/g
Eel	12 pg/g	4 pg/g	8 pg/g
Action limits[2]			
Fish and fish products	6 pg/g	3 pg/g	3 pg/g
Marine oil incl. fish oil	7.5 pg/g	1.5 pg/g	6 pg/g
Eel	12 pg/g	4 pg/g	8 pg/g

[1] EC Regulation 199/2006; [2] EC Recommendation 2006/88/EC

The two main fishmeal specifications used today in Norwegian aquaculture feed production are NorSeaMink and the high-quality Norse-LT 94 (Table 4). For further details, refer to Einarsson, Jokumsen et al 2019.

Table 28 Specification for NorSeaMink and Norse-LT 94

	NorSeaMink	Norse-LT 94
Crude protein (%)	Min. -, Typical 71	Min. 68, Typical 71
Water-soluble protein (% of crude protein)	-	Max. 32, min. 18
Moisture (%)	Max.10, min. 5	Max.10, min. 6
Fat (Soxhlet) (%)	Max. 13	Max. 13
Ash, without salt (%)	Max. 14	Max. 14
Salt (sodium chloride) (%)	Max. 4	Max. 4
Total volatile nitrogen (%)	Max. 0.20	Max. 0.18
Cadaverine (g kg^{-1})	Max. 1.8	Max. 1.0
Histamine (g kg^{-1})	Max. 0.7	Max. 0.5

Source: (Norsildmel 2018)

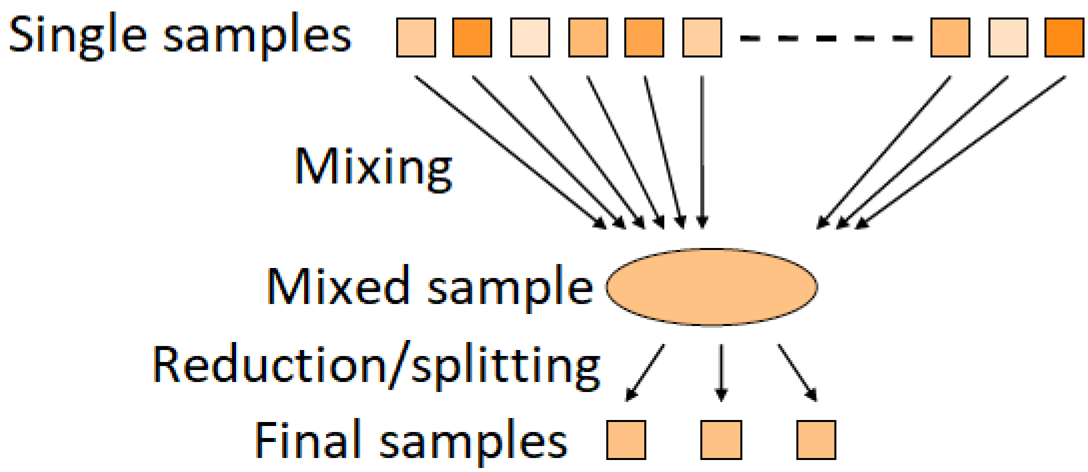
Quality guidelines for some important parameter for refined fish oils are provided in Table 5 as proposed by Hamm (2009).

Table 29 Some quality guidelines for refined fish oils.

Parameter	**Quality guidelines**
Colour	<3.0 Red, 30 Yellow
Odour and taste	Bland
Matter volatile at 105°C	<0.2 %
Insoluble impurities	<0.05 %
Soap content	<0.005 %
Iron	<0.12 mg/kg
Free fatty acids	<0.10 % (as oleic acid)
Copper	<0.05 mg/kg
Peroxide value	<0.1 meq O2/kg
Nickel	<0.20 mg/kg

The content of microorganisms in raw materials, production environment and finished goods is determined using microbiological analyses. The purpose is to check that the samples satisfy requirements for the absence or maximum content of specified microorganisms. Samples that are analyzed in the laboratory are often a small part of the submitted sample and this in turn may be a small part of a larger lot. The practical value of a correct analysis result is therefore completely dependent on the sample being representative of the batch. An average sample of a batch of goods is prepared by mixing a larger number of individual samples from the batch into a collective sample. The combined test is split (reduced) into several final tests. A final sample can be sent to a laboratory for analysis, another is stored as a reference in the event of a complaint, etc. As a general rule, the number of individual samples must be a minimum of 30 for the collective sample to be considered representative. There are several standards for sampling feed, e.g. The preliminary analysis regulations; FOR-2020-02-28-702 which is administered by the Norwegian Food Safety Authority.

