Seafood side stream Valorization:

Economic and Social Aspects

BlueAquaEdu

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Global Seafood Industry

Global seafood production: 223.2 million tonnes (2022) (CAGR 4.4 %). Production comprised 185.4 million tonnes of aquatic animals and 37.8 million tonnes of algae.

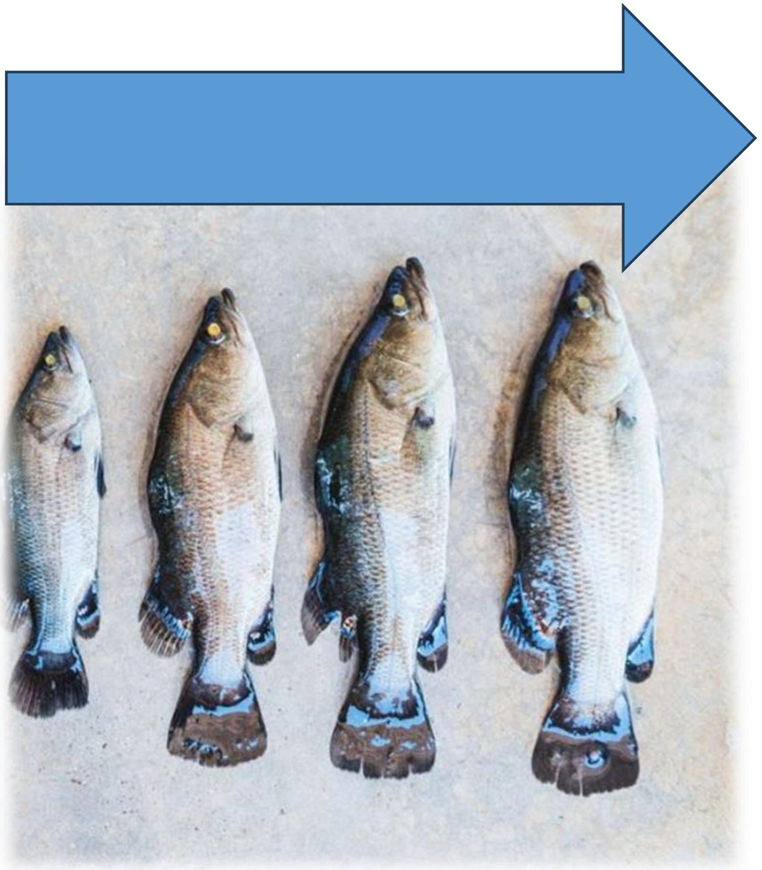
Aquaculture boom: In 2022 and for the first time in history, aquaculture surpassed capture fisheries as the main producer of aquatic animals. Global aquaculture production reached an unprecedented 130.9 million tonnes, of which 94.4 million tonnes are aquatic animals, 51 percent of the total aquatic animal production.

The global seafood market size: USD 386.73 billion in 2024 (CAGR of 10.14%).

Global Trend & Drivers: Increasing preference towards value added products (RTE/RTC) and a pescetarian diet.

New marketing channels: Super/hyper markets, Convenience/specialty stores, Online sales channels

Sustainable seafood market : (CAGR 6.5 %).



Ref: FAO, 2024; Seafood Market Size, Share, Growth | Industry Report [2032] (fortunebusinessinsights.com)

SEAFOOD?

‘Any edible material or ‘Food’ including both the flora and fauna, harvested, propagated, or collected from natural or artificial waterbodies irrespective of the salinity of the water media’.

DIVERSE

FISH

FIN FISHES

ELASMOBRANCHS

SHELL FISHES

CRUSTACEANS

CEPHALOPODS

MOLLUSCS

**Separation of side streams, impact on isolation efficiency*

Nutritious

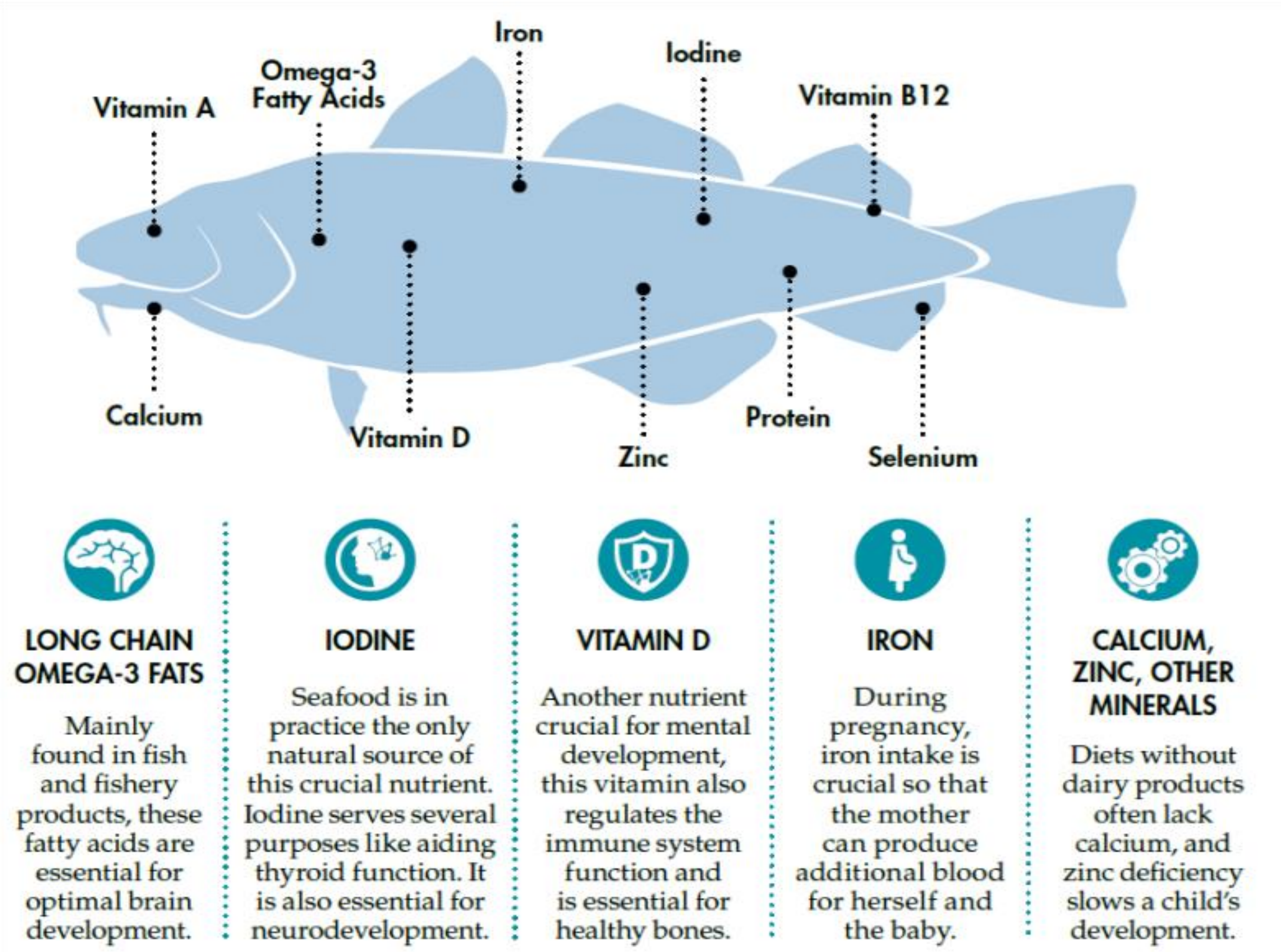
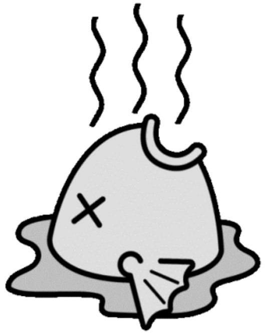
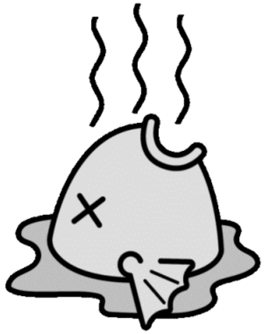


Image courtesy: FAO, 2023

**Species wise, seasonal fluctuations, impact on target component extraction, methodology and yield*

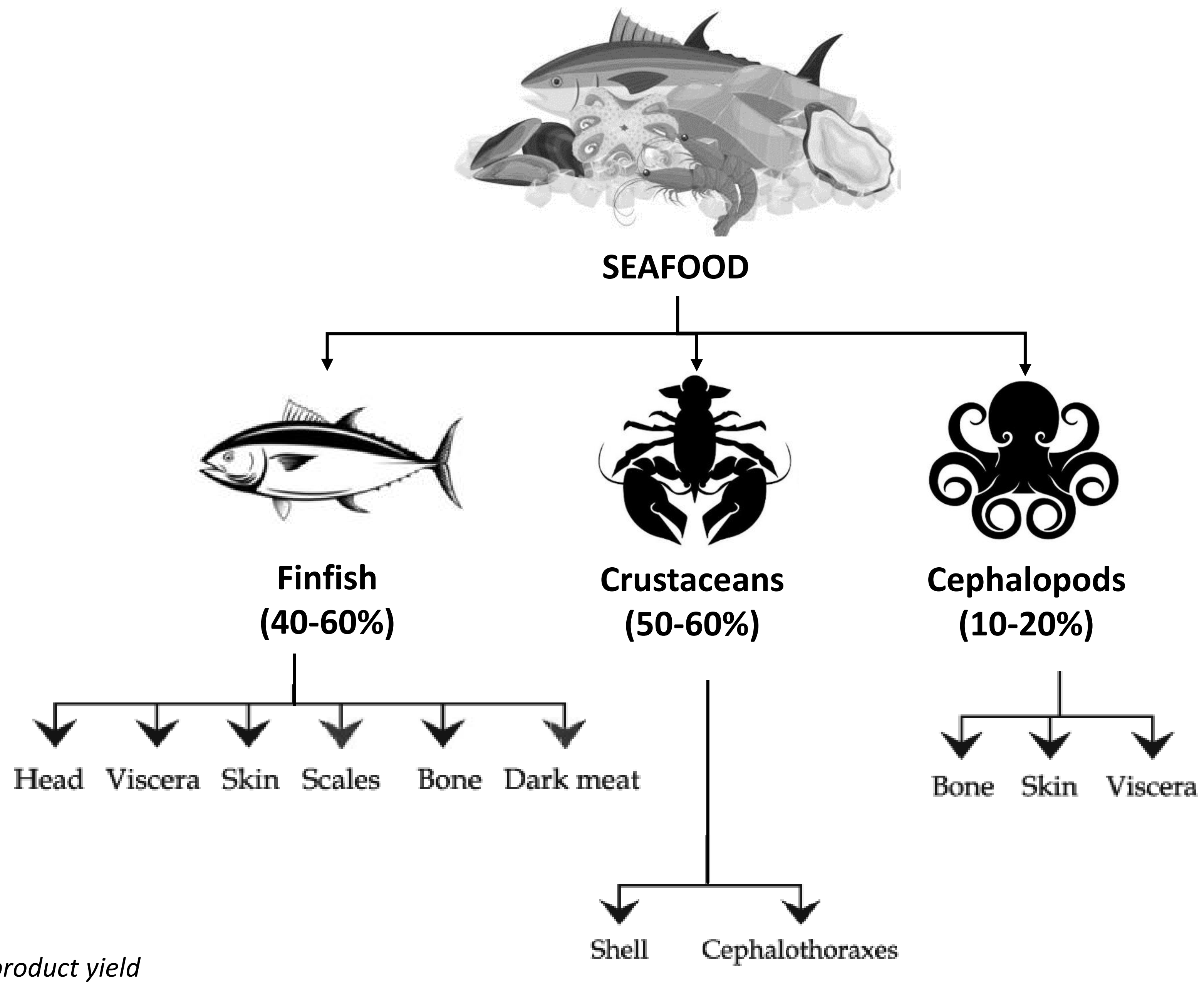
Perishable





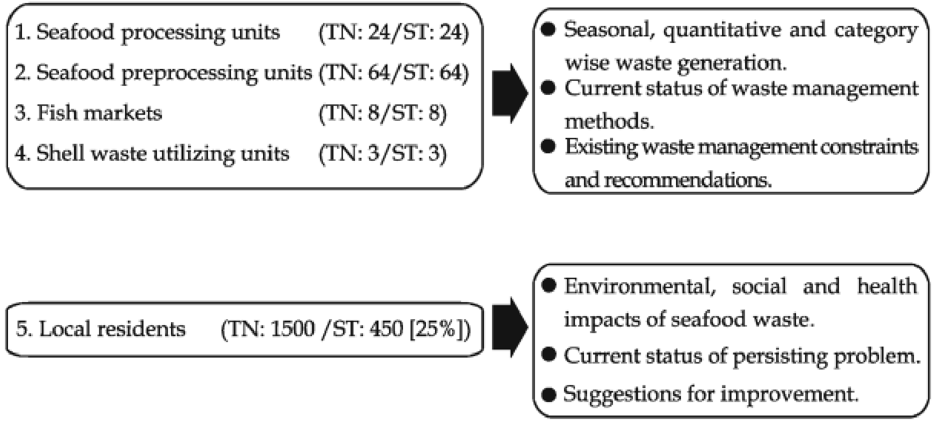
**Impact on side stream handling and by-product quality*

