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Exploitation of ReValue results

ReValue Project Deliverable 4.3

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ABSTRACT
This report is a part of Deliverable 4.3 of Revalue project highlighting the exploitation potential of the solutions developed in the project to reduce losses in the surimi supply chain in India. ReValue solutions have the potential to achieve a huge market impact, drastically increasing the Surimi industry profitability. The average value of fish used for surimi will increase significantly if the Rest Raw Materials (RRM) can be utilized into food and feed ingredients. In addition, ReValue solutions contribute to quality enhancement through improvement in processes and in the cold chain, as well as the introduction of functional ingredients derived from RRM that can be used as nutritional supplements. Further exploitation should focus on the marketing of surimi derived products, increasing consumer awareness for wider acceptance of surimi and derived products from India in the European market.

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1 Introduction

According to FAO, globally, fish losses amount to 160 million tonnes/year, out of which the surimi industry is responsible for more than 3.5%. Surimi processing generates rest raw materials (RRM) including viscera, skin, filleting frame, bone and wash water with potential to be used in preparation of valuable ingredients like marine proteins and oil, protein hydrolysate, and gelatine. Surimi is a product that is highly dependent on the cold chain because it deteriorates quickly if not chilled or frozen. A lack of proper handling of RRM can also be witnessed as a shortcoming in the surimi sector, but if fish intended for surimi production is handled and processed under good sanitary conditions, it results in human food-grade quality RRM, which can be used for production of valuable marine oil and proteins. Currently, the surimi RRM in India are not considered to be an important co-stream and are treated as a waste product from the sector. The ReValue project has focused on developing solutions for this sector that will improve the resource-use efficiency and upgrade the co-streams into value added products.

This report is a part of Deliverable 4.3 of the ReValue project highlighting the exploitation potential of the solutions developed in the project to reduce losses in the surimi supply chain in India. The project focused on the following key research and innovation areas:

1. Concepts for efficient supply chain logistics, cold chain management and climate friendly refrigeration technologies for optimal handling and storage of the fish resources and rest raw materials (RRM) in order to maintain their quality.
2. Improve the efficiency, profitability and environmental sustainability of the Indian seafood processing industry by valorisation of surimi RRM into high value-added functional ingredients for food and feed applications.

The exploitation potential of these solutions is discussed in this report.

2 Key exploitable output of ReValue

The ReValue project has developed several key concepts and solutions to improve the resource efficiency in the seafood supply chains. The overall project approach is embedded in the circular economy thinking of reduce and reuse. The concepts for climate friendly refrigeration and cold chain management when implemented by the industry will lead to reduction in losses in the seafood supply chain, especially in the fishing and subsequent handling and logistics operations, which are common due to temperature fluctuations. The co-streams from seafood processing which cannot be used as the main product can be converted into value-added ingredients for food and feed through the implementation of ReValue solutions.

To promote a relevant market uptake, ReValue outcomes are developed up to TRL 5-6 (described in Table 1), with their validation and demonstration in relevant environments facilitated by a strong industry involvement in the ReValue consortium (a Surimi processor in India and a food, feed and flavour manufacturer in Spain).

Table 1. Key Exploitable Results of ReValue

Key Exploitable Results (KER)	State of the art TRL	TRL at the end of the project
Climate-friendly refrigeration for Surimi industry	The individual components of the refrigeration system are at TRL 8. The system required for refrigeration is at TRL 2	TRL 5 – The developed concepts will be demonstrated in a relevant environment for Surimi industry
Technologies for an improved cold chain	The individual components including RFID, NFC and Bluetooth temperature sensors are at TRL 8. The various technologies for cold chain in different climates are at TRL 3	TRL 5 – The technologies developed for an improved cold chain will be demonstrated in an operational environment within a Surimi supply chain
Technological solution for processing fish RRM into production of high-quality ingredients.	TRL 3 – Proof of concept for using endogenous enzymes. The process has not been tested for the Surimi RRM	TRL 6 – Process validation in relevant environment at pilot scale
Technologies for food and feed formulation containing oil and protein fractions from Surimi RRM and wash water	TRL 3 - Studies and laboratory tests with Surimi RRM in matrix development have not been tested	Representative prototype product will be developed at TRL 5-6

The following sections provide detailed descriptions of the main outputs of the project and their foreseen exploitation by the seafood sector, specifically the surimi industry in India.