Picture 56 Sampling of samples for microbial analysis



Dry samples are microbiologically stable and can be stored at room temperature. Moist samples are cooled to freezing point and brought to the laboratory within 24 hours. If this is not possible, the samples must be frozen and sent to the laboratory in a frozen state. There are few statutory requirements for fishmeal for human consumption. Commission regulation EC/2073/2005 on microbiological criteria for foodstuffs has been applied in Norway but has no categories that cover fishmeal. In due course, the regulation replaced the Norwegian Food Safety Authority's Microbiological Guidelines. Although the Norwegian Food Safety Authority's previous guidelines have been repealed, they are still a very useful aid in connection with the preparation of own requirements specifications. There are also national guidelines from countries outside the EU that can be helpful, e.g. New Zealand's Microbiological Reference Criteria for Food (https://www.mpi.govt.nz/dmsdocument/21185/direct). Customer requirements will vary according to what the fish meal will be used for and how it will be used. Table 6 gives an example of a product specification for fishmeal for human consumption, prepared on the basis of statutory requirements, customer requirements and various available guidelines.

Table 30 product specification for fishmeal for human consumption

	Low limit	High limit
Salmonella	Not detected	Not detected
Total platelet count	10.000 CFU/g	500.000 CFU/g
Mould and yeast	100 CFU/g	1000 CFU/g

Enterobacteriaceae	10 CFU/g	100 CFU/g
S. aureus	10 CFU/g	100 CFU/g
C. perfingens	10 CFU/g	100 CFU/g
B. cereus	100 CFU/g	1000 CFU/g

For Salmonella there is always zero tolerance. For other parameters, an interval is given, where one can use the highest limits for most current applications and the lowest for sensitive applications. One can also take into account the method of use and choose lower limits if the product is to be consumed directly than if it is to be heat treated before consumption. Exceeding the limit value in an individual analysis must not necessarily have consequences for the party. One can e.g. consider deviating from a requirement, carrying out control analyzes or redistributing the lot. An exceedance for disease-causing bacteria (S. aureus, C. perfringens, B. cereus) must be interpreted more strictly than for indicator organisms (Coliform bacteria/Enterobacteriaceae) or for the broadest groups (aerobic microorganisms, mold/yeast).

18 Raw Material Inspection & Hygiene and Sanitation:

Nofima has recently published an open report related to microbiology and production hygiene in the fishmeal industry (Nygaard, H., Vander Roost, J. (2021). Mikrobiologi og produksjonshygiene i fiskemel-industrien. Nofima rapport 2/2021; in Norwegian). Main background information and an overview of critical control points are given in the text below.

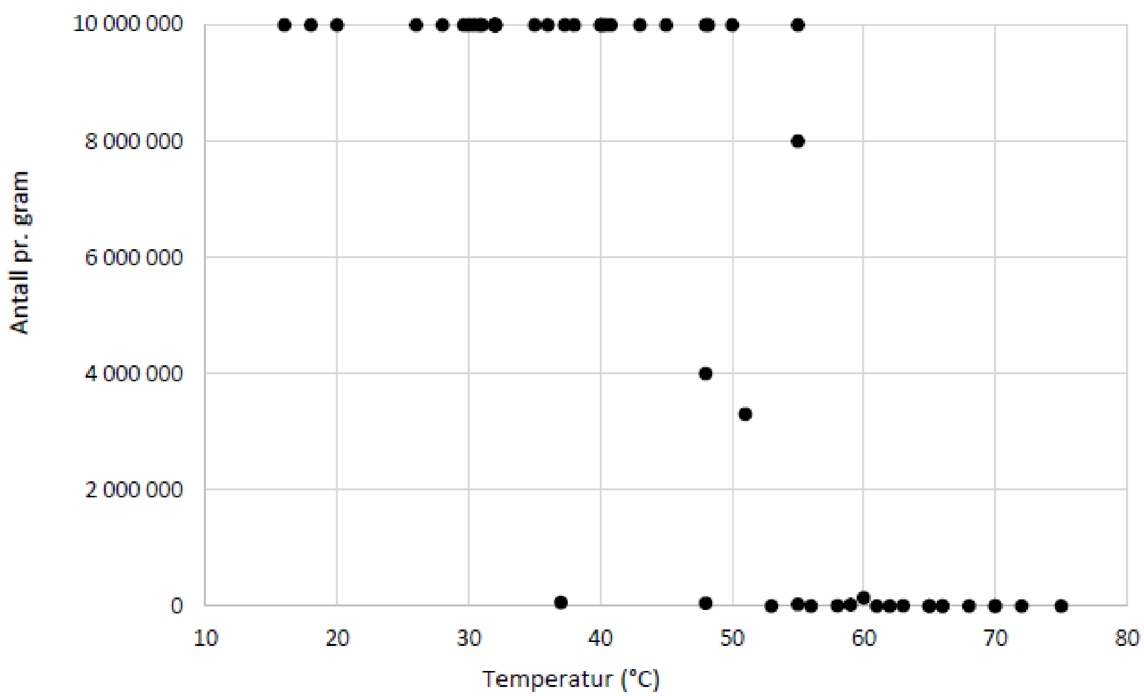
Live and freshly caught fish always contain bacteria on e.g. gills, skin and in the intestine. The flora consists of cold- and salt-tolerant bacteria. During storage of the raw material, the bacteria enter a growth period which depends on, among other things, temperature and residence time. Growth entails the breakdown of nutrients and the formation of, among other things, volatile N and S compounds that affect chemical and sensory quality. These heat-sensitive bacteria are killed in boiling and do not affect the hygienic quality of the fishmeal. Raw material from the boiler is practically free of micro-organisms. The presence of microorganisms in finished fishmeal is due to recontamination in the production line after cooking. The fishmeal therefore has a different bacterial flora than the fish and can contain e.g. intestinal bacteria from warm-blooded animals and heat-resistant spore-forming bacteria. The sources of infection are buildup of moist deposits of fish material with direct product contact in machines and conveyors. Deposits normally have both a lower temperature and higher humidity than the mass flow and can therefore offer favorable growth conditions even during ongoing production. An absolutely decisive reason why deposits can become so heavily contaminated is a long residence time.