Side stream yield

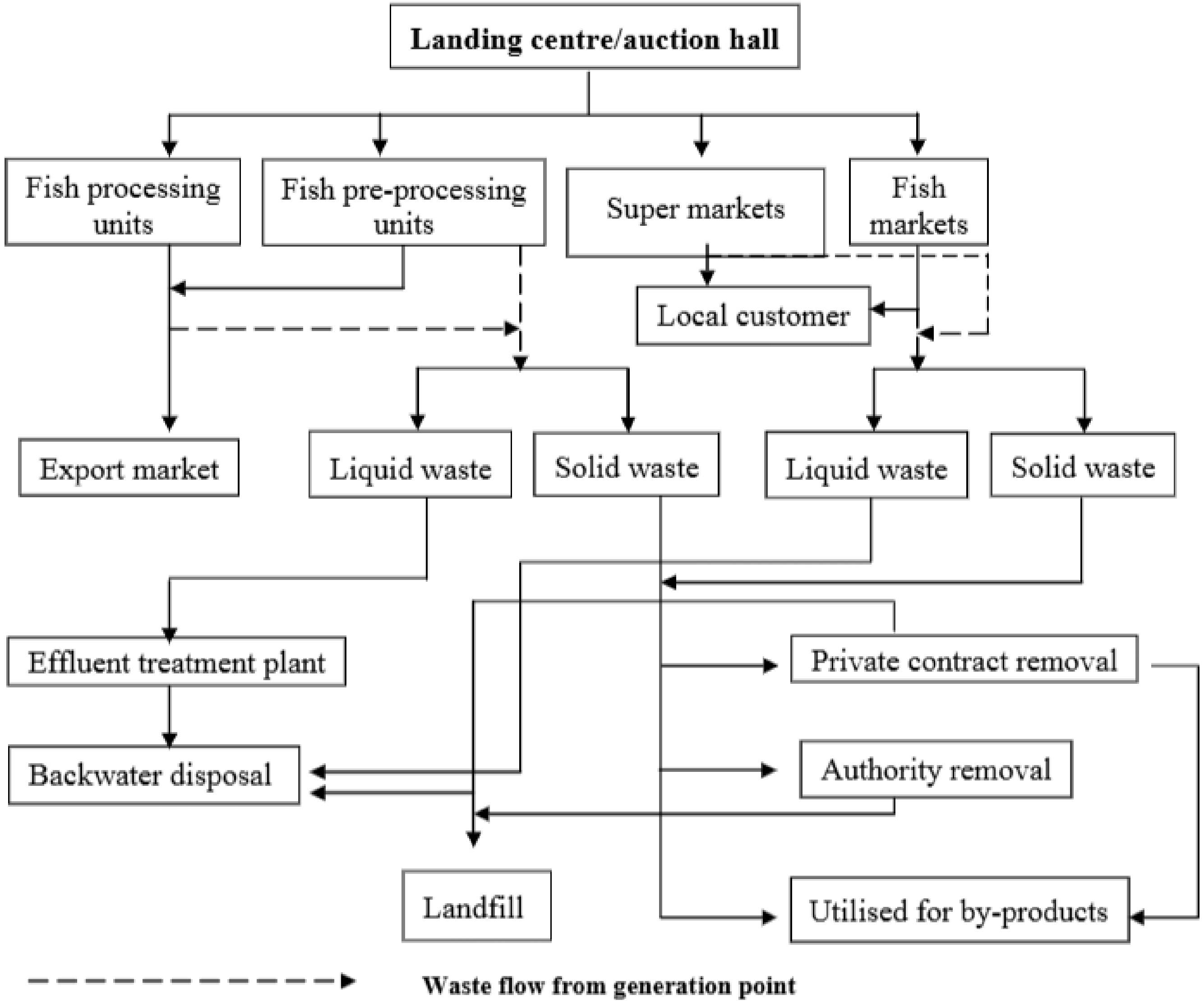


Side stream classification, characterization and byproduct yield

Side stream flow



TN-Total number, ST-Sample taken



A. Sasidharan et al., 2013

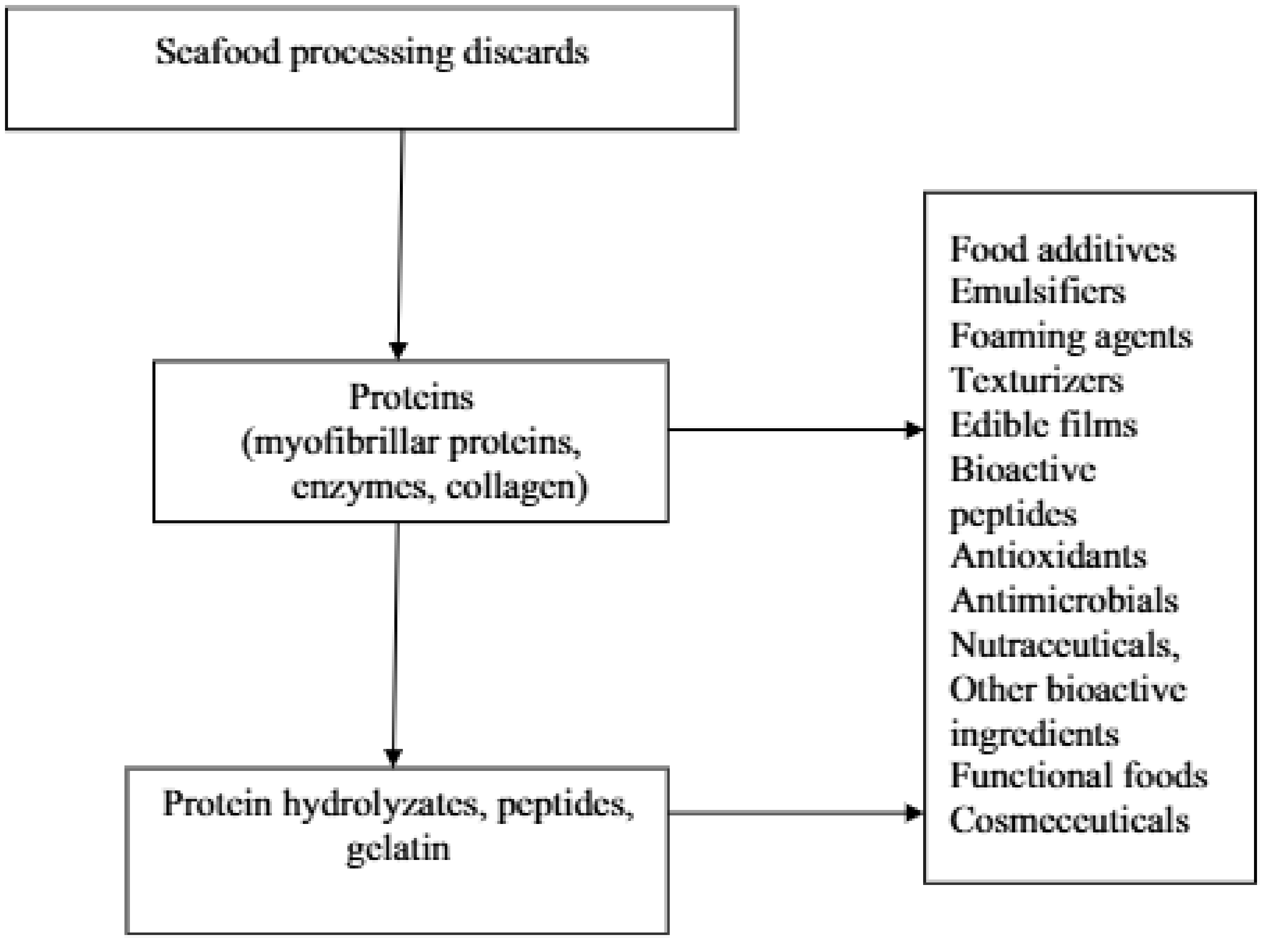
**Varies according to regulatory standards, Society/Industry perspective*

Side stream profiling

	Moisture (%)	Protein (%)	Fat (%)	Ash (%)
Tuna (*Thunnus albacares*)				
Tuna Head waste	59.9±1.01	14.8±0.35	13.5±0.7	11.7± 0.61
Tuna Viscera	77.0±1.38	16.1±0.42	4.6±0.5	1.7±0.42
Tuna Dark Muscle (Raw)	74.0±0.76	21.5±0.31	2.87±0.30	1.5±0.19
Tuna Dark Muscle (Pre-cooked)	73.3±0.83	24.5±0.70	0.57±0.06	1.1±0.15
Fish head & viscera				
Sardinella longiceps	67.3±0.93	19.0±0.36	11.63±0.70	1.8±0.20
Rastrelliger kanagurta	71.3±0.93	20.7±0.56	6.7±0.57	1.4±0.13
Nemipterus japonicus	77.4±0.55	18.0±0.66	3.0±0.37	1.7±0.31
Cephalopod processing waste				
Sepia pharonis	89.0±0.57	9.6±0.42	0.47±0.08	0.9±0.20
Loligo duvacelli	91.7±1.57	7.7±0.58	0.34±0.06	0.38±0.04
Shrimp head waste				
Metapenaeus dobsoni	82.6±0.50	9.7±0.50	2±0.10	5.7±0.45
Parapenaeopsis stylifera	81.0±1.01	9.5±0.45	4.7±0.4	4.8±0.33
Penaeus indicus	79.7±0.66	17.2±0.32	0.70±0.025	1.84±0.27
Aristus alcokii	77.4±0.53	9.7±0.75	8.13±0.25	4.5±0.46

A. Sasidharan, 2013

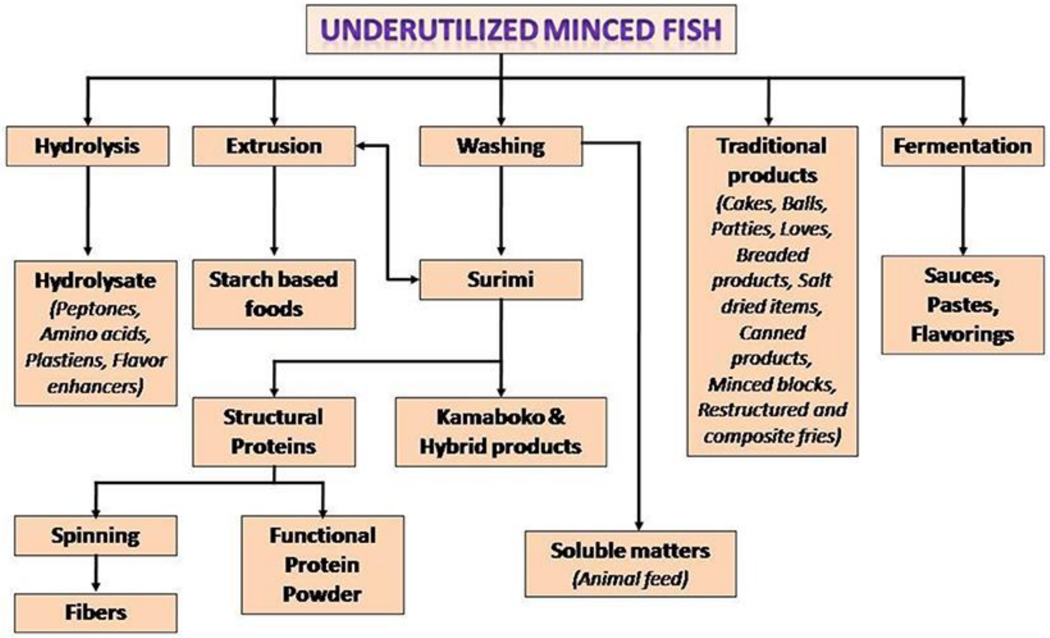
Side stream components (Protein)



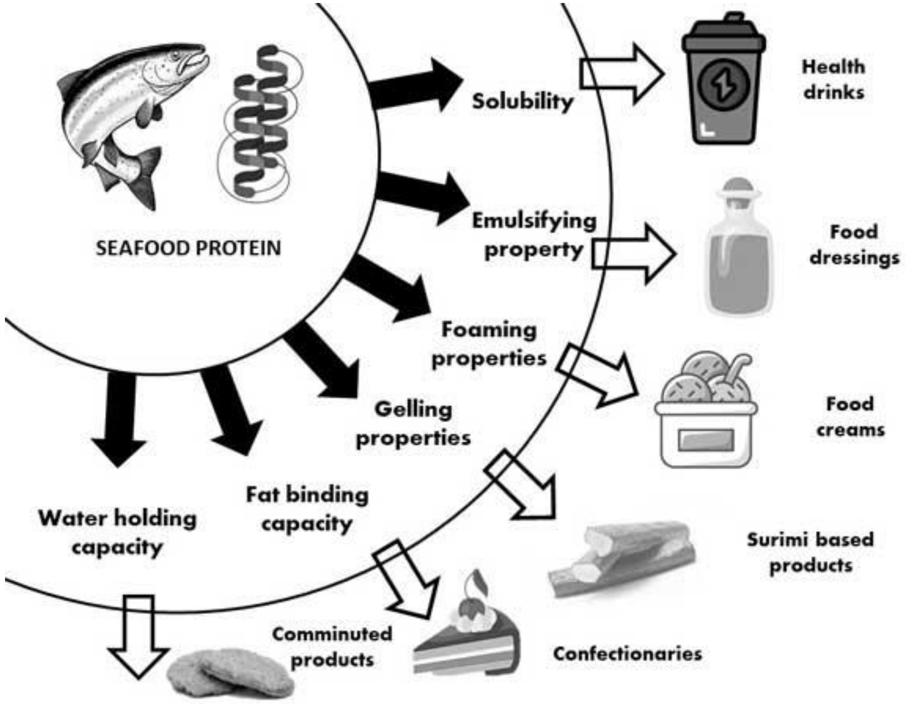
Sasidharan & Venugopal, 2019

Image courtesy: FROZEN SALMON TRIMMINGS Salmon By-Products Fish and By-products WHOLESALE WHOLESALE - Carnetrade.co.uk