2.1 Climate-friendly refrigeration

Fishing in the Indian coastal region is labour intensive, with large numbers of fishermen venturing out to sea in their small diesel engine-powered boats to catch fish. The boats carry a large quantity of crushed ice from land for preservation of the fish they catch, as they are not equipped with an on-board refrigeration system. A small, climate-friendly refrigeration system was proposed in ReValue, running on a vapour absorption system, which can compensate for the heat ingress into the iced compartments of a boat and reduce ice loss.

The onshore surimi production facility has a very large cooling demand in terms of its requirement for chilled wash water, ice, deep freezing of the product and subsequent cold storage. NH_{3-} or R404A-based refrigeration systems are commonly employed in India. An efficient and environmentally-friendly refrigeration system can provide substantial savings, while at the same time reducing the risk of both primary and secondary contributions to global warming. Innovative refrigeration systems are designed that are specifically suited for Indian coastal weather conditions and specific seafood processing demands. The proposed NH_3-CO_2-based cascade refrigeration systems ensure ~10% savings in annual energy consumption and an 8 to 12 % reduction in carbon emissions for surimi production in the climate conditions of Mumbai (India).

2.2 Solutions for an improved cold chain

With the surimi supply chain (SSC) in India (Fig. 1) being in its developing state, not all processes are organized, including logistics activities, Rest Raw Material (RRM) management and cold chain management. This has a negative impact on various aspects such as the fish quality, cost, profitability and quality of the value-added products. Field observations reveal issues of fragmented ownership, fishing area identification, issues with fishing boats and their capacity, boat unloading practice, real-time information sharing for the location of operations and underutilisation of the generated RRM.

To gain a deeper understanding of these issues, process flow maps are developed to indicate the operations involved. This is followed by constructing value stream maps (Fig. 2) to identify the various types of wastes

involved (i.e. Value adding and Non-value adding activities). Supply chain operational enhancements are suggested by identifying operational and environmental wastes (i.e. lean and green wastes). Improvements are proposed using Kaizens and supply chain localisations, namely, No Vertical Integration (NVI), Partial Vertical Integration (PVI) and Complete Vertical Integration (CVI), having varying levels of structural moderations. These moderations were evaluated both by shorthand calculations and simulations carried out for each supply chain operation, considering factors such as processing time, lead time, process cycle efficiency, value added time and non-value added time. Some major conclusions derived are as follows:

- Lean and green wastes were identified for various levels of the supply chain integration studied.
- Operational modifications use lean and Kaizens, whereas environmental improvements achieve greater significance under supply chain integration with sustainable transportation modes.
- A simulation model depicting variability and localization effects on the supply chain denoted a valid decrease in lead time and energy consumption under CVI.
- Results clarify the impulsive need for deep localization of processing plants for improved utilization and profits.