The fish meal process is a continuous process where mass flow is advanced through various process stages in constant contact with the internal surfaces of the production equipment. Bacteria that infect from protein deposits to the mass flow will be found in the finished product if they are not killed later in the process. The drying step can be an effective barrier for killing microorganisms. Steam dryers run without vacuum kill all microorganisms including spore formers such as *C. perfringens* and *B. cereus*. Vacuum drying and other low-temperature drying technologies provide less effective killing. Ready-dried fishmeal has a low water activity (aw = 0.40-0.50). Microorganisms that survive drying will be alive but cannot reproduce without the supply of moisture. During dry storage, the level will be stable or slowly decreasing. If, after drying, the production line is exposed to moisture (e.g. leakage or condensation), sources of contamination will form here as well. This is particularly serious because there are no longer any subsequent killing steps.

Infection from sources in the production line is considered the most important cause of recurring or lasting hygiene problems. The products can also be contaminated directly from insects, bird droppings etc., which gives single cases without lasting effects. Nofima has collaborated with the fishmeal industry on e.g. route of infection clarification. It has been shown that anaerobic spore formers (clostridia) mainly have sources of infection before the drying step. Other bacteria such as aerobic spore formers (Bacillus), Salmonella and Enterobacteriaceae have sources of infection both before and after drying. For non-spore formers, it is primarily infection that occurs after drying that has consequences, because these bacteria are easily killed in dryers. On the wet side of the process, i.e. between boiling and drying, high temperatures can prevent bacterial growth on surfaces in the production line.

Figure 4 shows the bacterial count in deposit samples taken from the wet side of several fishmeal factories during ongoing stable production. The figure shows that there is a critical temperature limit at around 55 °C. Below this limit, there is continuous growth of bacteria and the concentration quickly reaches a high level, over 10 million per gram. Above the critical temperature limit, killing occurs and the concentration falls below the detection limit. Nofima has shown that the types of Clostridium and Bacillus found in Norwegian fishmeal can multiply at temperatures all the way up to the threshold value of 55 °C. Above this temperature they are killed, but the killing occurs slowly at temperatures between 55 and 65 °C. The production facilities should therefore be set up so that the temperature in all moist deposits during production is at least 65 °C.

Picture 57 Temperature and total bacterial count in samples from the production lines at several factories under stable production



In the area between the dryer and the meal cooler, it is difficult to prevent growth based on temperature. The most important measure must be to avoid moisture buildup in the fish meal deposits by control of the temperature and humidity of the air. When air with a certain humidity is cooled, it will become saturated at a certain temperature, and water will begin to condense out. This limit value is called the dew point of the air. When moist air meets surfaces with a temperature equal to or lower than the dew point temperature, condensation will form with risk of establishment of moist meal deposits that support microbial growth.

Premises must also be kept clean and tidy to minimize infection pressure on the production line itself. This should be carried out when necessary, also during periods of production. It is assumed that methods are used that do not affect the conditions in the production line itself. The company's cleaning plan must take into account the special conditions that characterize a fishmeal factory. Many processing and transport links only have contact with dry goods. The use of water in cleaning here can be counter productive, because a lack of water is the only factor that prevents bacterial growth. Dry-ice blasting can be effective in some places. Areas with a moist process should, on the other hand, be cleaned using water. This applies primarily in the area between boiling and drying. When preparing a cleaning plan, collaboration with a renown supplier is recommended to ensure that funds, methods and equipment are agreed. In addition to costs and effectiveness, emphasis should be placed on protecting personnel, production equipment and the environment.

Conclusion

This assignment is a high-level outline and requires more detailed engineering, financial planning, and operational management expertise to develop into a full-fledged project plan. Main issue for start-up definition is devoted by this project to SINTEF OCEAN and NOFIMA in process engineering and design setup, logistics, quality control, and environmental management to refine and implement this plan effectively.

This outline provides a framework for project. Depending on the specific requirements and constraints of project, we may need to replace, adjust or add more details in each section.

There is a possibility and recommendation to define

- Main line - fish meal/fish oil

- Auxilary line for high quality products

- Silage

- Plus laboratory

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