Side stream components (Protein)…..cnt

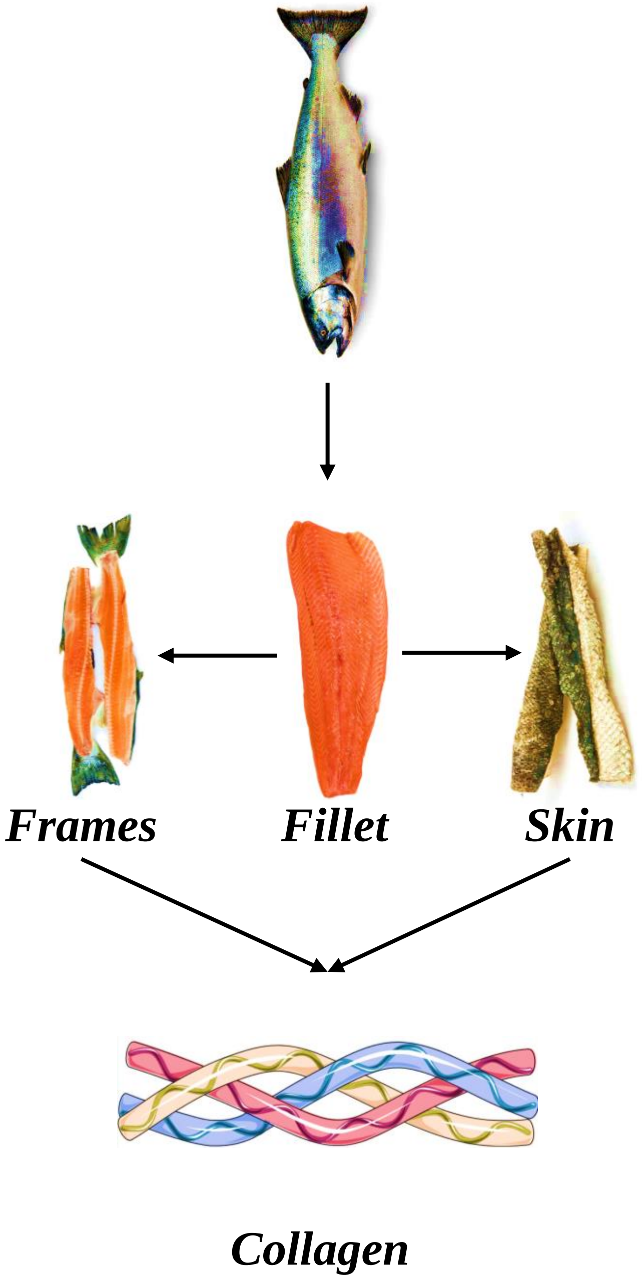


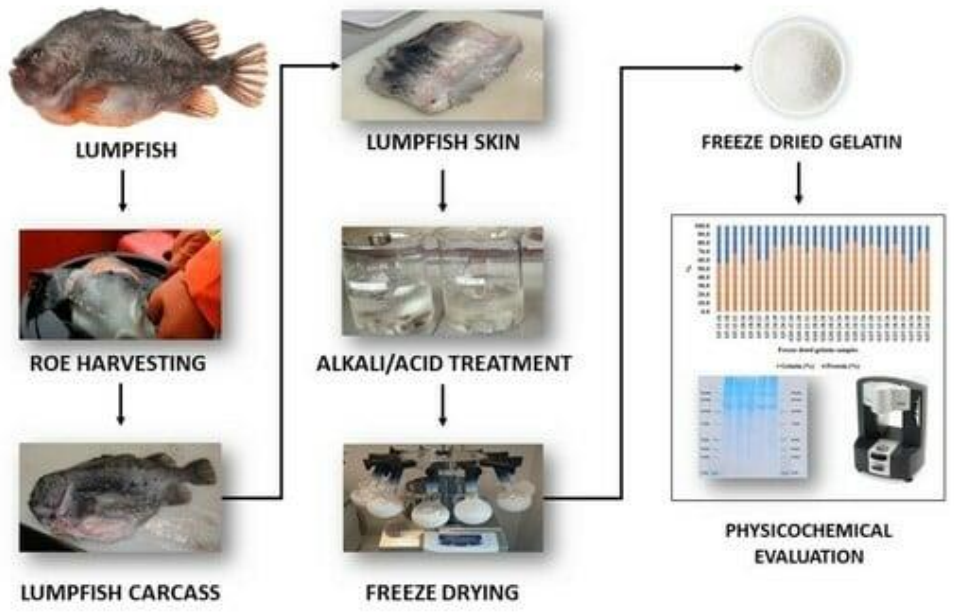
Venugopal & Sasidharan, 2022



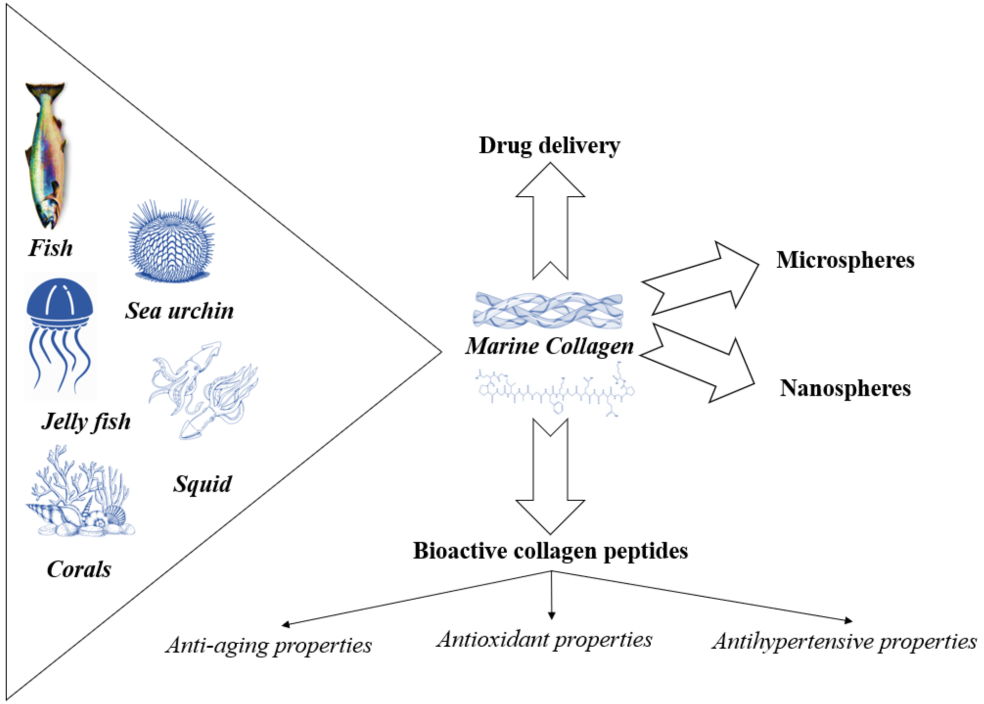
Sasidharan, 2023

Side stream components (Protein)…..cnt



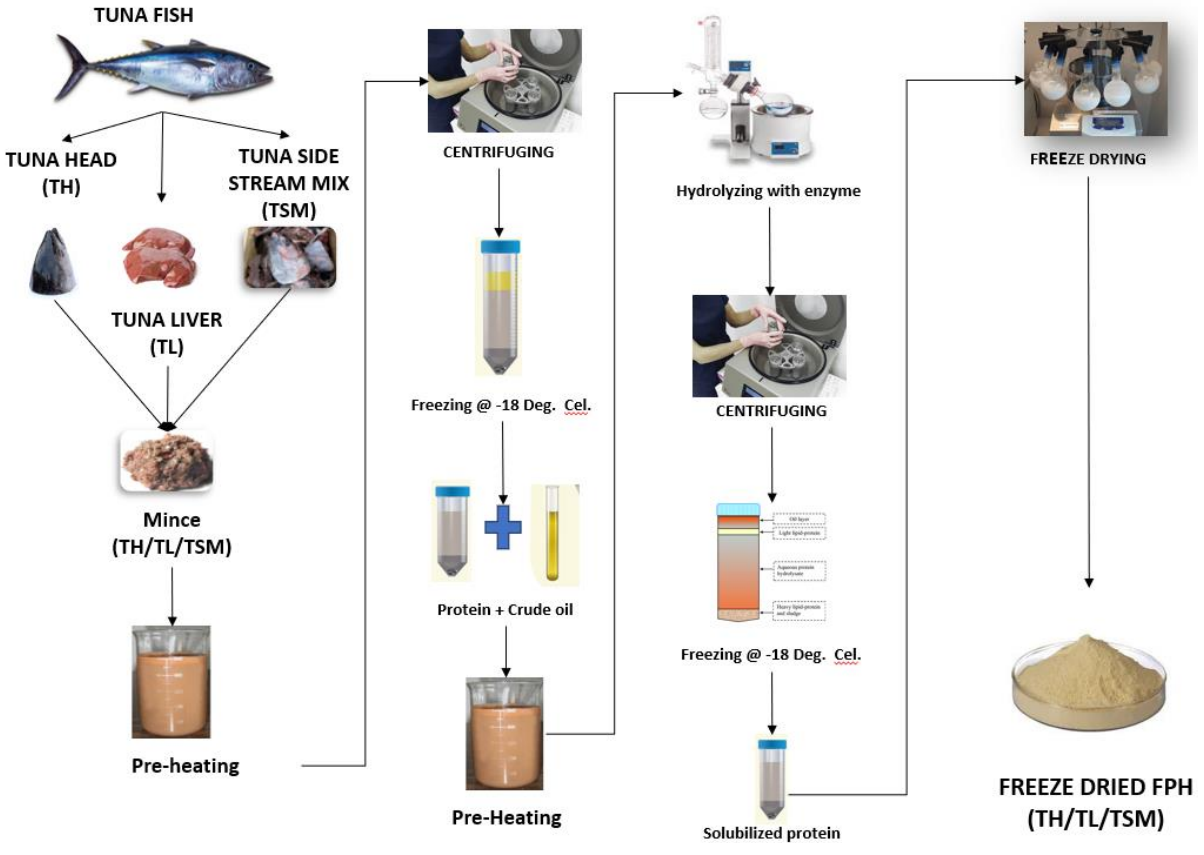


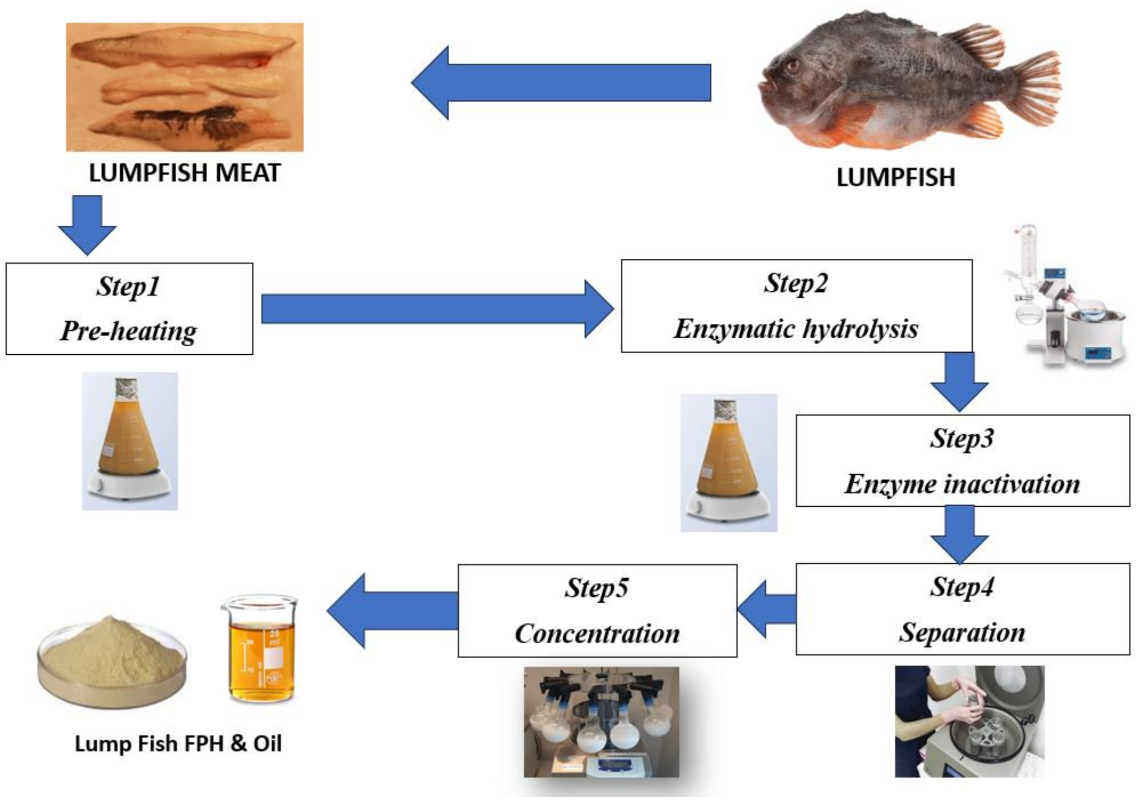
Sasidharan et al., 2024



Sasidharan, 2024

Side stream components (Protein)…..cnt

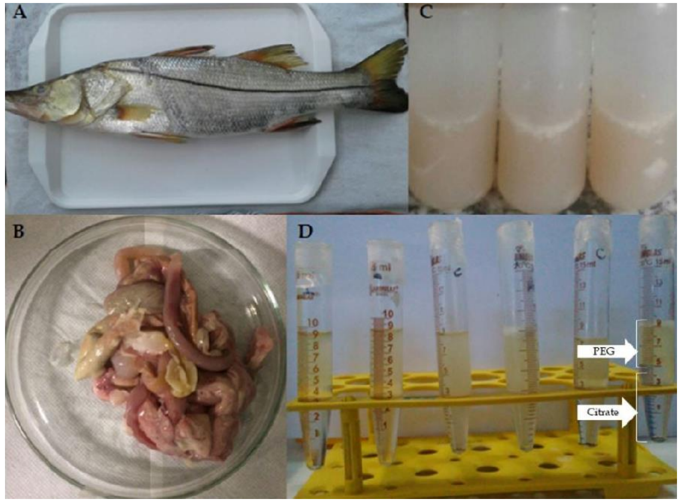




Side stream components (Protein)…..cnt

PROTEASE

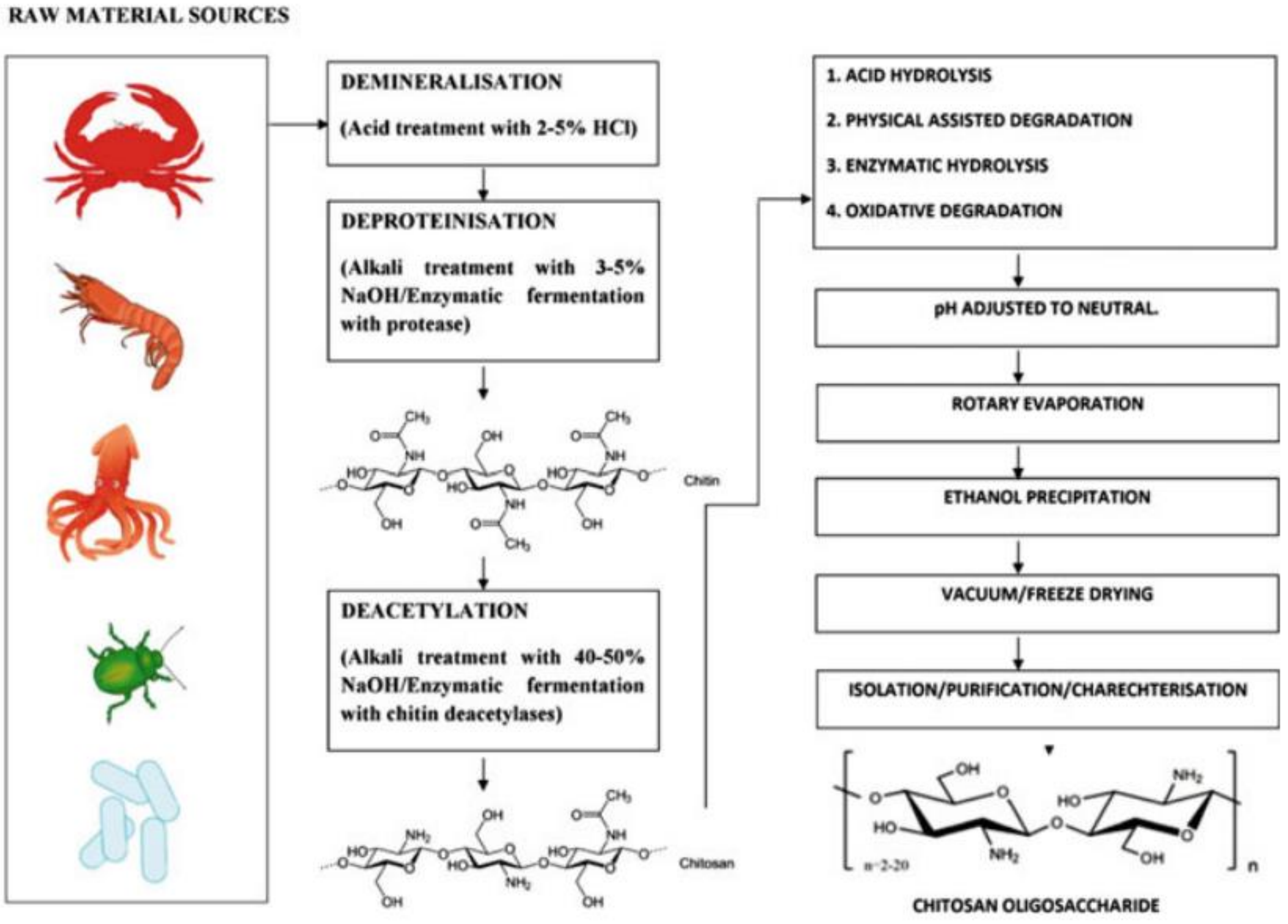
- Tenderization of fish meat
- Tenderization of squid
- Hydrolysis
- Debittering of hydrolysate
- Extraction of seafood flavourings
- Scaling of fish
- Peeling and deveining of shrimp
- Removal of clam viscera
- Ripening of salted fish