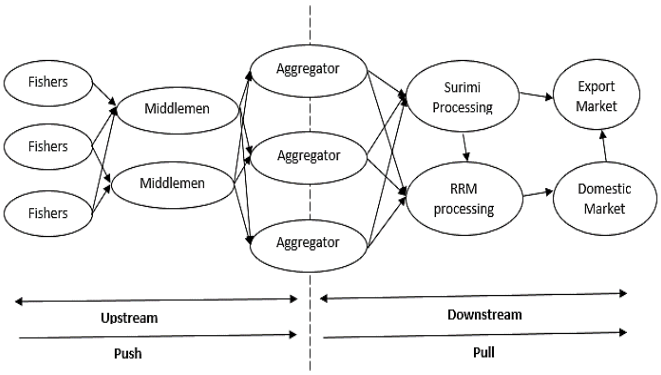

Fig 1. Surimi supply chain in India

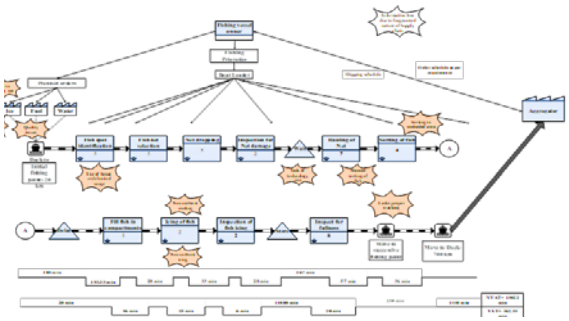

Fig 2. Sample Value stream map of fishing

Logistics and cold chain management

The fragmented nature of the Indian SSC and reduced level of coordination existing between supply chain stakeholders causes a complete dependence on third-party logistics, and condensed cold chain robustness reduces efficiency. Hence, the existing level of supply chain uncertainty and the hold time (inventory time) along the supply chain shows the need for gaining a clearer understanding of the various cold chain-related operations in the SSC. The supply chain response matrix (SCRM) (Fig. 3) has been developed to analyse the existing supply chain scenario in India. The outcomes visualise the current level of cold chain with improvements, and level of responsiveness that is required in terms of logistics. The results obtained are further subjected to a 5W2H model (i.e. What, Why, Where, When, Who, How and How often) model to identify and rectify existing problems (Fig. 4). The conclusions derived are used as struts for structured improvements called Kaizens. The results obtained from this task aim to remove wasteful activities and propose cost-effective adaptable developments by standardizing operations using lean management techniques. Some major conclusions derived from this work are as follows:

- Long-distance transportation and improper cold chain account for a significant portion of wasteful activities.
- Proposed supply chain structures have a significant influence on lead time and hence need to be improved.
- There is an impulsive need for deep localization of surimi processing plants in order to improve responsiveness and cut transportation costs.

- A Supply Chain Response Matrix (SCRM) has been developed considering inventory (time) and lead time to prioritize zones requiring enhancement.
- A 5W2H model is used to identify various issues, and Kaizens are proposed for rectifications.

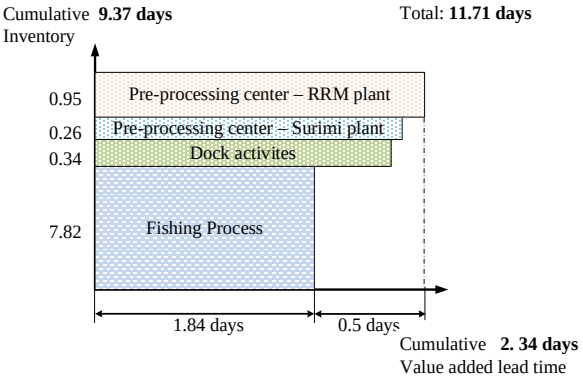

Fig 3. Supply Chain Response Matrix of Indian SSC

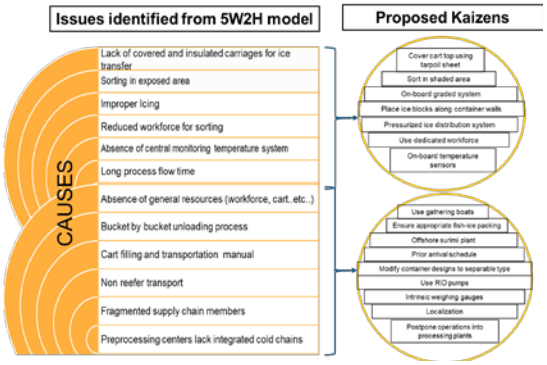

Fig 4. Issues identified in Surimi cold chain

2.3 Technological solution for processing fish RRM into production of high-quality ingredients

A lack of proper handling and further utilisation of co-streams such as wash water and RRM is one of the shortcomings of the surimi industry. The RRM from surimi industry in India are currently used for feed/fertilizer applications or are discarded without any attempt to recover valuable components. To increase the value-addition along the supply chain by producing functional ingredients, high quality fish and RRM are required. In the ReValue project, performed tests and analyses indicated that different RRM obtained from surimi processing factories in India and Spain have a potential to be used as valuable ingredients in different formulations (both in food and feed markets). Some variation in chemical composition as well as microbial quality indicated that proper storage and handling methods, and optimal processing technologies need to be applied in order to produce high-quality final products. No pathogenic bacteria were found in any analysed RRM, whole fish, surimi or wash water.

There is no regulation available for the microbiological load of fish-related raw material used in the food industry in India. According to the Food Safety and Standards Authority of India (FSSAI), permitted aerobic plate count in fish mince/surimi and analogues are 1 X 10^6, but yeast and mould should be absent. However, some of the analysed samples contained yeast and mould, with the highest levels being found in skin and bone fraction and in wash water. RRM obtained from surimi processing industries are rich in proteins (40-80 % of dry material) and are good sources for the production of protein-rich products and ingredients.