Silva et al., 2021

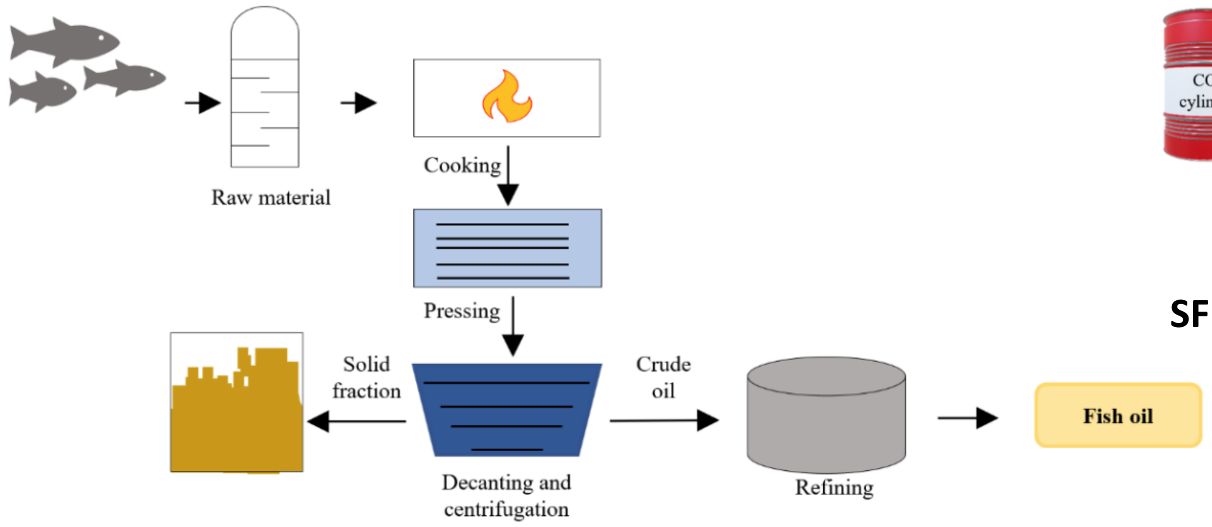
Venugopal & Sasidharan, 2022

Side stream components (Shell derivatives)

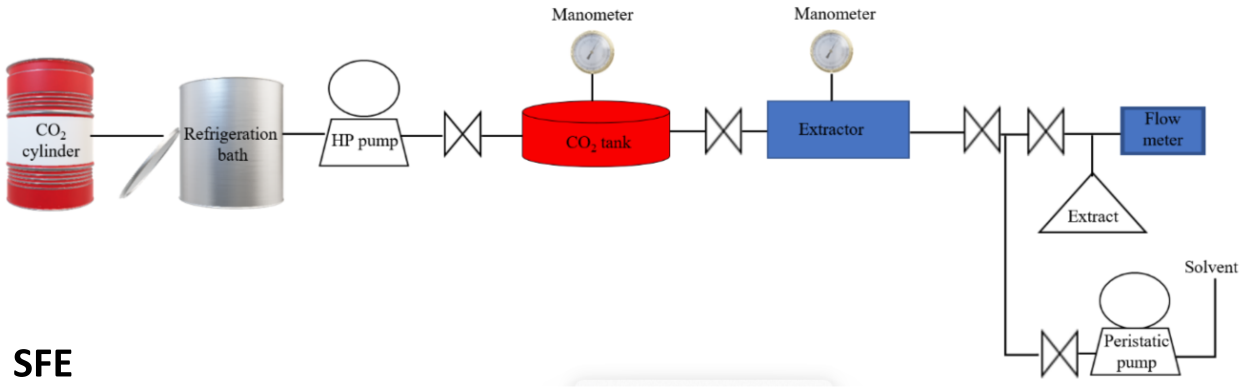


S. Sabu et al., 2022

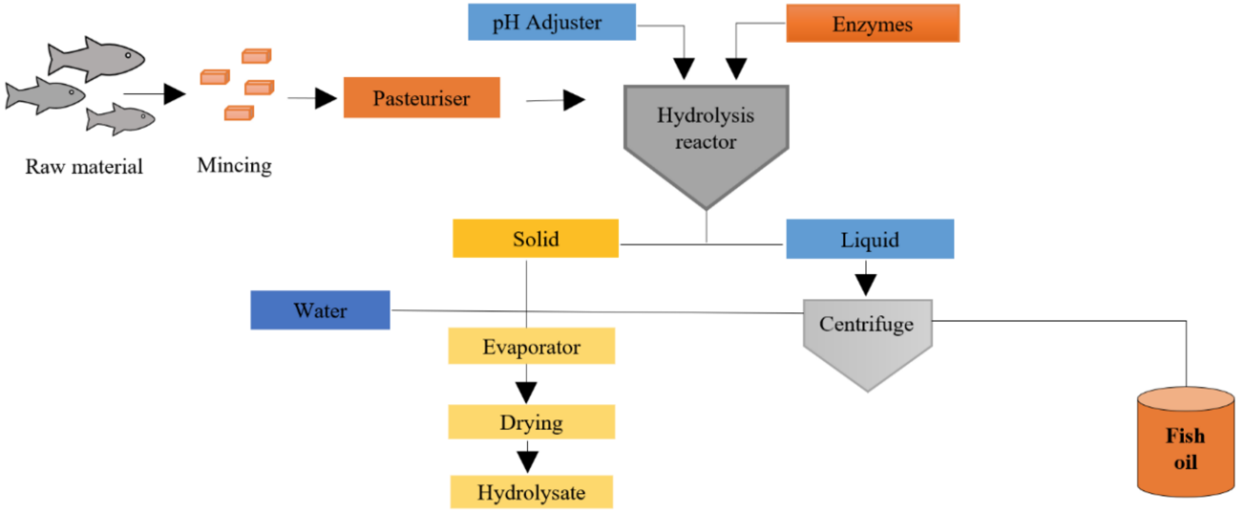
Side stream components (Lipid)



Wet reduction



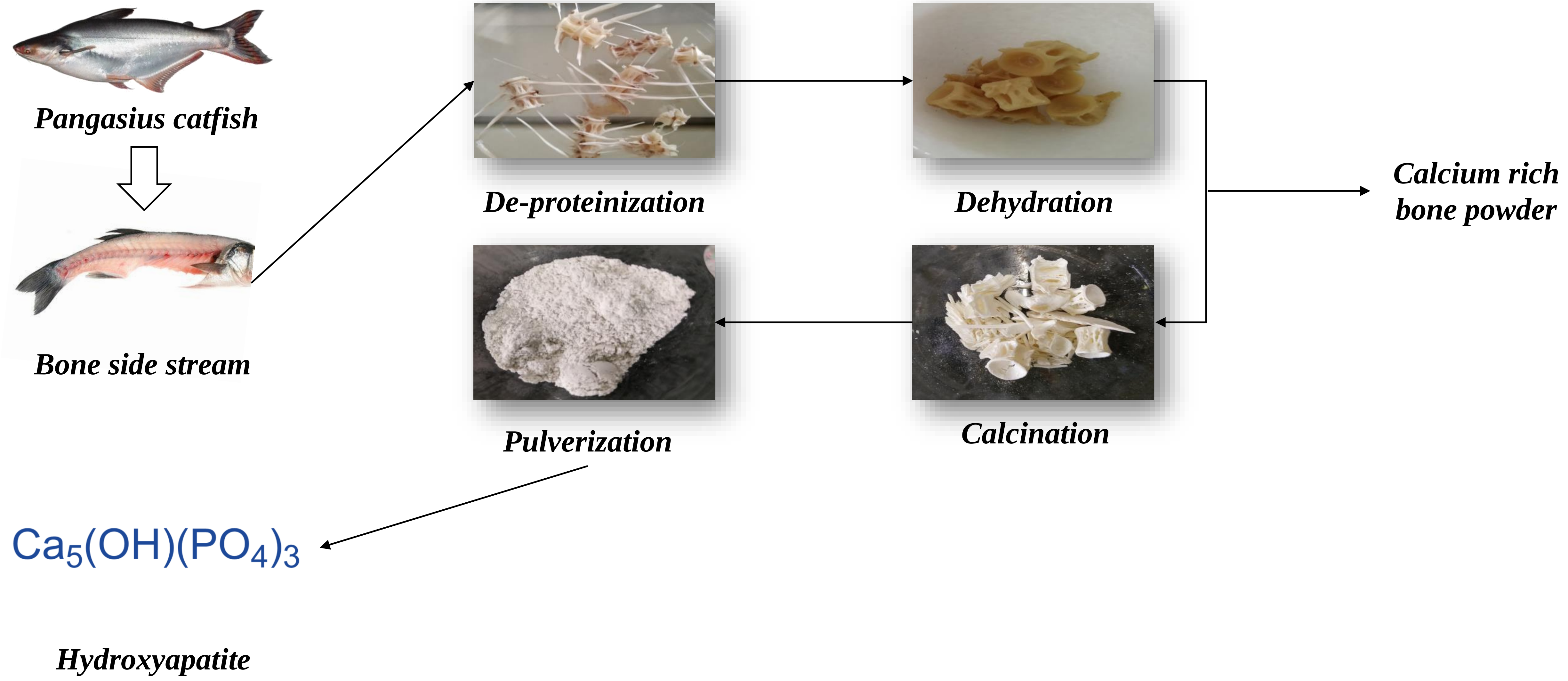
SFE



Hydrolysis

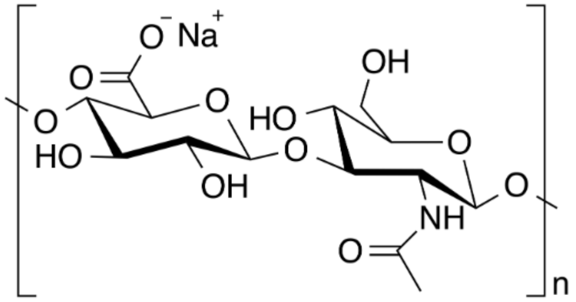
Adapted from Vaska et al., 2023

Side stream components (Biominerals)

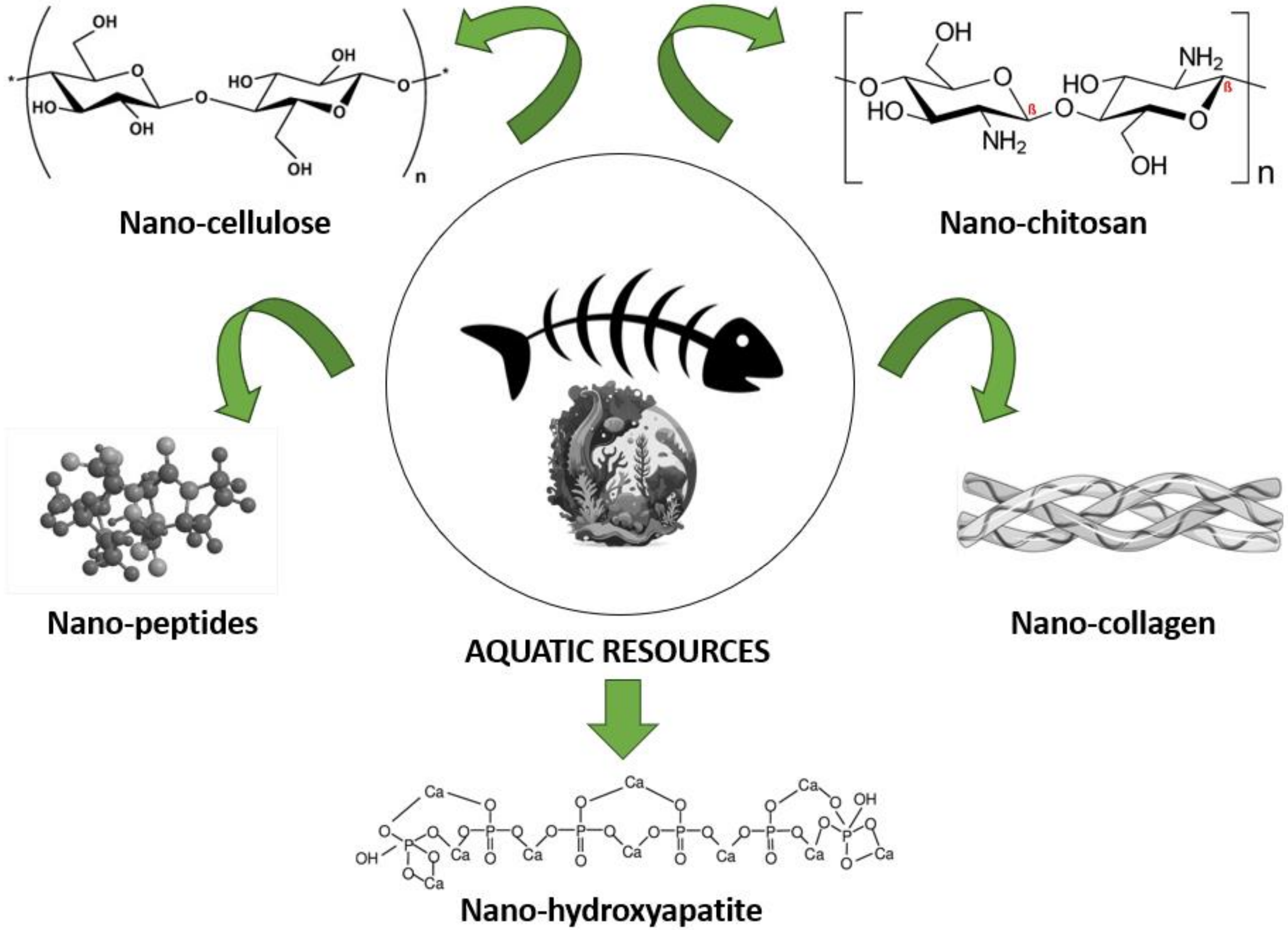


Side stream components (GAGs)

Hyaluronic Acid



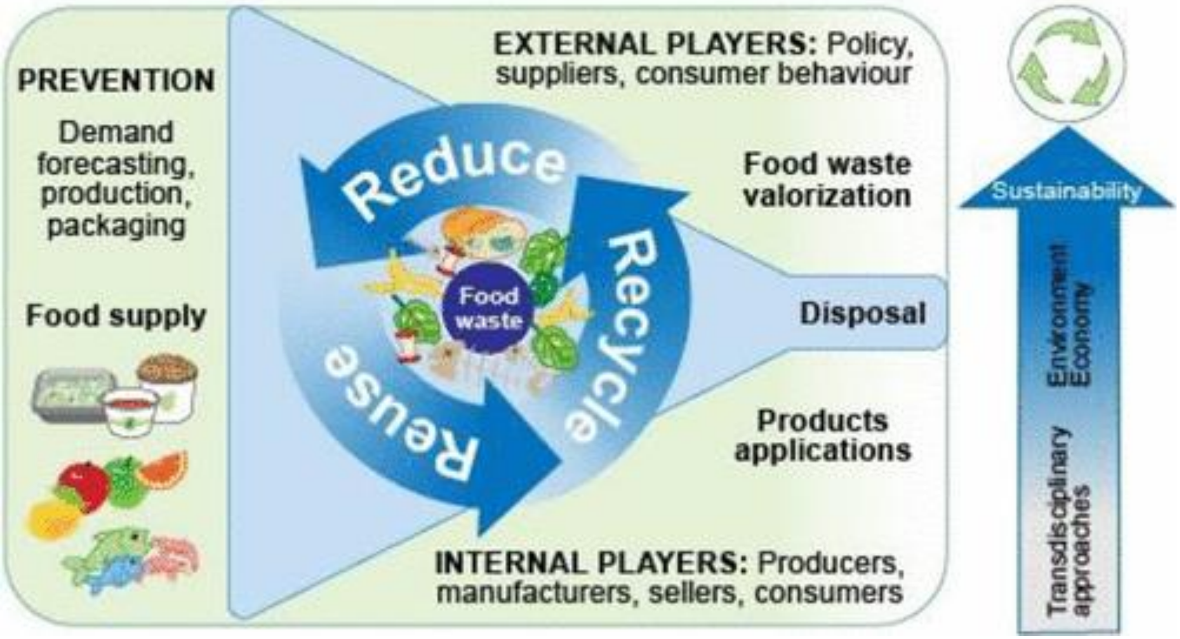
Side stream components (Bio-Nanos)



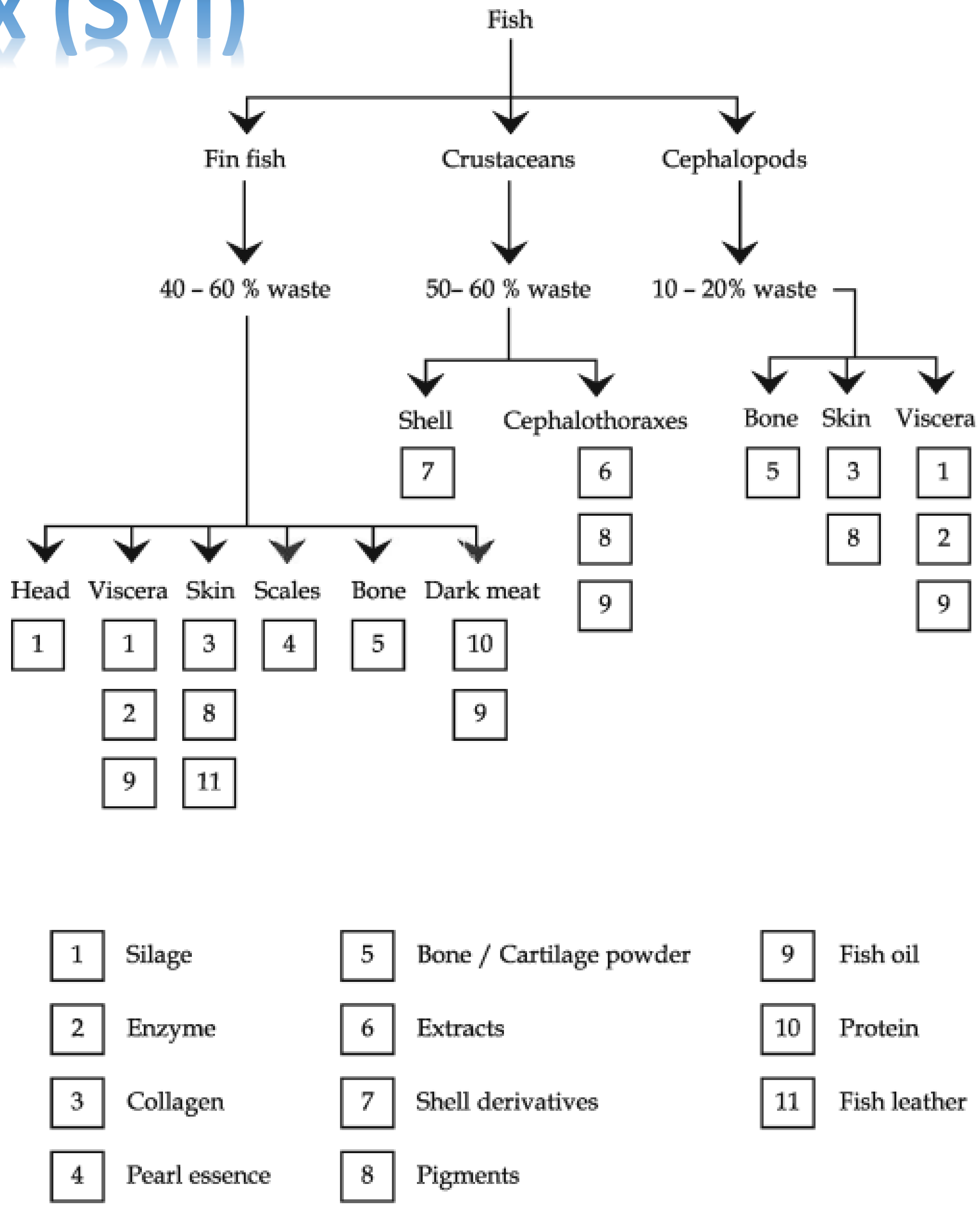
Adapted from Shahida et al., 2024

Side stream valorization Index (SVI)

PR4 (Prevention-Reduce-Reuse-Recycle-Recover)



Roy et al., 2023



Sasidharan, 2013

Sustainability perspective

Is it time that the seafood sustainability certifications focus on responsible resource utilisation along with responsible resource management and harvesting? (or they do already?). To complete the sustainability cycle, isn't it necessary to utilize the resources including the side streams? Dont we need a parallel seafood sidestream valorization value chain to complement a sustainable seafood resource? The seafood clusters around the world are successfully demonstrating how its done I suppose.

Seafood side stream valorization is a sustainable practice as it reintroduces the otherwise wasted nutritional components into the consumption channel.

- **Contributes towards food security.**
- **Creates complementary value chains.**
- **Reduce environmental foot prints by removing organic load from the ecosystem.**

But is side stream recovery and utilization really sustainable?

***Importance of LCA.**

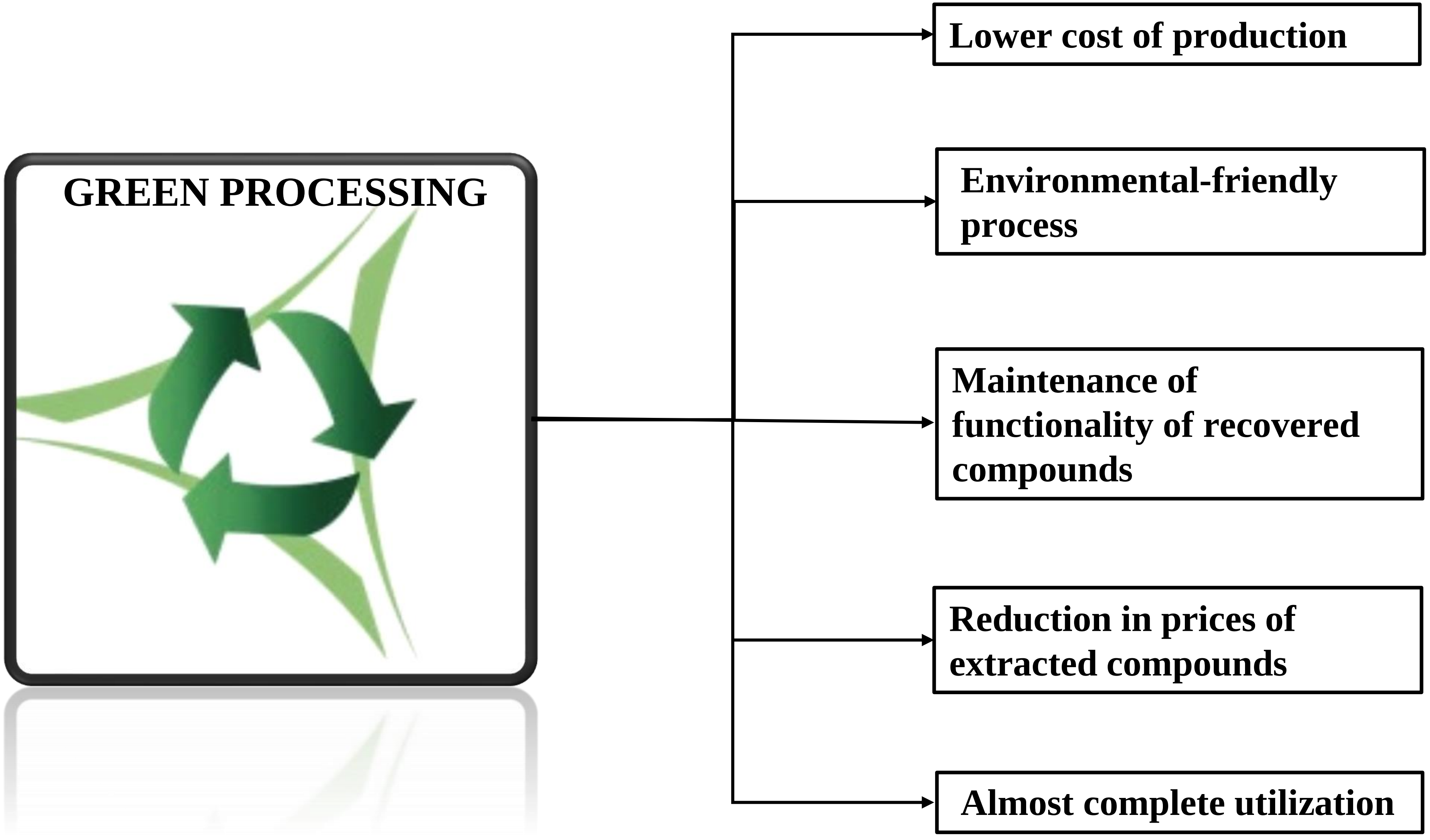
Depends on energy consumption.
Chemicals involved.

Need more Green technologies that runs on renewable energy or minimum conventional Energy/Chemical resources.

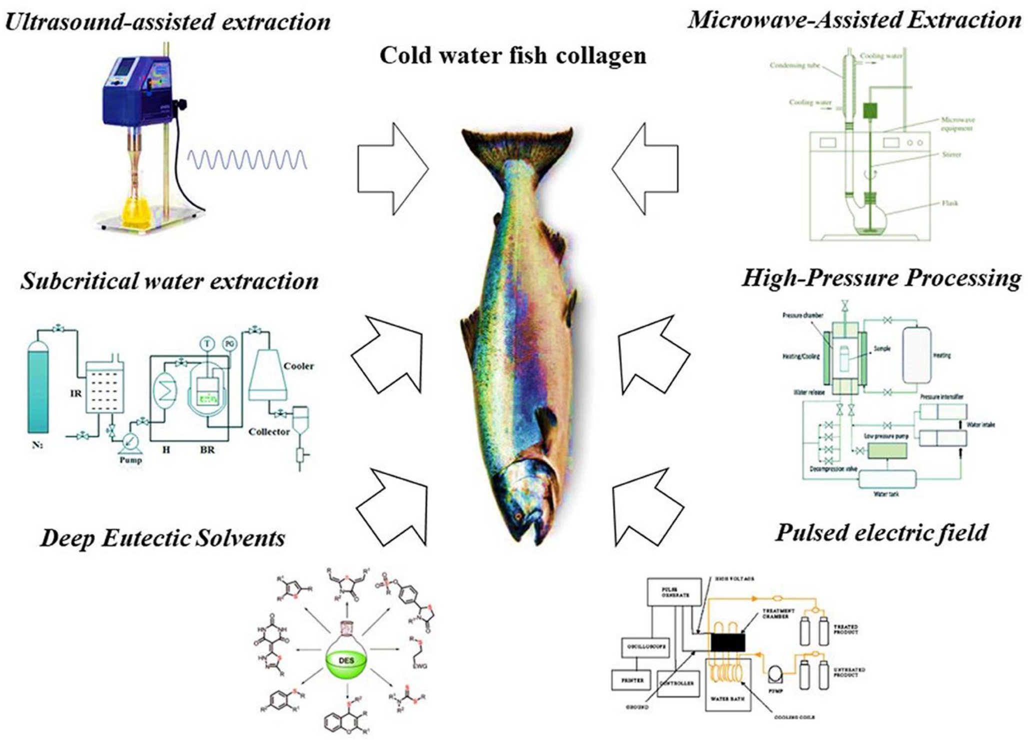
Sustainability limitations of conventional recovery processes