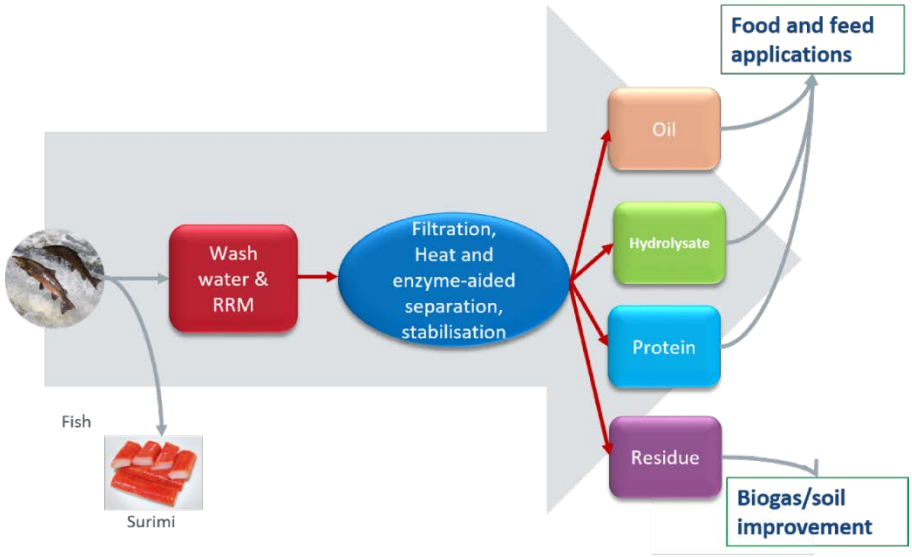

Fig.5. Overview of the potential for utilisation of co-streams (wash water and rest raw materials) generated through the surimi processing industry.

Screening for optimal processing technology, together with the optimisation steps taken, indicated that Pink Perch and Croaker RRM (head and viscera, and skin and bones) which contain valuable nutritional compounds can be used to produce nutritional protein hydrolysates with desirable functional properties, as well as for the extraction of marine gelatine. All tested enzymes (Alcalase, mixture of bromelain and papain, trypsin and endogenous enzymes) yielded good quality protein hydrolysate, but the highest yield (up to 26.4 % of dry material) and best protein quality was obtained using Alcalase. The findings also indicated a potential for using acids for the protein precipitation from wash water. Treatment of wash water with lactic acid led to the removal of 87% of protein from wash water. Several extraction technologies were applied on RRM to extract gelatine, indicating the potential of RRM to be used as sources for marine gelatine.

Ingredients obtained from marine RRM can exhibit an undesirable fish taste and smell. Nowadays, microencapsulation is highly recommended in different food industries because of the benefits provided, such as thermostability enhancement, bioactive compound protection, controlled release, volatiles maintaining, odour shelter, and texture/sense improvement. Experimental work performed with hydrolysates obtained from the Pink Perch heads and viscera indicated that microencapsulation can be used to make the hydrolysates thermostable and mask the fish odour. Different wall materials were used for the microencapsulation process to stabilize and mask the fishy odour of protein hydrolysates, and the most promising combination of wall material was selected on the basis of encapsulation efficiency. The combination of hydrolysate + Maltodextrin + Gum Arabic + Sodium Alginates, as well as hydrolysate + Maltodextrin showed a higher encapsulation efficiency compared to other combinations of wall materials. These results can provide a promising and feasible method for the application of marine functional ingredients for fortification of different food formulations.

2.4 Technological solution for processing fish RRM into production of high-quality ingredients

The Surimi processing industry generates large amounts of by-products in the form of head & viscera and bones & skins during the production of surimi as product yields were only 30–50 %. These head & viscera and skin & bones were converted into protein hydrolysate and gelatin respectively. The protein hydrolysate was first extracted through enzymatic hydrolysis of Pink Perch head & viscera by using alcalase enzymes. This protein hydrolysate was further microencapsulated by using different wall material (maltodextrin, gum

arabic, sodium alginates, carboxy methyl cellulose) to minimize the fishy odour of protein hydrolysates. Among all the microencapsulates, combination of protein hydrolysates + maltodextrin + gum Arabic + sodium alginate was selected for development of protein rich ready to cook soup. Three types of soups were prepared i.e., Soup 1 (Blank soup: without protein hydrolysates and microencapsulated protein hydrolysates); Soup 2 (Protein hydrolysates soup); Soup 3 (Microencapsulates soup) and Soup 4 (Fish powder soup) having more than 15 % protein content. The soup developed using microencapsulated protein hydrolysates had higher overall acceptability and acceptable aroma among all soups. After chemical and physical characterization of soup ethical clearance for animal trial will be obtained and approval from Food Safety and Standards Authority of India (FSSAI) will be taken. Trial of soup before commercialization will be done using the help of Anganwadi workers followed by technology transfer.