Component	Method	Limitations
Proteins	Chemical extraction under elevated temperatures	Longer time, high energy consumption, possible racemization of amino acids, splitting of disulfide bonds, loss of cysteine, serine and threonine via β-elimination reactions, formations of toxic compounds such as lysin alanine. D-Amino acids are not absorbed by humans
Peptides	Chemical hydrolysis and solvent extraction	Toxic compounds, residual solvents
Oil and biodiesel from oil	Acid digestion using HCl at high temperature until complete dissolution, other conventional methods	High reaction temperature, contamination of glycerol with alkali, soap formation, waste generation
Chitin, chitosan, chitin oligosaccharides	Demineralization by mineral acids, deproteinization by alkali such as sodium or potassium hydroxide	Hazardous, energy consuming, chemicals-rich effluents can cause health and safety concerns, affect intact nature of chitin, higher costs
Chitin, chitosan	Derivatization of functional groups for a wide spectrum of compounds	Chemicals used entail risks for human health and the environment
Chondroitin and hyaluronic acid	Solvent extraction	Most solvents used entail risks for human health and the environment. May also lead to compound degradation

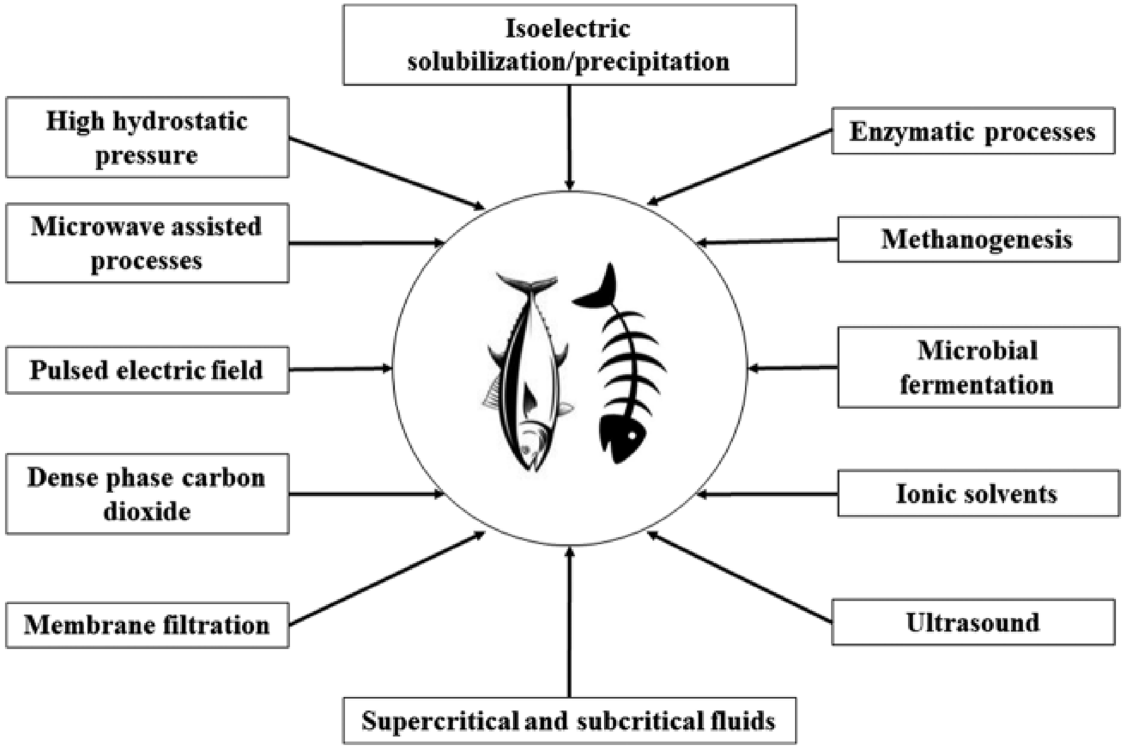
Adapted from Venugopal et al., 2023



Adapted from Venugopal et al., 2023



Kendler et al., 2024



Sasidharan et al., 2023

Conventional Vs Green recovery processes

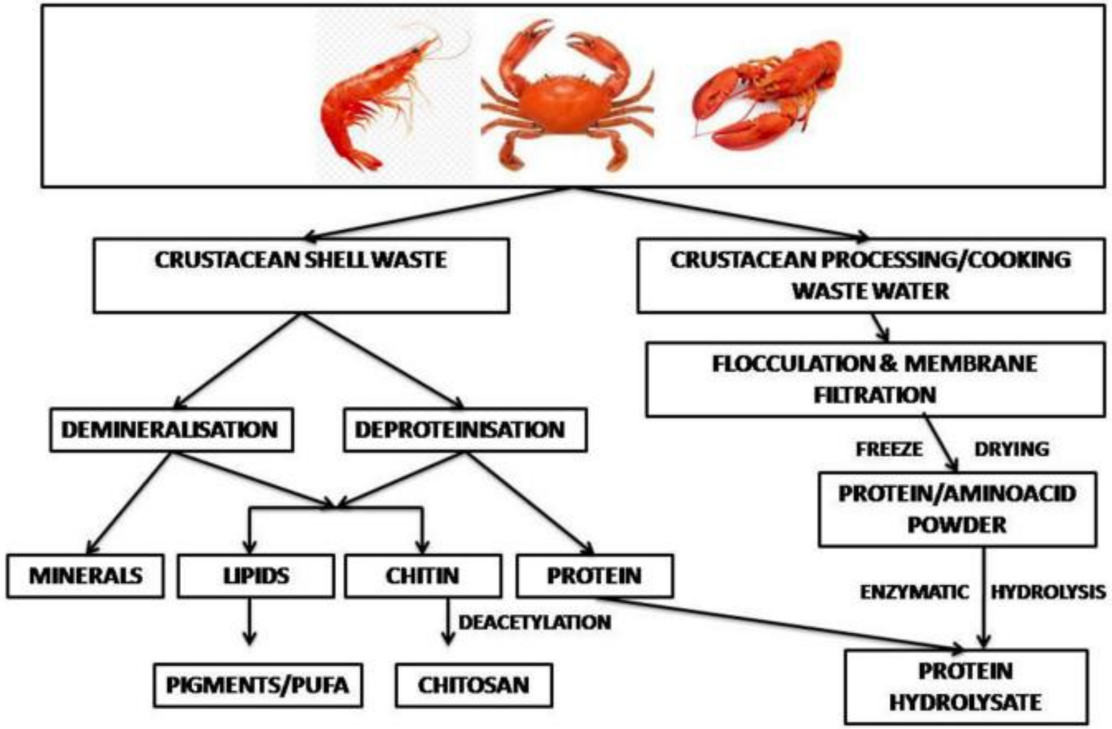
Parameters	Traditional	Green
General reaction conditions	Chemical treatment, likely at high temperature and pressure	Chemical reactions take place usually at ambient temperature and pressure
Nature of reagents	Reactive, persistent, or toxic. Many organic solvents have adverse health effects	Green solvents are inert, recyclable, and sustainable
Energy source	High energy generally from fossil feedstock	Low-energy chemical reactions
Catalysts	Catalysts may include elements from the entire periodic system. Some may be toxic. Some processes require high heat or pressure conditions	Microorganisms and enzymes serve as low cost, stable biocatalysts.
Changes in resources	Drastic degradation. Design exclusively for use phase	Degradation is part of design, "timed degradation" or "triggered instability".
Creation of functionality of the product	Functionality is created by the new material itself	Functionality is created by the structure. Scope for improved bioactivities
Type of processes	Linear	Circular
Management approach	Waste treatment	Waste utilization
Profitability	Maximum chemical production for minimum profitability	Maximum chemical production with minimum benign material use for increased profitability

Adapted from: Green and Sustainable Chemistry Framework Manual; United Nations Environment Programme, 2021, www.unep.org

Biorefinery approach

A systematic installation of a series of Green by-product recovery processes predominantly from side streams materializing completes utilization of resources in a sustainable manner resulting in multiple commercially significant end products.

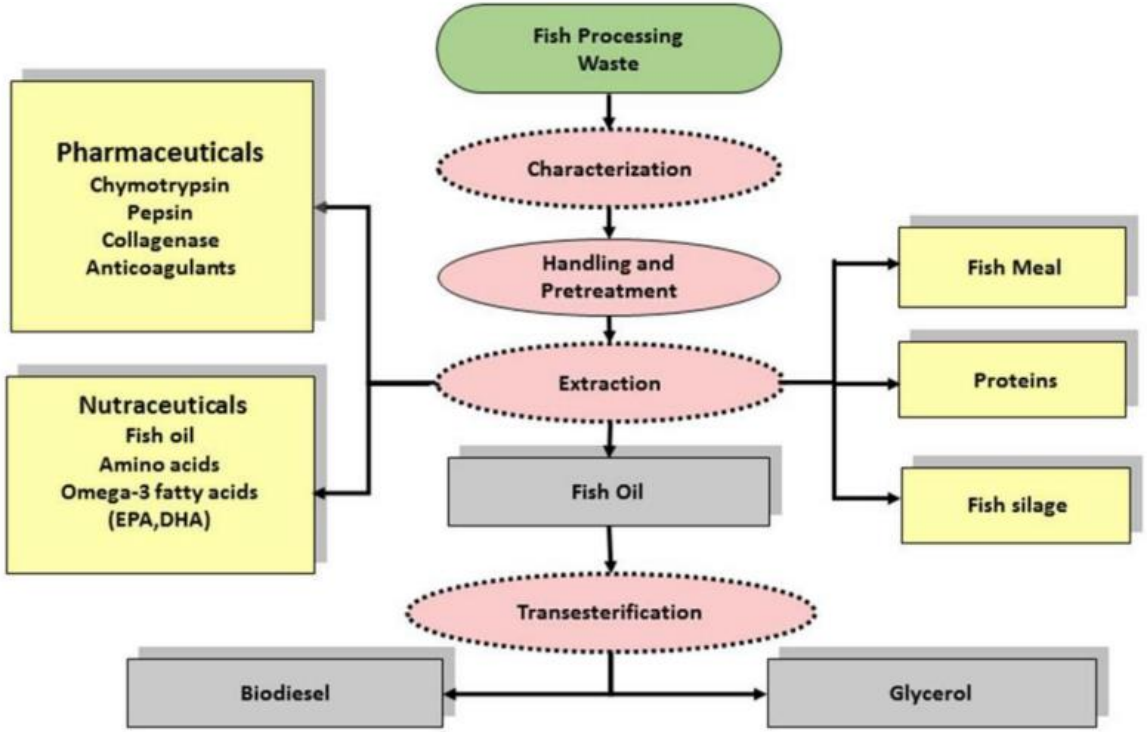
**Industrial symbiosis and co-location principles play into action in a successful biorefinery installation.*



Crustacean side stream biorefinery

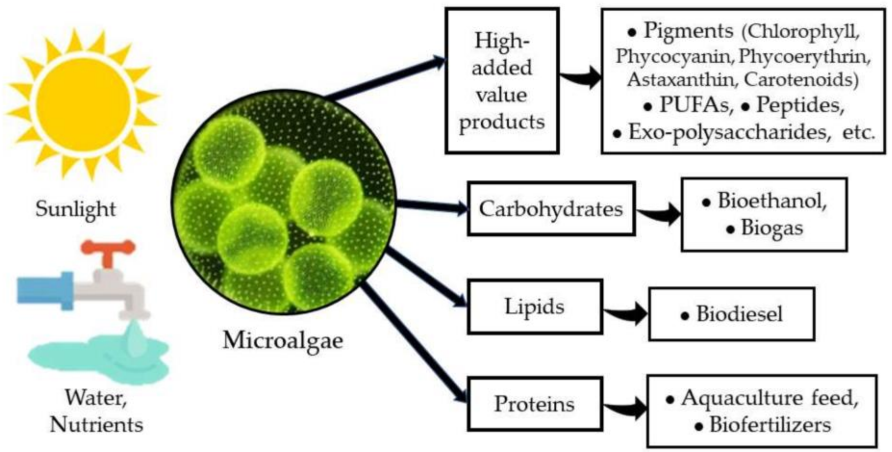
Venugopal & Sasidharan, 2023

Fish side stream biorefinery

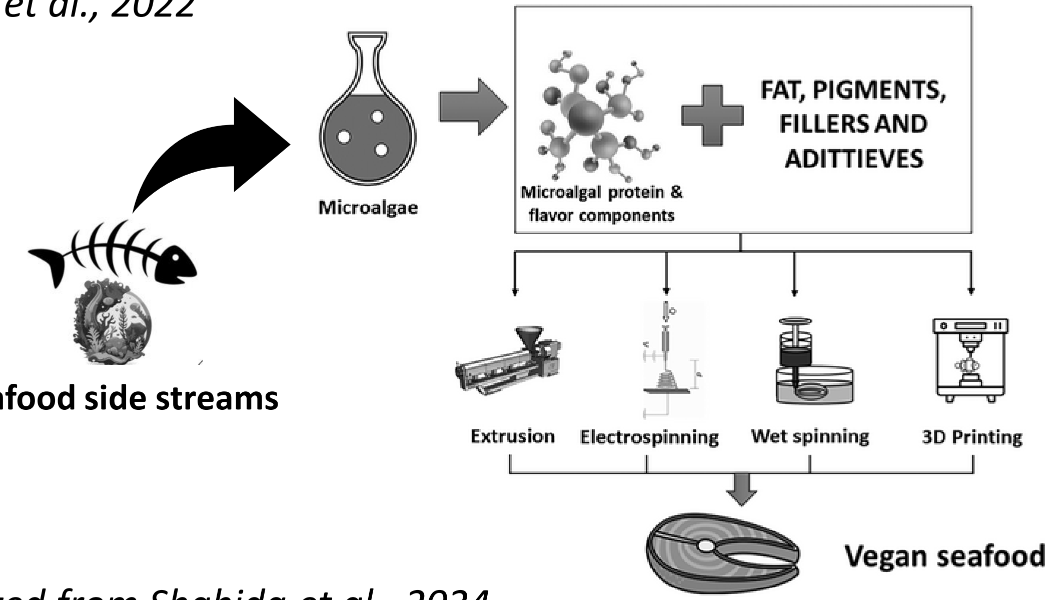


Ramakrishnan et al., 2017

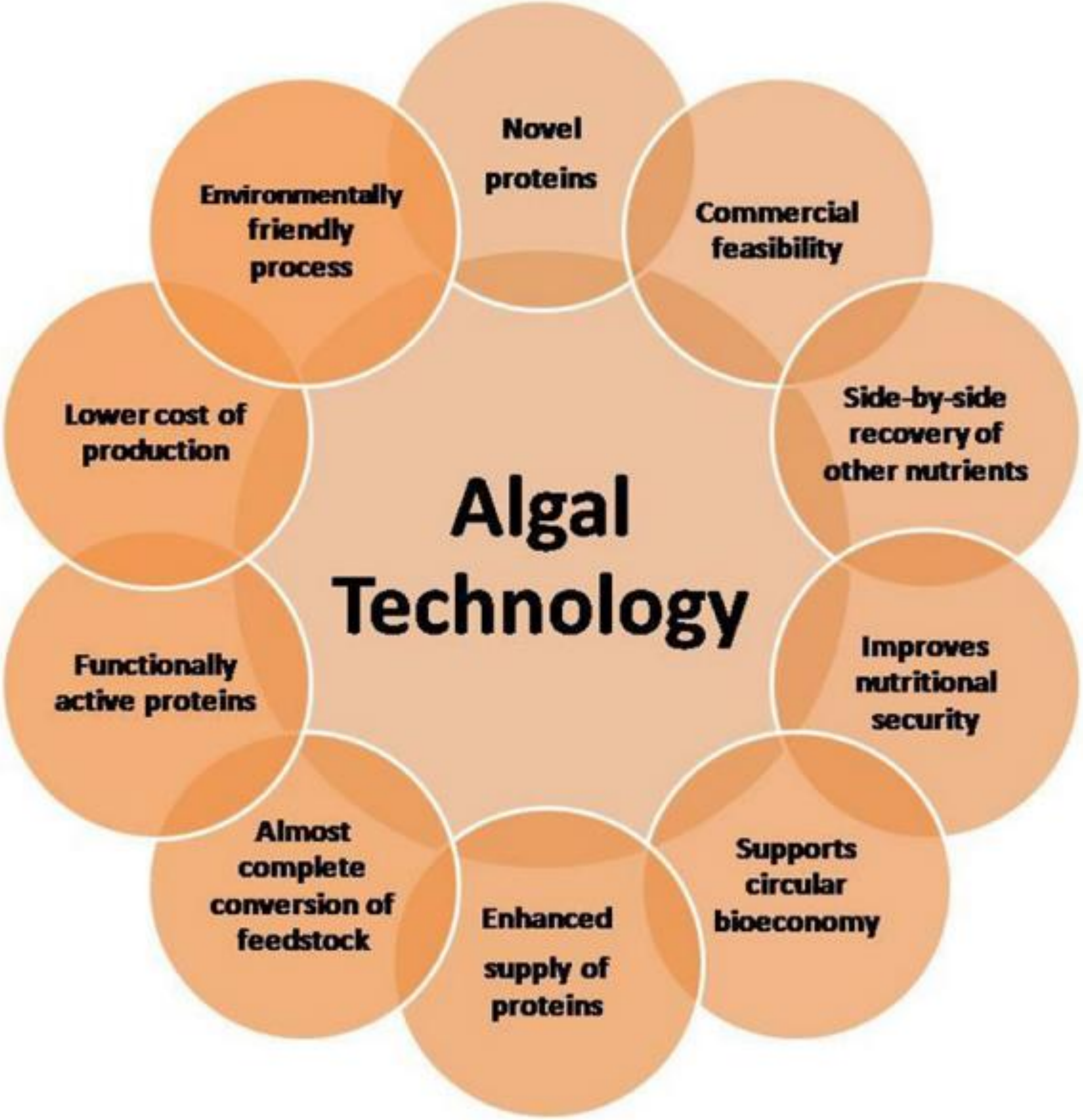
Microalgal Biorefineries



Olguin et al., 2022

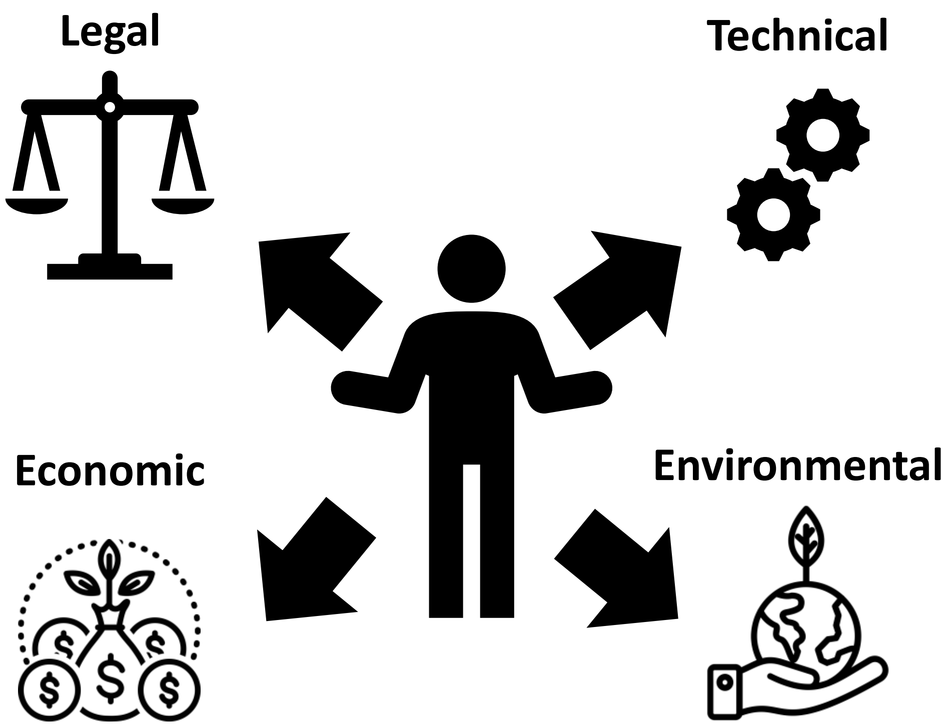


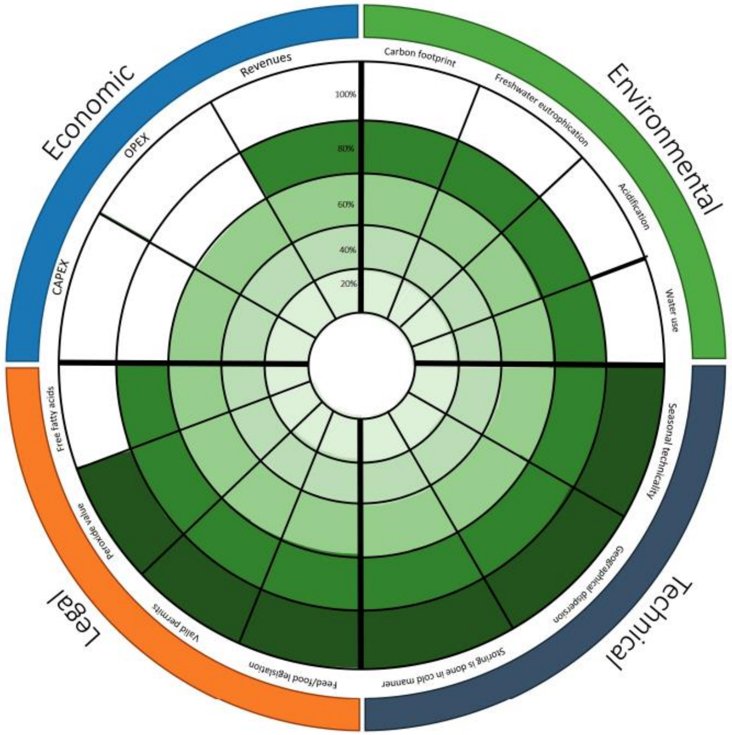
Adapted from Shahida et al., 2024



Venugopal & Sasidharan, 2023

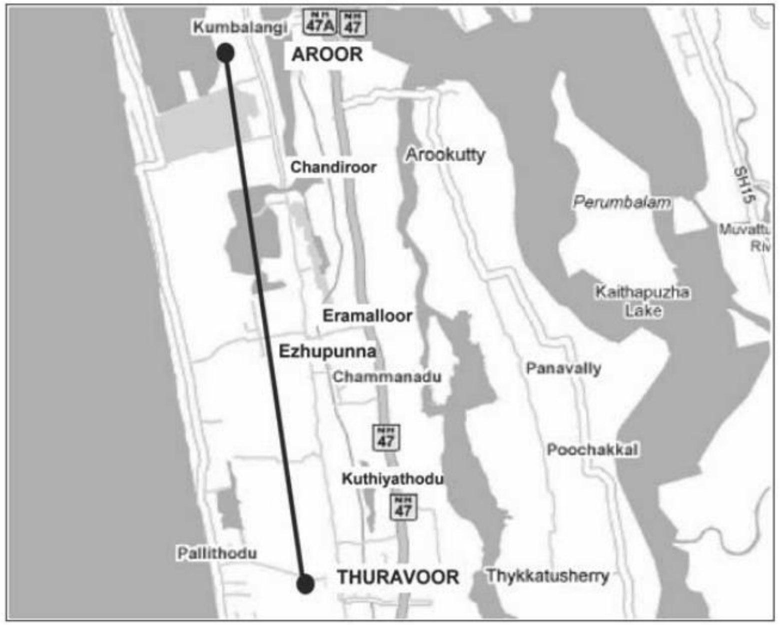
Choosing the right path – Ideal recovery process

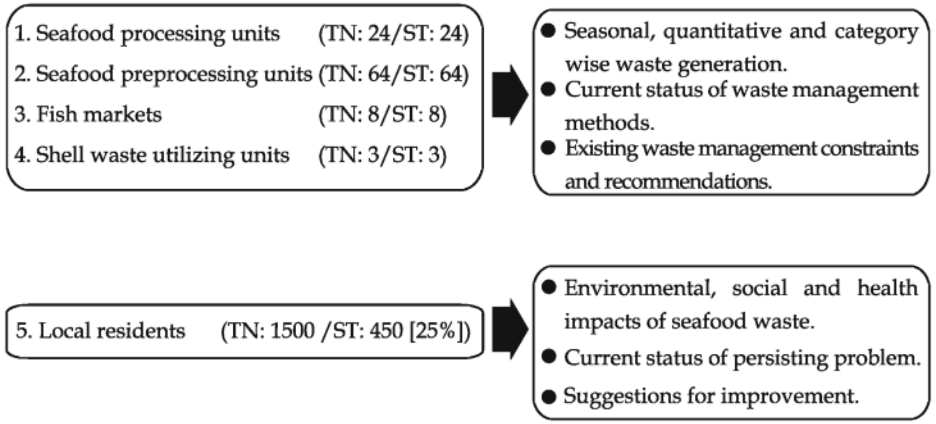


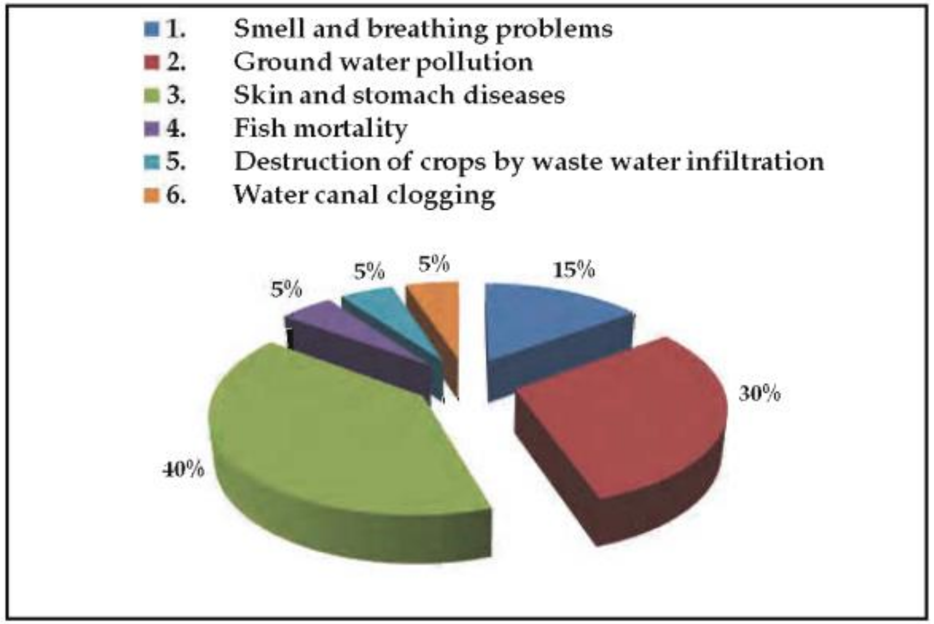


Ref: Cadena et al., 2024, WaSeaBi Project

Experiences from the project ‘Fish waste management and its socio-environmental impact assessment in Cochin Corporation and Aroor industrial area’, India, 2007-2010







Required immediate intervention.
Two sides of the coin- Industry and Community
Sustainable, locally adaptable, low investment, marketable by-product technology.

Fish Silage (Complete transformation of the side streams to by-product, marketable in both dry and liquid form, easy to adapt)

By-product marketing – Marine Protein

Forms

- **Fish Meal:** Animal feed.
- **Fish Protein Hydrolysates (FPH), Fish Protein Concentrates (FPC) and Fish Protein Isolates (FPI):** Sports nutrition, infant formula, and functional foods.
- **Collagen and Gelatine:** cosmetics and nutraceuticals industry, gelling agent in the food industry and has applications in pharmaceuticals for capsule manufacturing.
- **Crustacean Protein:** Food industry, particularly in high-protein snacks, and in animal feed production.
- **Algal Protein:** Vegan and vegetarian products, dietary supplements, and functional foods.
- **Marine Peptides :** Has antioxidant, anti-inflammatory, and antihypertensive effects. Used in functional foods, nutraceuticals, and pharmaceutical products.

Market Drivers

- A growing demand for high-quality, economic and sustainable protein. Alternatives to traditional animal proteins (like beef, pork, and chicken).
- A ricing awareness on the health and nutritional benefits of marine protein.
- An increased sustainability and environmental concerns among the consumers.
- An heightened demand for eco-friendly functional foods and nutraceuticals.
- A increase in popularity of plant based alternative proteins.

Marine Derived Proteins Market Size: USD 7.46 billion in 2023 (10.2% CAGR)'
Major market: Asia Pacific
Trend: Increasing marine collagen market.

Market Research and Consulting | Future Market Insights, Inc

By-product marketing – Marine Lipid

Forms

- **Fish Oil**: The major segment (high omega-3 content)
- **Krill Oil**: Higher astaxanthin content.
- **Algal Oil**: A vegan alternative.

Market Drivers

- A ricing awareness on the health benefits of marine lipids. (Heart health, anti-inflammation, promoting brain function.)
- An increased sustainability and environmental concerns among the consumers.
- An heightened demand for dietary supplements.

Marine derived lipids market size: **USD 10,401.5 million in 2024** (9% CAGR).
Major market: North America and Europe, Asia Pacific (Emerging)
Trend: Increasing animal feed demand.