Pink Perch skin and bone gelatin not only serves as a promising alternative to bovine gelatin, it can also create economic value to the surimi industry by-products and reduces the waste generated from the surimi industry. Gelatin can be extracted from skin and bones biomass. Gelatin is commonly used to impart novel and improved rheological characteristics to food products and added benefits include fat reduction and reduction in costs. Different variants of meatballs were made from different concentration of Pink Perch skin and bones gelatin (3-6%) to analyse effects of gelatin in improving the quality of the processed meat products (chicken ball), resulting in a novel range of gelled comminated meat system replacing typical meat emulsions.

Chicken meatball with 5% gelatin depicted the best rheological properties along with highest overall acceptability in sensory evaluation. Chicken meatballs were fairly stable at-18°C temperature for longer duration of time. Pink Perch gelatin incorporated meatballs can be commercially exploited after testing for its nutritional profile and bioavailability of nutrients. Animal trials must be conducted before taking approval from FSSAI.

3 Exploitation events

The exploitation events with stakeholders have helped shape the output of the ReValue project to better serve the target audience. Several ReValue open days, workshops and webinars were organised to present and discuss the project results with industry actors, project partners and the general public. Some of these were organised alongside the annual project meetings and in collaboration with the INTPART project RE-food. These included:

1. Open day 1 in Goa, India – February 2018
2. Open day 2 in Mumbai, India – November 2018
3. Open day 3 in Trondheim, Norway – September 2019
4. Open day 4 in Kolkata, India – December 2019
5. Webinar 1 – June 2021
6. Final project meeting with external participants – June 2021
7. Webinar 2 – August 2021

The project has also resulted in several presentations at scientific conferences and industry events which are detailed in the final dissemination and communication report.

4 Potential impact and exploitation of results

The bio-economy business model is directed towards sustainable production via conversion of natural biomass and by-products into a range of food, health, and other industrial products. Reduction of losses and valorisation of RRM in the fish value chains is a global societal challenge, and at the same time a great opportunity for market competition. The vast impact of the Surimi industry on global food waste production, being that it is responsible for more than 3.5% of the global fish losses, is due to its low-efficiency processing, which generates huge amounts of RRM and wash water. In this context, a series of innovations will enable ReValue to optimize the Surimi value chain, including improved temperature management, reduction of the waste generated by processing, conversion of RRM into high value-added ingredients for food and feed, and a business strategy for commercial exploitation of the project outcomes in India and Europe. Currently, the number of value-added products derived from fish RRM is very low, primarily because alternative uses of RRM require the demonstration of the product's feasibility and profitability.

A high market and economic impact can be achieved through strengthening the competitiveness of the industry in target market sectors by:

1. Promoting the use of ReValue materials, components and systems in high value-added applications while keeping costs competitive,
2. Strengthening and differentiating the EU and Indian Industry,
3. Increasing workers' skills.

Global fish production has grown steadily in the last five decades, increasing at an average annual rate of 3.2%. Worldwide, the fish processing industry leads to the production of a large amount of RRM which are generally discarded (~7.3 million tons/year). This results in an increase of RRM available for use in other applications, for example in the production of gelatine and derivatives for food and feed. India is the largest country in the Indian Ocean and has a long coastline with over 200 varieties of commercially important fishes and shellfishes. India produced nearly 95 000 MT of Surimi in 2019, a 35 000 MT increase since 2012. Europe uses about 70 000 tons of Surimi for producing over 210 000 000 tonnes of Surimi-based products. The main consumer in Europe is France (whose market accounts for about 60 000 tonnes of Surimi-based products) followed by Spain (consuming about 40 000 tonnes), Ukraine (14 000 tonnes), the UK (12 000 tonnes) and Italy (8000 tonnes). In the last decade, Surimi penetration in the European market was slow. In 2016 it increased by around 20,000 metric tons (about 3%), and in 2018 the EU market produced nearly 170 000 tonnes of Surimi product, from its top producers in Spain, France, and Lithuania, signalling a true rise in demand (European Commission, 2018).

In this scenario, ReValue has the potential to achieve a huge market impact, drastically increasing the Surimi industry profitability. The average value of fish used for surimi will increase significantly if the RRM can be utilized in feed ingredients (and the value will be even higher for food applications). In particular, ReValue solutions contribute to quality enhancement through the improvement of processes and cold chain, and through the introduction of functional ingredients derived from RRM that can be used as nutritional supplements. Further exploitation should focus on the marketing of surimi-derived products, which can help to increase consumer awareness and create a wider acceptance of Indian surimi and the products derived from it in the European market.

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