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By-product marketing – Marine shell polysaccharides

Forms

- Chitin/Glucosamine hydrochloride
- Chitosan/Chitosan Oligosaccharides

Market Drivers

- A growing demand for bio-based polymers.
- An increasing demand for biocompatible and versatile materials in biomedical and pharmaceutical applications.
- An increased application in organic farming practices.
- An heightened demand for eco-friendly water purification technology.

Marine shell polysaccharides market size: USD 10.88 billion in 2022 (20% CAGR).
Major market: Asia Pacific, North America and Europe (Emerging)
Trend: Increasing demand in biomedical, packaging and water purification applications.

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By-product marketing – Marine biominerals

Forms

- **Fish Bones and Scales**: marine hydroxyapatite (Bone & Dental care)
- **Mollusc Shells**: marine calcium carbonate (Calcium fortification)

Market Drivers

- An increasing demand for biocompatible and versatile materials in bone and dental applications. (Bone and Joint Health awareness).
- An increased demand for organic (bioavailability) food fortification components.

Global hydroxyapatite market size: US$ 480.2 million in 2022 (7.8% CAGR).
Marine calcium market size: USD 349.5 Million in 2024 (5.9% CAGR).
Major market: Asia Pacific, North America and Europe, Latin America and Africa (Emerging)
Trend: Increasing demand in biomedical and food fortification applications (Plant based milk).

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By-product marketing – Hyaluronic acid

Forms

- Algae-based HA
- Aquatic animal-based HA

Market Drivers

- An increasing demand for clean and natural beauty products (skin serum, moisturisers, injectables).
- Rising Demand for organic anti-aging and hydration products.
- Increased awareness in skin and joint health.
- An increased demand for biocompatible materials for ophthalmic treatments, dermal fillers, and osteoarthritis injections.

Marine shell polysaccharides market size: USD 213.7 million in 2023 (11% CAGR).
Major market: Asia Pacific, North America and Europe (sustainable cosmetics).
Trend: Increasing demand for ecofriendly and organic beauty products.

Marine Hyaluronic Acid Market Size, Demand & Growth Report (factmr.com)

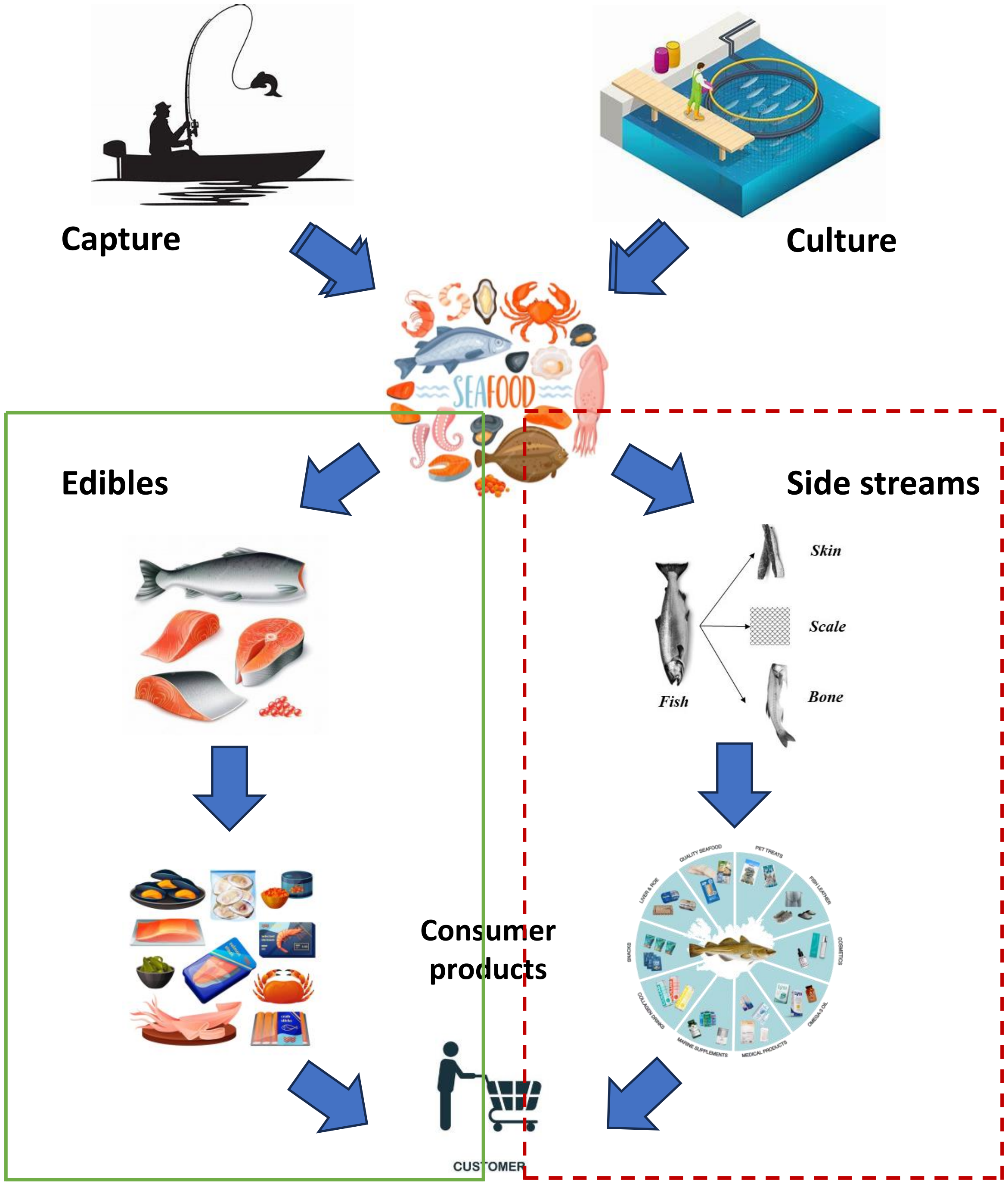
Social impacts and community benefits of seafood side stream valorization (SSV).

1. **SSV introduces new jobs and economic activities:** SSV based industries, skilled and unskilled industrial labor force, alternative livelihood opportunities for fishermen.
2. **SSV contributes towards food and nutritional security:** Recovery of otherwise wasted nutritional components complements existing supply chains.
3. **SSV assures environmental and public health safety**: By reducing organic waste load on the environment assures both environmental and public health.
4. **SSV contributes towards cultural and social empowerment:** Integrating indigenous traditional knowledge (ITK) on seafood side stream valorisation with modern technical knowhow and there for encouraging community participation in the process.
5. **SSV contributes towards education and skill development:** Research, innovation and skill development programs on SSV introduced to the area by the industry/authorities enriches the learning pool of the immediate community.
6. **SSV contributes towards economic resilience:** SSV value chain enables the industry and the community which was otherwise solely dependent on the performance of the primary products.
7. **SSV encourages gender equality:** Role of women in SSV based activities is much more significant due to their increased association with the land based post-harvest activities, providing them more revenue windows.
8. **SSV accelerates local and regional economic development:** Parallel mushrooming of allied industries and export market could boost the economic development of the region.
9. **SSV promotes social responsibility and ethical consumption:** Establishment of economically viable SSV activities increases the local sustainability awareness and attracts more customers towards ethical consumerism.

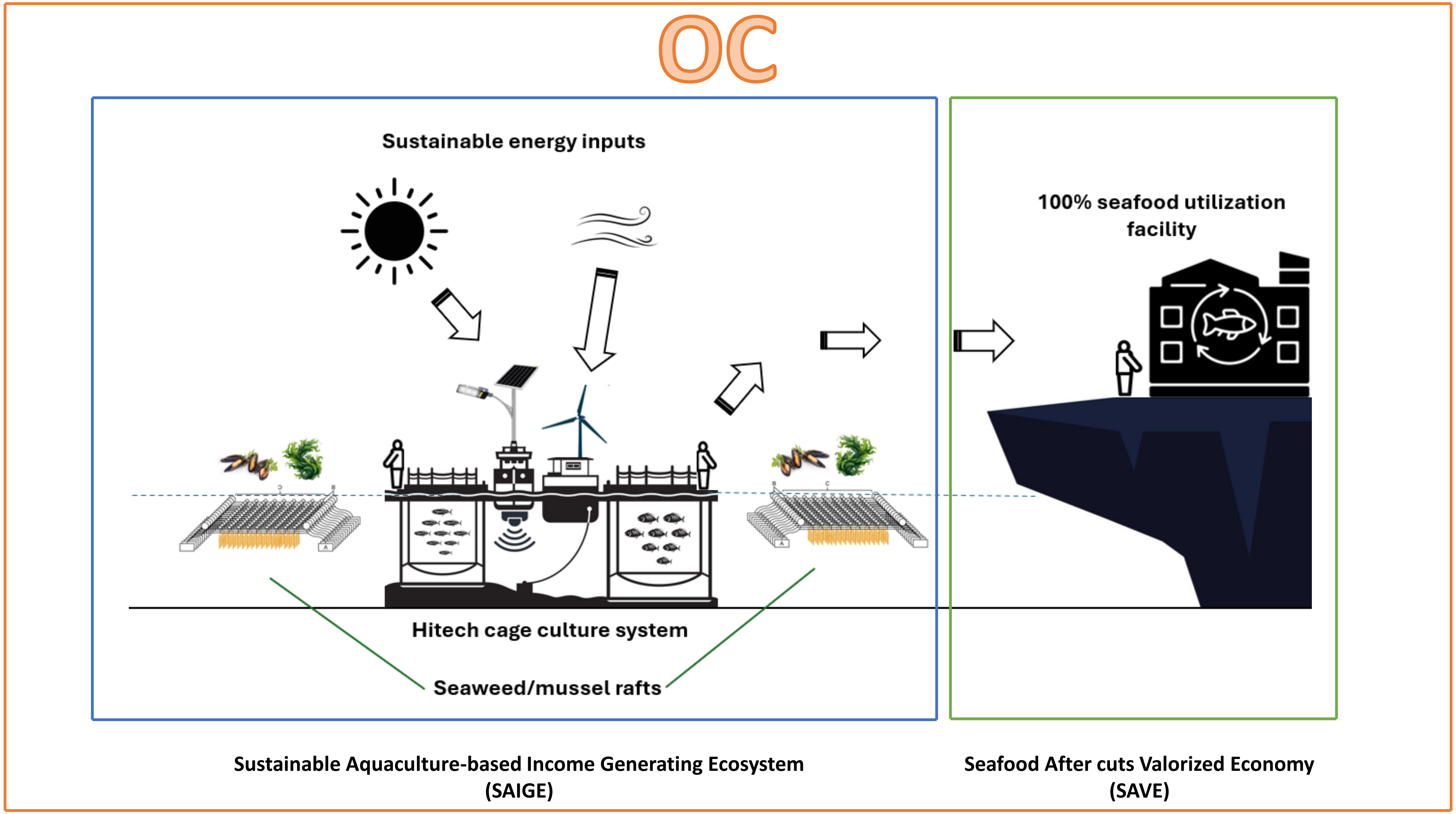
Economic benefits of seafood side stream valorization (SSV).

1. New high value revenue streams.
2. Reduced disposal and environmental compliance costs.
3. Development of small businesses (MSMEs)
4. Enhanced profitability through product diversification and attracting high value sustainability markets.
5. Enhancing export performance and global sustainability competitiveness.
6. Accelerates interdisciplinary research and innovation.
7. Contributes towards circular economy.
8. Ensures long term economic resilience and sustainability.

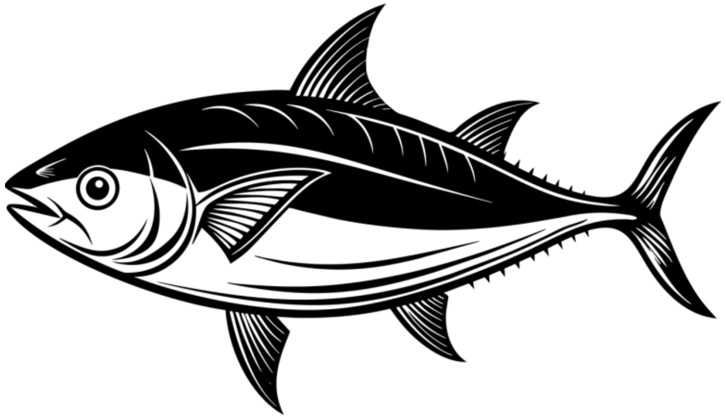
Creating a parallel side stream value chain



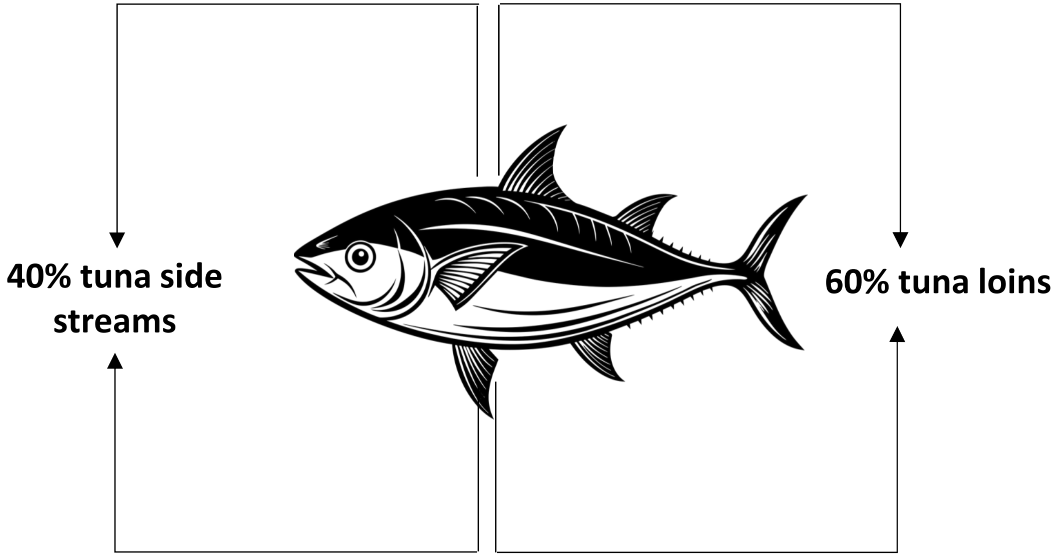
ARE OCEAN CLUSTERS THE ANSWER?



100% value realization



10 pound tuna @$20/pound = $200



Loins= 6 pounds ($120) (Selling price $50/pound)

Side streams=4 pounds

Emulsion= 3 pounds ($2/pound) = $6
Bone=1 pounds ($3/pound) = $3
Value added= $9

Collagen = $20/pound
Fish Protein hydrolysate = $8/pound
Tuna oil = $80 /pound

Nutraceuticals and functional foods

THANK YOU

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